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Person-Oriented and Subject-Specific Methodology: Some Additional Remarks

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Abstract: Objections that dynamic factor analysis, a prime subject-specific variable-oriented method, enables testing of all central person-oriented theoretical principles are answered in principled ways and a conjecture is presented regarding the relation between person- and variable-oriented methods.

Keywords: dynamic factor analysis, measurement invariance, time-varying parameters, person- and variable-oriented methods

Introduction

Subject-specific methodology is derived from the requirement that psychological knowledge should be validly applicable to each individual human subject. It can be proven that standard inter-individual variation approaches to the statistical analysis of psychological data do in general not obey this requirement, using general theorems from the fundamental mathematical-statistical theory about the relation between results obtained in analyses of inter-individual (between-subjects) variation and intra-individual (within-subject) variation (Molenaar, 2004; Molenaar & Campbell, 2009; Molenaar & Nesselroade, 2015). The latter standard inter-individual variation approaches include all well-known techniques such as MAN(C)OVA, multilevel (e.g., latent growth curve) modeling, (longitudinal) factor analysis, mixture (e.g., cluster) modeling, etc. Results obtained with these standard techniques apply at the (sub-)population level but do in general not validly generalize to the level of individual subjects making up this (sub-)population.

An important example is classical test theory, the results of which do not validly apply at the level of individual assessment (cf. Molenaar, 2008). Yet most psychological inventories have been constructed based on classical test theory and their (invalid) use in individual assessments is commonplace. Perhaps item-response theory also is non-ergodic, especially if the probability in its models is based on the "stochastic subject" interpretation (cf. Holland, 1990). But contrary to classical test theory, to the best of my knowledge a formal proof of the non-ergodicity of item-response theory is not yet available[1].

To obtain results which are valid at both the individual and population level, it is necessary to start with analysis of intra-individual variation (single-subject time series analysis); hence the label subject-specific data analysis. Employing state-of-the-art time series analysis techniques, results thus obtained obviously apply to the subjects whose intra-individual variation has been assessed. In the next phase, using the time series analysis results obtained in the first phase, generalization can be attempted to the population to which these subjects belong (Gates & Molenaar, 2012). Taken together these two phases imply that the goal of subject-specific data analysis is to obtain nomothetic knowledge about ideographic variation.

Subject-specific methodology, being rooted in general

[1] I thank the editor Dr. Wolfgang Wiedermann for making this suggestion.

mathematical-statistical theory, would seem to be unrelated to person-oriented theory and methodology. The latter is based on general holistic-interactional psychological theory. Yet is was argued in Molenaar (2015b) that subject-specific approaches provide for excellent methodological-statistical tools to test the central person-oriented theoretical principles. Sterba and Bauer (2010a) present a convenient summary of the principles underlying person-oriented theory and the methods used to test them. They distinguish six principles and four types of method, one type of method being what they call "single-subject analysis". In my commentary (Molenaar, 2010) it is claimed that dynamic factor analysis in its current form (e.g., Molenaar, 2006) enables testing of all six person-oriented theoretical principles. In their response Sterba and Bauer (2010b) agree with a particular qualification which is addressed below. Hence subject-specific methodology, in particular dynamic factor analysis, enables integral testing of person-oriented theory.

Within the context of this interesting match between person-oriented theory and subject-specific methodology I would like to present some additional remarks concerning person-oriented methodology in general. What follows is based on Molenaar (2015a) to which the reader is referred for further details and background.

Further Questions whether Subject-Specific Methodology Enables Testing of all Person-Oriented Theoretical Principles

As indicated above, Sterba and Bauer (2010b) made a qualification when agreeing that dynamic factor analysis in its current form (Molenaar, 2006) enables testing of all six principles characterizing person-oriented theory. The qualification concerns the use of dynamic factor models with time-varying factor loadings (cf. Molenaar, Beltz, Gates, & Wilson, 2016, for a detailed presentation of this innovative technique). According to Sterba and Bauer (2010b) factor models having time-varying factor loadings violate the basic criterion for measurement invariance. They argue that latent factors in a longitudinal or multi-group factor model only have the same meaning (interpretation) if at least the factor loadings are invariant across measurement occasions or across the multiple groups. According to this well-established criterion (cf. Millsap, 2011) the latent factor series in a dynamic factor model with time-varying factor loadings therefore appear to have time-varying meaning and therefore are incomparable across time. In Molenaar (2015b) a generalized methodology for testing factor invariance is introduced according to which factor series in dynamic factor models with time-varying loadings can have identical (time-invariant) meaning and are comparable across time. This methodology generalizes the standard linear factor rotation techniques to appropriate nonlinear transformations which can uncover invariances underlying time-varying factor loadings.

Recently Bergman (2015) put forward another possible objection to the point of view that dynamic factor analysis in its present form enables testing of all six person-oriented theoretical principles distinguished by Sterba and Bauer (2010a), asking how a subject-specific data analysis could be formulated that treats patterns as indivisible. Bergman (2015) gives an example of treating patterns as indivisible in terms of natural clusters of phenotypic expression of genes. So presumably cluster analysis is one principled way to treat patterns as indivisible. Then Bergman's (2015) question can be reformulated as: is cluster analysis of intra-individual variation possible? The answer is confirmative: one can conceive of cluster analysis within the context of multivariate time series analysis in a variety of ways. One way is to fit the same parametric dynamic model to data obtained in a replicated time series design and then, in a second step, cluster-analyze the parameter vectors obtained with the sample of replications. The so-called dynamic cluster analysis of Babbin, Velicer, Aloia, and Kushida (2011) is an example. It also is possible to cluster analyze a multivariate time series of a single subject, where the clusters now constitute dynamically homogeneous stretches of intra-individual variation. The well-known class of regime-shifting state space models (Kim & Nelson, 1999) is good example of this kind of analysis.

In sum, the original claim that dynamic factor analysis in its present form enables testing of all six person-oriented theoretical principles still stands. Admittedly, the replies summarized above to the objections made by Sterba and Bauer (2010b) and Bergman (2015) require much more elaboration and have to be shown to be effective by means of appropriate empirical applications. Molenaar, Sinclair, Rovine, Ram, and Corneal (2009); Molenaar et al. (2016) present successful applications of dynamic factor models with time-varying factor loadings to empirical data, but do not yet consider the generalized methodology for testing factor invariance presented in Molenaar (2015b). See Yang and Chow (2010) for an interesting psycho-physiological application of regime shifting state space modeling.

The Difference Between Variable-Oriented and Person-Oriented Methods

Person-oriented methods often are contrasted with variable-oriented methods (for an excellent discussion, see Bergman & Trost, 2006). Because dynamic factor analysis appears to be a variable-oriented method, yet enables testing of all six person-oriented theoretical principles specified by Sterba and Bauer (2010a), it would seem that the difference between person- and variable-oriented methods requires further scrutiny. In what follows an argument is presented aimed to show that the difference between these two types of methods is not fundamental. To do so, the following explicit conjecture is made: the difference between person-oriented methods and variable-oriented methods is not fundamental, but at most gradual.

A possible defense of this conjecture runs as follows. a) Cluster analysis is a person-oriented method. For instance Bergman (2015) considers cluster analysis to be an appropriate person-oriented method to test pattern indivisibility and Sterba and Bauer (2010a) include classification meth-

ods among the four methods they evaluate regarding appropriateness to test person-oriented theoretical principles. b) Cluster analysis can be conceived of as a special case of finite mixture modeling (for proof, see Frühwirth-Schnatter, 2006). Stated more specifically, the model underlying cluster analysis constitutes a mixture model in which the models in the mixture are marginalized (integrated out), leaving only the mixture distribution. c) The class of finite mixture models contains mixed factor models (e.g. Dolan & van der Maas, 1998). d) Marginalizing (integrating out) the latent mixing distribution in mixed factor models yields the standard factor model.

The above sequence of propositions starts with considering a typical person-oriented method, namely cluster analysis, and ends with a typical variable-oriented method, namely factor analysis. But it would seem that nowhere along the sequence a fundamental transition is made. Hence, the conjecture that the distinction between person-oriented and variable-oriented methods is at most gradual appears to have been confirmed. Perhaps one or more of the propositions is false, but each step appears to be intuitively correct and also can be backed up with mathematical-statistical proof. So, assuming that a)-d) is correct, can we pinpoint where some noteworthy boundary between person-oriented and variable-oriented methods could be drawn? Perhaps this boundary could best be located at d): integrating out the latent discrete distribution characterizing the mixture of factor models. If this intuition is justified then it would seem that the difference between person-oriented and variable-oriented methods is related to whether latent variables are discrete or continuous.

Given the correctness of the above reasoning, a further argument can be given supporting the conjecture that the difference between person-oriented and variable-oriented methods is not fundamental. Molenaar and von Eye (1994) show, based on a preliminary proof by Bartholomew (cf. Bartholomew & Knott, 1999), that each latent profile model is, up to first- and second-order moments, equivalent to a latent factor model, and vice versa. In a latent profile model the latent variables are discrete; in a factor model the latent variables are continuous. Both models are equivalent (related by an invertible transformation) up to first- and second-order moments. In practice this means that for each given factor model an equivalent latent profile model can be derived that has the same number of free parameters and has the same goodness of fit to the observed mean vector and covariance matrix. Alternatively, for each given latent profile model an equivalent factor model can be derived that has the same number of free parameters and has the same goodness of fit to the observed mean vector and covariance matrix. This suggest, paraphrasing Bartholomew and Knott (1999), that the decision whether latent variables are discrete or continuous is more a matter of taste than a fundamental choice.

The latter statement is exaggerated, because it only holds in a limited sense (equivalence up first- and second-order moments) for the relation between two particular latent variable models (latent profile and factor models). But at least in this particular case the difference between latent discrete variables and latent continuous variables is "a matter of taste". In sum, taking also our previous argumentation into consideration, it is concluded that no fundamental difference exists between variable- and person-oriented methods. This is corroborated by variable-oriented dynamic factor analysis being a powerful person-oriented method.

Conclusion

Dynamic factor analysis in its present form (allowing for time-varying parameters, including time-varying covariates, accommodating replicated heterogeneous multivariate time series) enables testing of all six person-oriented theoretical principles specified by Sterba and Bauer (2010a). Dynamic factor analysis is a variable-oriented subject-specific method, but the difference between person- and variable-oriented methods does not appear to be fundamental.

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