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ABSTRACT

Exploratory and confirmatory factor analytic techniques are compared, and how to conduct a confirmatory factor analysis is reviewed. A sampling of "fit" statistics and suggestions for methods to improve models for testing are also presented. Exploratory factor analysis is used to explore data to determine the number of the nature of factors that account for the covariation between variables when the researcher does not have, a priori, sufficient evidence to form a hypothesis about the number of factors underlying the data. Confirmatory factor analysis is a theory-testing model as opposed to a theory-generating method like exploratory factor analysis. In confirmatory factor analysis, the researcher begins with a hypothesis prior to the analysis. This model specifies which variables will be correlated with which factors, and which factors are correlated. The process of confirmatory factor analysis is described, and it is emphasized that it is important to realize that more than one model may accurately describe the data and that a number of fit indices should be used to determine the fit of the various models. Methods that may increase the fit of the researcher's model to the data are described. (Contains 22 references.) (SLD)

Running Head: CONFIRMATORY FACTOR ANALYSIS

Basic Concepts and Procedures of Confirmatory Factor Analysis

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Abstract

This paper presents a brief comparison between exploratory and confirmatory factor analytic techniques. The criticisms of exploratory factor analysis follow a definition of this method. A definition of confirmatory factor analysis precedes a description of the process of conducting a confirmatory factor analysis. A sampling of "fit statistics" is provided, as well as suggestions for methods to improve models for testing.

Confirmatory Factor Analysis

Factor analysis includes a variety of correlational analyses designed to examine the interrelationships among variables (Carr, 1992; Gorsuch, 1983). Summarized in a succinct manner, Daniel (1988) stated that factor analysis is "designed to examine the covariance structure of a set of variables and to provide an explanation of the relationships among those variables in terms of a smaller number of unobserved latent variables called factors" (p. 2).

Many definitions are offered in the literature for factor analysis. A comprehensive definition was provided by Reymont and Joreskog (1993):

> Factor analysis is a generic term that we use to describe a number of methods designed to analyze interrelationships within a set of variables or objects [resulting in] the construction of a few hypothetical variables (or objects), called factors, that are supposed to contain the essential information in a larger set of observed variables or objects...that reduces the overall complexity of the data by taking advantage of inherent interdependencies [and so] a small number of factors will usually account for approximately the same amount of information as do the much larger set of original observations. (p. 71)

The procedures for factor analysis were first developed early in the twentieth century by Spearman (1904). However, due to the complicated and time-consuming steps involved in the process, factor analysis was inaccessible to many researchers until both computers and user-friendly statistical software packages became widely available (Thompson & Dennings, 1993). Regarding the utility of factor analysis, Kerlinger (1986) described it as "one of the most powerful tools yet devised for the study of complex areas of behavioral scientific concern" (p. 689).

Exploratory Factor Analysis and Confirmatory Factor Analysis

Exploratory Factor Analysis

Two major dichotomies exist regarding factor analysis: exploratory and confirmatory. The determination as to which form to use in an analysis is made based on the purpose of the data analysis. Exploratory factor analysis is used to explore data to determine the number or the nature of factors that account for the covariation between variables when the researcher does not have, a priori, sufficient evidence to form a hypothesis about the number of factors underlying the data. Therefore, exploratory factor analysis is generally thought of as more of a theory-generating procedure as opposed to a theory-testing procedure (Stevens, 1996).

Factor analysis is also "intimately involved with questions of validity" (Nunnally, 1978, p. 112). In the process of determining whether the identified factors are correlated, exploratory factor analysis answers the question asked by construct validity: Do the scores on this test measure what the test is supposed to be measuring?

Several shortcomings are associated with exploratory factor analysis, which are to be addressed; yet, when used appropriately, exploratory factor analysis can be helpful to researchers in assessing the nature of relationships among variables and in establishing the construct validity of test scores. In reality, the majority of factor analytic studies have historically been exploratory (Gorsuch, 1983; Kim & Mueller, 1978). Nevertheless, there are those researchers who vehemently sing the praises of this method and others who equally chastise it. Nunnally (1978) noted that exploratory methods are neither "a royal road to truth, as some apparently feel, nor necessarily an adjunct to shotgun empiricism, as others claim" (p. 371).

Criticisms of exploratory factor analysis

Several criticisms have been aimed at exploratory factor analysis. The first, according to Mulaik (1987), pertains to the perception that exploratory factor analysis may "find optimal knowledge" (p. 265). Mulaik made clear that "There is no rationally optimal ways to extract knowledge from experience without making certain prior assumptions" (p. 265).

Also, exploratory assumptions may not always honor the relationships among the variables in a given data set. The common factor analysis model is a linear model, appropriate for only certain kinds of data. Many causal relationships are nonlinear. Superimposing a linear relationship will yield results, but these results may be misleading.

In addition, the factor structures yielded by an exploratory factor analysis are determined by the mechanics of the method and are dependent on specific theories and mechanics of extraction and rotation procedures. This, too, can result in inaccurate results. Mulaik (1987) made clear that exploratory techniques do not provide any way of indicating when something is wrong with one's assumptions, because the technique was designed to fit the data regardless. Rather than justifying the "knowledge" produced, exploratory factor analysis suggests hypotheses, but does not justify knowledge.

Another problem with exploratory methods lies in the interpretation of the results. The interpretation of factors measured by a few variables is frequently complicated (Nunnally, 1978). Mulaik (1972) suggested that the difficulty in interpretation often comes about because the researcher lacks prior knowledge and therefore has no basis on which to make an interpretation.

Yet another problem frequently associated with exploratory factor analysis is that exploratory factor analysis does not yield generally optimal solutions for the factors or unique interpretations for them, which makes it difficult to justify results. In summarizing the utility of exploratory factor analysis, Mulaik (1972) stated:

> In a practical sense, there is no question that exploratory factor analysis serves a useful purpose in suggesting hypotheses for further research. But one must not be misled into thinking that exploratory factor analysis-or any exploratory statistical technique, for that matter-is the only way, or even the optimal way, available to us to obtain suggestions for hypotheses. One's own direct experience with a phenomenon often suffices to suggest hypotheses. (p. 269)

Confirmatory Factor Analysis

Confirmatory factor analysis is a theory-testing model as opposed to a theory-generating method like exploratory factor analysis. In confirmatory factor analysis, the researcher begins with a hypothesis prior to the analysis. This model, or hypothesis, specifies which variables will be correlated with which factors and which factors are correlated. The hypothesis is based on a strong theoretical and/or empirical foundation (Stevens, 1996).

In addition, confirmatory factor analysis offers the researcher a more viable method for evaluating construct validity. The researcher is able to explicitly test hypotheses concerning the factor structure of the data due to having the predetermined model specifying the number and composition of the factors.

Confirmatory methods, after specifying the a priori factors, seek to optimally match the observed and theoretical factor structures for a given data set in order to determine the "goodness of fit" of the predetermined factor model. Commenting on the utility of confirmatory factor analysis, Gorsuch (1983) stated: "Confirmatory factor analysis is powerful because it provides explicit hypothesis testing for factor analytic problems....Confirmatory factor analysis is the more theoretically important-and should be the much more widely used-of the two major facto analytic approaches" (p. 134). He specified that exploratory methods should be "reserved only for those areas that are truly exploratory, that is, areas where no prior analyses have been conducted" (p. 134).

Confirmatory Factor Analysis Procedure

The first step in a confirmatory factor analysis requires beginning with either a correlation matrix or a variance/covariance matrix or some similar matrix. The researcher proposes competing models, based on theory or existing data, that are hypothesized to fit the data. The models specify things such as predetermination of the degree of correlation, if any, between each pair of common factors, predetermination of the degree of correlation between individual variables and one or more factors, and specification as to which particular pairs of unique factors are correlated.

The different models are determined by "fixing" or "freeing" specific parameters such as the factor coefficients, the factor correlation coefficients, and the variance/covariance of the error of measurement. These parameters are set according to the theoretical expectation of the researcher. Gillaspy (1996) provided definitions for fixing and freeing variables:

> Fixing a parameter refers to setting the parameter at a specific value based on one's expectations. Thus, in fixing a parameter the researcher does not allow that parameter to be estimated in the analysis....Freeing a parameter refers to allowing the parameter to be estimated during the analysis by fitting the model to the data according to some theory about the data. The competing models or hypotheses about the structure of the data are then tested against one another. (p. 7)

The actual confirmatory factor analysis can be conducted using one of several computer programs such as LISREL VII (Joreskog & Sorbom, 1989). The competing models are then tested against one another via the computer program. The completed analysis yields several different statistics for determining how well the competing models fit the data, or explain the covariation among the variables. These statistics are referred to as "fit statistics". The fit statistics test all of the parameters simultaneously (Stevens, 1996). These fit statistics are evaluated to determine which predetermined model(s) best explain the relationships between the observed and latent variables. This process was described by Bentler (1980):

> The primary statistical problem is one of optimally estimating the parameters of the model and determining the goodness-of-fit of the model to sample data on measured variables. If the model does not fit the data, the proposed model is rejected as a possible candidate for the causal structure underlying the observed variables. If the model cannot be rejected statistically, it is a plausible representation of the causal structure. (p. 420)

Fit Statistics

As stated previously, the fit statistics test how well the competing models fit the data. Stated more eloquently, Mulaik (1987) noted, "a goodness-of-fit test evaluates the model in terms of the fixed parameters used to specify the model, and acceptance or rejection of the model in terms of the overidentifying conditions in the model" (p. 275). Examples of these statistics include the chi square/degrees of freedom ratio, the Bentler comparative fit index (CFI) (Bentler, 1990), the parsimony ratio, and the Goodness-of-fit Index (GFI) (Joreskog & Sorbom, 1989).

Chi square/degrees of freedom ratio

The chi square tests the hypothesis that the model is consistent with the pattern of covariation among the observed variables. In the case of the chi-square statistic, smaller rather than larger values indicate a good fit. The chi-square statistic is very sensitive to sample size, rendering it unclear in many situations whether the statistical significance of the chi square statistic is due to poor fit of the model or to the size of the sample. This uncertainty has led to the development of many other statistics to assess overall model fit (Stevens, 1996).

Another way to describe the chi square goodness of fit statistic is to say that it tests the null hypothesis that there is no statistically significant difference in the observed and theoretical covariance structure matrices. The chi-square statistic has been referred to as a "lack of index fit" (Mulaik, James, Van Alstine, Bennet, Lind & Stilwell, 1989) because a statistically significant result yields a rejection of the fit of a give model.

Goodness-of-fit index (GFI) and adjusted goodness-of-fit index (AGFI)

The good of fit index "is a measure of the relative amount of variances and covariances jointly accounted for by the model" (Joreskog & Sorbom, 1986, p. I. 41). This index can be thought of as being roughly analogous to the multiple R squared in multiple regression. A model is considered to have a better fit when "it has a lower ratio computed as the noncentrality parameter divided by degrees of freedom" (Thomas & Thompson, 1994, p. 10). The closer the GFI is to 1.00, the better is the fit of the model to the data.

The adjusted goodness of fit statistic is based on a correction for the number of degrees of freedom in a less restricted model obtained by freeing more parameters. Both the GFI and the AGFI are less sensitive to sample size than the chi square statistic.

Parsimony ratio

One of the goals of science is parsimony, because as William of Occam argued, parsimonious solutions are more likely to be true and are therefore typically more generalizable. The parsimony ratio, is therefore important when interpreting the data. This statistic takes into consideration the number of parameters estimated in the model. The fewer number of parameters necessary to specify the model, the more parsimonious is the model. By multiplying the parsimony ratio by a fit statistic an index of both the overall efficacy of the model explaining the covariance among the variables and the parsimony of the proposed model is obtained (Gillaspy, 1996).

Interpreting Confirmatory Factor Aanalyses

It is important to remember when interpreting the findings from a confirmatory factor analysis that more than one model can be determined that will adequately fit the data (Biddle & Marlin, 1987; Thompson & Borrello, 1989). Therefore, finding a model with good fit does not mean that the model is the only, or optimal model for that data. In addition, because there are a number of fit indices with which to make comparisons, "fit should be simultaneously evaluated from the perspective of multiple fit statistics" (Campbell, Gillaspy, & Thompson, 1995, p. 6).

When a confirmatory analysis fails to fit the observed factor structure with the theoretical structure, the researcher can evaluate ways to improve the model by exploring which parameters might be freed that had been fixed and which might be fixed that had been freed. The computer packages can be utilized to change parameters one at a time in order to determine what changes offer the greatest amount of improvement in the fit of the model.

Summary

The present paper illustrated the difference between exploratory and confirmatory factor analyses. The shortcomings of exploratory methods were provided. It was indicated that confirmatory factor analysis is advantageous over exploratory factor analysis as CFA allows the researcher to test numerous competing hypotheses regarding the factors underlying the data. The process of confirmatory factor analysis of data was described. It was emphasized that it is important to realize that more than one model may accurately describe the data and that a number of fit indices should be used to determine the fit of the various models. Finally, methods available to increase the fit of the researcher's model to the data were explained.

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