A comparison of confirmatory factor analysis methods

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General discussion

In this dissertation we discussed and compared several confirmatory factor analysis methods that can be used when researchers want to verify whether an a priori assignment of items to subtests is supported by the data. The main goal was to compare the most often used Confirmatory Common Factor (CCF) method with a less often used and less known method, the Oblique Multiple Group (OMG) method. Because not much was known about the OMG method in general, we first studied some of the properties of this method to see which OMG variant was overall the best method to use in the subsequent comparative studies. The main question was whether we should correct for two sources of spuriously high correlations. It appeared that best results were obtained when we corrected for both sources, namely for self-correlation as well as for test length. This method was used in the subsequent three chapters (Chapters 5, 6 and 7) where we extensively compared the OMG and CCF methods.

In the three chapters that focused on the comparison of the OMG and CCF methods we studied several aspects, namely the detection of correct and incorrect assignments of items to subtests (Chapter 5), the ability to adjust incorrect assignments of items to subtests (Chapter 6) and their application on empirical data sets (Chapter 7). In Chapters 5 and 6 we compared both methods mainly on simulated data sets. These data sets were constructed following the common factor model which means that the data consist of a common and unique part. This data construction method was inspired by the difference in characteristics between the two methods. The OMG method is mainly a descriptive method that is not able to distinguish between the common and unique part present in the data, whereas it is the main characteristic of the CCF method to estimate both parts separately. The fact that the CCF method is able to include an estimate of the amount of unique variance is often considered as an advantage of using this method.

To check whether it is a proper assumption of researchers that the inclusion of an estimate of the amount of unique variance adds to the quality of the method we manipulated the amount of unique variance in the data. It can be expected that including an estimate of the amount of unique variance can become increasingly important with higher amounts of unique variance; this is because the unique variance is then more prominent in the data and can distort the pattern present in the common part. We studied several performance measures of both methods under varying
conditions, such as the detection of correct assignments and the quality of suggested adjustments after finding an incorrect assignment. Despite the fact that the CCF method includes an estimate of the amount of unique variance, we did not find that the CCF method systematically outperformed the OMG method under high amounts of unique variance in all conditions. We found that in low to medium amounts of unique variance both methods performed similarly. With high amounts of unique variance the CCF method appeared to be better in detecting the correct assignments especially when sample sizes were rather low, whereas the OMG method was better in detecting the incorrect assignments and adjust these incorrect assignments so that the correct assignment was obtained.

The fact that the CCF method is better able to detect the correct instead of the incorrect assignments is not surprising as the CCF method assumes that a perfect (correct) model is used on the data. With the use of an incorrect assignment this assumption is violated. However, the main goal of the CCF method is to model the relationship between latent and observed variables. As the use of an incorrect assignment represents a serious modelling error between the latent and observed variables, we argue that the CCF method should be able to detect and adjust these incorrect assignments.

Because none of both methods was well able to detect both the correct and incorrect assignments we decided to study a Common Multiple Group (CMG) method which shares properties of both the OMG and CCF method. It appeared that especially with the use of correct assignments better results were obtained with CMGmrfa compared to OMG with high amounts of unique variance. When it is known that high amounts of unique variance are present in the data this method is probably to be advised as it is then best able to distinguish between correct and incorrect assignments. Unfortunately, in practice the amount of unique variance is not known. Often, the amount of unique variance will be lower than the 80% unique variance studied here. In these conditions the OMG method is probably the best method to use for reasons indicated below. It can be argued that the CMGmrfa method should be used always as it is best able to distinguish the correct from the incorrect assignments under all amounts of unique variance conditions. However, the method has certain drawbacks. The method is computationally demanding and it is slightly more difficult to understand than the OMG method. More importantly, it is yet not possible to apply this method with often used software packages such as SPSS.

From the positive results obtained with low to moderate amounts of unique variance, but also for some other reasons that will be discussed below, we would
advise researchers to use the OMG method when their research question is limited to
the verification of an assignment of items to subtests. The simulation studies revealed
promising results for the OMG method. Furthermore, in Chapter 7 we found that with
both methods similar conclusions could be drawn when used on empirical data sets.

In Chapter 7 the clear advantage of the OMG method appeared to be the ease
with which we could draw a conclusion about the research question. With the CCF
method researchers have to combine several, sometimes even contradictory, sources
of information into one single conclusion. In practice, researchers using the CCF
method will base their conclusions on aspects such as model fit, size of parameter
estimates and possible suggestions for model modification and relate these findings to
their theoretical knowledge. As several studies have shown that researchers frequently
make mistakes using statistical techniques (e.g., see Hoekstra, Finch, Kiers &
Johnson, 2006) it is advisable to use a method that is as simple as possible and does
not need the integration of several sources of information.

The integration of several sources of information also becomes increasingly
difficult when the number of items of a test or questionnaire increases. With an
increase of the number of items there is not only an increase in the number of
parameter estimates that need to be interpreted but also in the number of possible
adjustments that can be made to improve the model. It could then be the case that
several adjustments can result in the same improvement in model fit. Especially when
theoretical support for making adjustments is lacking, these decisions about possible
adjustments become very difficult. In general, even those who regularly use the CCF
method will now and then have some doubts about the model fit and which model of
several alternative models to choose, so this can be expected to hold strongly for the
researcher that rarely uses this method. It is one of the advantages of the OMG
method that its interpretation is not influenced by the number of items. Furthermore,
occasionally similar correlations for an item with more than one subtest are obtained.
This indicates that an item is not well able to discriminate properly between these two
subtests. With the CCF method this can only be seen when secondary loadings are
specified and estimated which is not automatically done. Apart from these advantages
of the OMG method, we also have several concerns related to the practical use of the
CCF method.

Our first concern is the strong reliance of the CCF method on fit indices. On
some occasions this strong reliance could result in incorrect conclusions (also see,
Marsh, Hau and Wen, 2004) as we found that the optimal criterion values (those with
the highest proportions of correct judgments) for the fit indices studied in this
dissertation depend on several sources, such as the amount of unique variance in the
data and the amount of model error, which are both properties that are not known by the researcher. When regularly used fit criteria indicate a bad model fit, this does not necessarily imply that the model used is indeed an incorrect model. This can also be due to the fact that the chosen criteria are inadequate for the data set under study. In Chapter 5 it was shown that a correct assignment was often judged incorrectly when data were constructed such that a small amount of model error was present. Some may argue that this sensitivity to model error should not be treated as a concern. Clearly, the CCF model assumes the use of the correct model and the presence of model error would imply a violation of this assumption. However, we have some concerns about the degree of sensitivity to model error. In reality, models will always be an approximation, so model error will always be present to some extent. The question then is how much model error is likely to be present in practice and how much model error researchers would accept. When researchers would accept that 20% of the common variance would be due to the minor factors that represent the model error, fit indices probably should not be too sensitive to model error and under these conditions still indicate that the assignment of items to subtests used is supported by the data.

Another concern is related to the default modification setting of the LISREL program, which not only allows modifications in $\Lambda$ but also in $\Theta$. Previous research (Fornell, 1983; Bagozzi, 1983; Breckler, 1990; MacCallum, 1992) has revealed that these elements are often added just to improve the model fit. To prevent such behaviour it could be advisable to change the default setting of the LISREL program. In the current version of the program it is rather difficult to change this default setting which enhances the chance of drawing incorrect conclusions. Our simulation studies have shown that better results are obtained with the CCF method when the restricted search procedure was used. Clearly, the incorrect use of modification indices as well as the strong reliance on fit indices can be remedied to some extent by increasing the awareness of these problems under the applied researchers.

We think that the CCF method is to be preferred over the OMG method when the main goal of researchers is to model the relations between latent and observed variables. This is a far more general goal than the verification of an assignment of items to subtests which is the only question that can be answered with the OMG method. Another advantage of the CCF method is that it provides (accuracy of the) parameter estimates and estimates of the amount of unique variance. This information is not provided by the OMG method, although it is possible to compute confidence intervals around each (corrected) correlation which will tell something about the accuracy of the correlation and its generalizability to the population.
All of these conclusions are based on the limited set of studies reported in this dissertation. Therefore, these conclusions should not be discussed here without mentioning some limitations and points for further research.

First, it should be noted that in this dissertation the main focus was on CFA models with three subtests indicated by a rather small number of items per subtest, namely four. In Chapter 6 we saw that the quality of the OMG and CCF adjustment procedures increased when the number of items per subtest was increased to six. How both methods perform with a further increase of the number of items per subtest is yet unknown. For the CCF method some contradictory findings have been reported about the influence of the number of items per subtest on its performance. Guidelines provided by Tanaka (1987) and Bollen (1989) indicate that with an increase of the number of items per subtest more observations are needed to obtain good results. Simulation studies performed by Marsh, Hau, Balla and Grayson (1998) indicate the opposite, namely that with lower sample sizes better results can be obtained when the number of items per subtest is increased. However, as Marsh et al. did not specifically focus on the detection of correct and incorrect assignments and the quality of adjustment procedures, additional comparative (simulation) studies are needed to see how both methods will perform with more items per subtest and under which conditions differences between the methods are observed. In these comparative studies it would also be interesting to see whether the CCF assumptions are violated more often with an increase of the number of items per subtests. We would, for example, expect that with an increase of the number of items per subtest the chance of finding correlations between the unique parts of the items increases.

In Chapter 6 we studied the quality of adjustment procedures when items are incorrectly assigned to a specific subtest. It would also be interesting to study a more complex incorrect assignment that could also occur in practice, namely when there are more subtests specified than are present in the true assignment. With the CCF method not only should the Modification Indices indicate that the items initially assigned to the redundant subtest should be reassigned to a different (nonredundant) subtest but also that all incorrectly estimated parameters corresponding to the redundant subtest should be removed. The OMG method would indicate that a subtest is redundant when all item-subtest correlations with this subtest are small compared to at least one of the other subtests. We could imagine that this incorrect assignment is more difficult to handle by the CCF method than by the OMG method, because with the CCF method several respecifications of the model are necessary to come to the correct conclusion.
Finally, it should be noted that the data in this dissertation were constructed such that the assumption of a multivariate normal distribution (necessary for Maximum Likelihood (ML) estimation with CCF) was not violated. It would be interesting to see what happens in case of small to large deviations from this multivariate normal distribution, especially with the OMG method. Several robustness studies (e.g., Hu, Bentler & Kano, 1992; Hoogland, 1998, 1999) have been performed that study the sensitivity of the CCF method to deviations of the multivariate normal distribution. In general, these studies indicate that the alternative estimation procedure, Weighted Least Squares (WLS), which can be used when the assumption is violated, is only to be used with rather high sample sizes. With low sample sizes ML appears to perform better than WLS. As it is unknown how well the CCF method performs under these conditions in comparison to the OMG method, it would be interesting to perform simulation studies to sort this out. With the OMG method no specific assumptions are made about the item distributions, therefore it can be the case that under these conditions the OMG method would outperform the CCF method. Further simulation studies are needed to test this hypothesis.