Application of bifactor models in criminal psychology research: a guide to researchers

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Abstract

Purpose – *The purpose of this paper is to introduce the reader to the nature of confirmatory bifactor modelling. Confirmatory bifactor modelling is a factor analytic procedure that allows researchers to model unidimensionality and multidimensionality simultaneously. This method has important applications in the field of criminal psychology.*

Design/methodology/approach – *This paper begins by introducing the topic of factor analysis and explains how confirmatory bifactor modelling is similar yet distinct to the more familiar factor analytical procedures in the psychological literature.*

Findings – *Through practical examples this paper explains the value of this analytical technique to researchers in criminal psychology. Examples from the existing criminal psychological literature are used to illustrate the way in which bifactor analysis allows important theoretical questions to be addressed.*

Originality/value – *This paper highlights the strengths and limitations associated with traditional "restricted" confirmatory bifactor models and introduces the notion of the "unrestricted" bifactor model. The unrestricted bifactor model allows greater flexibility for addressing interesting research questions. The paper concludes by providing the reader with an annotated Mplus syntax file for how to perform confirmatory bifactor modelling.*

Keywords *Psychopathy, Bifactor, Confirmatory factor analysis (CFA), Criminal social identity, Latent variable modelling, Structural equation modelling (SEM)*

Paper type *Conceptual paper*

Introduction

Factor analysis

The use of latent variable modelling techniques in the social sciences has greatly improved the scientific integrity of these disciplines. Application of latent variable modelling techniques such as factor analysis and structural equation modelling (SEM) have allowed social science researchers to more precisely measure their target variables of interest (through removal of measurement error) and to develop more parsimonious theoretical models (through the construction of latent variables). Factor analytical procedures, whether exploratory or confirmatory, have substantial value to the scientifically minded criminal psychologist. Criminal psychologists who seek to understand the factors that contribute to the development and maintenance of criminal behaviour often investigate numerous psychological constructs to explain these actions: psychopathy (Hare, 1991); personality traits (Eysenck and Gudjonsson, 1989); self-esteem (Boduszek *et al.*, 2012a, b); criminal thinking styles (Walters, 2012); and criminal social identity (Boduszek and Hyland, 2011). All of these constructs, and every other psychological variable, is termed a "latent variable" given that it cannot be directly observed. Latent variables are distinguished from "observed variables" which, as the name suggests, are directly observable (e.g. type of criminal conviction, amount of time spent in prison, number of criminal convictions).

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When criminal psychologists seek to measure latent variables the general strategy for measurement is the use of psychometrically validated questionnaires. Researchers obtain self-report or clinician-administered total scores on such scales and analyse the data accordingly. The assumption is implicitly made that the observed score are a true and accurate reflection of the latent variable of interest. This practice of assuming that the observed score is equal to the true score of the latent construct is problematic given that it is well established that "[…] all measurement is befuddled with error" (McNemaer, 1954, p. 294). The inclusion of error in our measurements means that observed scores (total scores on a validated questionnaire) will not be a true and accurate reflection of the latent variable of interest (Klein, 2011). The great value of factor analytic procedures to psychologists is the ability to account for measurement error and obtain more precise measurements of latent variables of interest. This is the primary, although certainly not the only, reason why factor analysis and SEM procedures have been adopted widely across the social sciences.

In an important paper on the topic of bifactor modelling Chen *et al.* (2006) describe how "Researchers interested in assessing a construct often hypothesise that several highly related domains comprise the general construct of interest" (p. 189). In other words, researchers interested in a given phenomenon usually suggest that the construct is multifaceted. For example, in an attempt to detail the specific nature of criminal social identity Boduszek *et al.* (2012a, b) hypothesised that there exists three related aspects of criminal social identity: cognitive centrality, in-group ties, and in-group affect. In Hare's (1991) original formulation of the structure of psychopathy, he suggests the presence of two broad but related constructs: interpersonal/affective symptoms; and antisocial/lifestyle symptoms. As a consequence of describing a single theoretical construct in a multidimensional manner, and constructing questionnaires in a way that reflect these multiple dimensions, factor analytic research often provides conflicting evidence of unidimensionality and multidimseionality (Reise *et al.*, 2010).

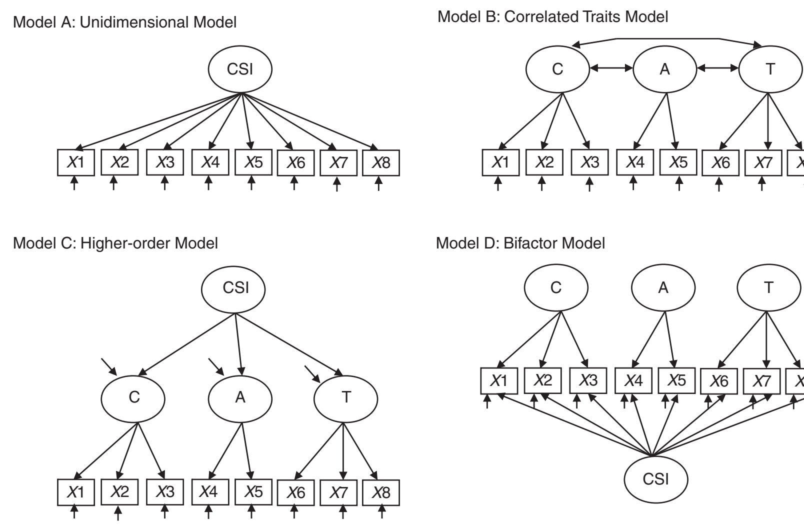
Exploratory factor analysis research often provides evidence for a single source of covariation among all indicators (Factor 1 extracted frequently possess a very large eigenvalue which is many times the magnitude of Factor 2). In contrast, confirmatory factor analytic research very rarely demonstrates satisfactory model fit for unidimensional structures, and instead produces evidence of multidimensionality. These contradictory findings frequently lead to confusion with regards to the exact structure of a given psychological construct, and the appropriate scoring scheme for the questionnaire designed to measure that construct. Do scores on a self-report measure reflect a single underlying latent factor (e.g. psychopathy) or are scores reflective of multiple latent factors (e.g. interpersonal symptoms, affective symptoms, lifestyle symptoms, and antisocial symptoms) and thus require the construction of subscales? A solution to this kind of problem lies in the application of bifactor models.

Alternative model structures

Reise (2012) states "A bifactor structural model specifies that the covariance among a set of item responses can be accounted for by a single general factor that reflects the common variance running among all scale items and group factors that reflect additional common variance among clusters of items, typically, with highly similar content" (p. 668). This explanation of a bifactor model is illustrated in Figure 1, Model D. As a means of illustrating the structure of a bifactor model in relation to more familiar unidimensional, multidimensional, and higher-order structures, the Measure of Criminal Social Identity (MCSI; Boduszek *et al.*, 2012a) will be used. The MCSI is an eight-item measure that was constructed to capture the three domains of criminal social identity: cognitive centrality (three items), in-group affect (two items), and in-group ties (three items).

Model A is a familiar unidimensional structure in which covariation among the eight indicators is explained in terms of a single common factor (criminal social identity). Very often this kind of unidimensional structure is the one that many theoreticians and scale develops would desire to see supported in the data because such a model would indicate that summed scores on a scale represent individual differences on the latent variable of interest (Reise *et al.*, 2010).

Figure 1 Alternative model structures of the measure of criminal social identity



Notes: CSI, criminal social identity; C, cognitive centrality; A, in-group affect; T, in-group ties; *X*1-*X*8, measured variables

Model B is a correlated-factor model in which criminal social identity is separated into its component parts (centrality, in-group affect, and in-group ties). The important thing to notice about the correlated-factor models is that no measurement structure is included. The factors are intercorrelated, however there is no attempt to model or explain why these three factors are correlated. Theoretically we believe these factors to be correlated because they are each components of criminal social identity, however we do not explicitly model this.

Model C is a "higher order" structural model in which a measurement structure is imposed on the three first-order factors. In this case we explain the covariation between cognitive centrality, in-group affect, and in-group ties in terms of a single source: criminal social identity. Important to observe in this kind of model is the relationship between the target construct (criminal social identity) and observable indicators of that construct. Unlike in Model A, the relationship here is indirect. The impact of a criminal social identity on the observable phenomena is mediated via the first-order factors of cognitive centrality, in-group affect, and in-group ties. Model C is often invoked and investigated because it appears to provide a theoretically and methodologically satisfying means of resolving debates over unidimensionality vs multidimensionality. These types of models are frequently tested in the psychological literature. However they are not the only means of integrating unidimensionality and multidimensionality.

Model D is the bifactor model (Holzinger and Swineford, 1937). As can be seen the bifactor solution includes an explanation of unidimensionality: all items in the scale load onto a single common source of covariation (criminal social identity). This factor is commonly referred to as the "general factor" (Reise *et al.*, 2010). Importantly, in the bifactor model the relationship between the general factor and the observable indicators is direct rather than indirect, as is the case in the higher-order model (Model C). The bifactor model also specifies that in addition to the general factor, there can be multiple other factors contributing covariation among the indicators. These sources of covariation are frequently referred to as "grouping factors". The grouping factors in the current example are the three factors of cognitive centrality, in-group affect, and in-group ties. Consequently, aspects of multidimensionality are also included along with aspects of unidimensionality.

Reise *et al.* (2010) suggest that because bifactor models can incorporate elements of both unidimensionality and multidimensionality they should always be used as a baseline comparison model rather than the normal practice of comparing multidimensional structures to a unidimensional structure. Bifactor models can be estimated and tested in terms of their fit of the data in just the same way as each of the alternative model structures are tested. Moreover, since the bifactor model structure is a nested version of the alternative model structure, model comparison tests are appropriate for comparing a bifactor solution to alternative model structures.

Bifactor models: issues of concern

The bifactor model structure outlined in Figure 1, Model A is known as a confirmatory bifactor model. It is important to recognise that just as with standard factor analytic models, bifactor modelling can be performed in an exploratory or confirmatory manner. The examples raised and discussed in this paper relate solely to confirmatory bifactor modelling but see Reise (2012) and Reise *et al.* (2010) for discussions on exploratory bifactor procedures.

Classical descriptions of confirmatory bifactor models make a number of fundamental requirements about the specification of the model which requires consideration (Reise *et al.*, 2010; Yung *et al.*, 1999). First, an individual item is restricted to load onto the general factor of interest, and to only one grouping factor. Second, bifactor models restrict the grouping factors to be uncorrelated with one another, and to be uncorrelated with the general factor. Third, a bifactor model includes just one general factor of interest. In other words, for those interested in applying a bifactor model structure, traditional descriptions of the model necessitate that the researcher can only be interested in modelling one general factor (the latent variable of interest), and that the grouping factor being modelled must be unrelated to one another, and unrelated to the general factor.

Restricted or unrestricted bifactor models?

Reise *et al.* (2010) have termed this traditional model conceptualisation the restricted bifactor model. The necessity to restrict all factors in the model to be uncorrelated has led to criticism that the bifactor model simply doesn't make sense theoretically. For example, as described in Figure 1, how can it be proposed that cognitive centrality, in-group affect, and in-group ties are each components of a latent variable termed criminal social identity but subsequently model that psychological construct in such a way that each factor is unrelated to the other; and that each factor in unrelated to criminal social identity? In such situations the requirement to model all factors as uncorrelated violates theoretical sense. As such, researchers have argued that restricting factors to be uncorrelated is not a fundamental requirement (Rindskopf and Rose, 1988).

It is suggested that decisions regarding when to restrict model factors to be uncorrelated, and when to allow them to correlate should be guided by theory. In a series of studies the latent structure of the Rosenberg Self-Esteem Scale (RSES; Rosenberg, 1989) was studied in a sample of prisoners (Boduszek *et al.*, 2013) and the general population (Hyland *et al.*, 2014a). A one-factor model, a two-factor model (positive self-esteem and negative self-esteem) and a bifactor model were compared. It was hypothesised that within the general population evidence of multidimensionality was a spurious discovery arising as a methodological artefact of constructing five positively phrased items, and five negatively phrased items. In this case, it was hypothesised that the general factor (self-esteem) was the primary source of covariation among the indicators, along with two other sources of covariation (grouping factors) that arise due to methodological effects (item phrasing). In situations such as these where the working hypothesis is that the grouping factors reflect method effects, it is reasonable to assume that these factors should be uncorrelated with each other, and that each should be uncorrelated with the general factor of interest.

On the other hand, based on previous findings (Boduszek *et al.*, 2012b) it was hypothesised that within a criminal population the two grouping factors are more than just methodological effects and are in-fact meaningful constructs that are distinct but related. Based on theoretical and empirical indications, it was appropriate in this case to unrestrict the constraints of the classical model structure and allow all factors to correlate[1]. It seems reasonable therefore that in situations where it is suspected that the grouping factors are meaningful constructs and there are theoretical indications to assume intercorrelations between the factors that the restrictions of uncorrelated grouping factors be relaxed.

How many general factors can be included?

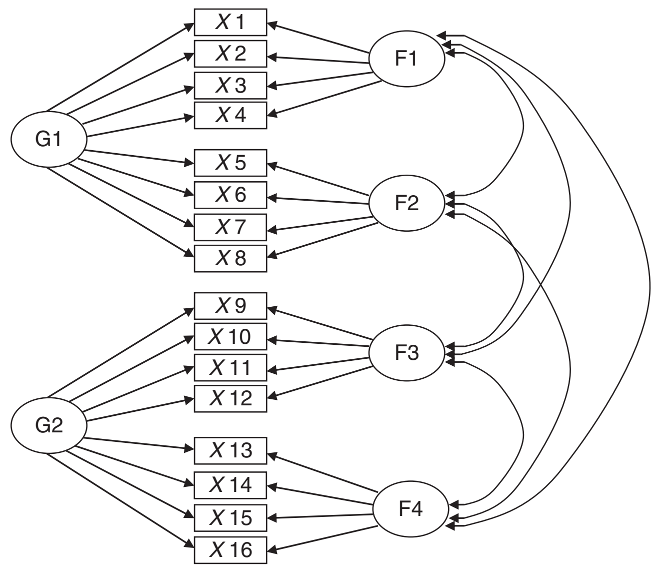
Bifactor modelling has found growing prominence in the psychological literature in the past decade because of its ability to test and identify individual differences on a single latent variable of interest, even in the presence of multidimensionality. The classical descriptions of bifactor models specify the presence of a single general factor (Reise *et al.*, 2010). However, there is nothing inherent to the bifactor model that restricts the general factor to just one factor. For example, in a study assessing the structure of the 72-item Attitudes and Belief Scale-2 (DiGiuseppe *et al.*, 1989), a measure rational and irrational beliefs, it was hypothesised that the scale measured eight intercorrelated cognitive factors consistent with theoretical models from the Rational Emotive Behaviour Therapy literature (Hyland and Boduszek, 2012; Hyland *et al.*, 2014b). Model fit of this structure was unsatisfactory. We argued that the presence of three method effects was impacting on model fit. These three method effects were thus modelled as grouping factors, and the eight cognitive factors were retained as meaningful "general factors". Results of the bifactor analysis indicated support for this structural representation. The results of this study indicated the theoretical and empirical feasibility of modelling more than one general factor. This has important implications for the criminal psychology literature.

The use of bifactor modelling has been employed frequently in the psychopathy literature. As described previously, Hare's (1991) original formulation of the structure of psychopathy described two related general factors: interpersonal/affective and lifestyle/antisocial. Research however has suggested a number of alternative structural formulations for psychopathy. Neal and Sellbom (2012) using the Self-Report Psychopathy Scale III, suggested that psychopathy can be explained in terms of four correlated factors: Interpersonal Manipulation; Callous Affect; Erratic Lifestyle; and Antisocial Behaviour. Paulhus *et al.* (in press) replicated this structure. In addition to support for an intercorrelated four factor structure, two (Harpur *et al.*, 1998) and three (Cooke and Michie, 2001) factor solutions have also been supported. Clearly, research findings are inconsistent with regards to the appropriate structure of psychopathy. Patrick *et al.* (2007) sought to resolve this inconsistency in the literature through the use of bifactor modelling. They investigated a number of competing latent models of psychopathy and found that a bifactor model including a single general "psychopathy" factor and two grouping factors, in-line with Hare's original two-factor model of psychopathy (interpersonal/affective and lifestyle/antisocial), was the best fit of the data. Flores-Mendoza *et al.* (2008) followed up this study and also found that this bifactor solution was a superior representation of the data than any other tested model. These findings appeared to provide clarity to the research, however psychopathy has never been explained in terms of a single general construct.

Boduszek *et al.* (in press) extended the traditional bifactor model by including two general factors consistent with Hare's (1991) original conceptualisation (Interpersonal/Affective and Antisocial Behaviour/Erratic Lifestyle) and four grouping factors that take into account the recent empirical findings (Interpersonal, Affective, Antisocial Behaviour, and Erratic Lifestyle). It was assumed that these four grouping factors were simply method effect arising as a result of item phrasing and once controlled for, evidence of two prominent (and related) general factors of psychopathy would emerge. Results of the analysis supported this assumption.

This line of research in psychopathy not only indicates the value and utility of bifactor modelling to address important theoretical questions in the criminal psychology literature, but highlights the flexibility of bifactor models. Researchers need not be constrained to only include a single general factor. It is recommended that in situations where it is theoretically plausible, multiple general factors can be included, along with multiple grouping factors (see Figure 2 for an example of a bifactor model with more than one general factor). In contrast to Reise *et al.* (2010) who describe the restricted bifactor model, this paper introduces the term "unrestricted bifactor models" for those situations where traditional constraints of uncorrelated factors and/or only one general factor are relaxed.

Figure 2 Bifactor model with more than one general factor



Notes: G1 and G2, general factors; F1-F4, grouping factors; *X*1-*X*16, measured variables

General factors or grouping factors: which are more important?

When researchers utilise a bifactor model structure, a reasonable question to ask is which factors matter most? Is the general factor more important than the grouping factors, or vice versa? The answer to this question can be ascertained from inspection of the factor loadings (Reise *et al.*, 2010). If the bifactor model should be found to be a good representation of the obtained data, researchers should then inspect the factor loadings for each latent variable. In situations where items in a scale display higher factor loadings on the general factor than they do on their respective grouping factors, this is clear evidence that the general factor is of primary importance. Such results indicate that the majority of covariation between observable indicators is being explained by the general factor in the model (see Table I for such an example).

Conversely, should inspection of the factor loadings indicate that the observable indicators are loading more strongly (or equally strongly) on their respective grouping factor than they are on

Table I Example of standardized factor loadings on a general factor and three grouping factors suggesting the primacy of the general factor

Items	*General factor*	*Grouping Factor 1*	*Grouping Factor 2*	*Grouping Factor 3*
1	0.85	–0.12		
2	0.77	0.18		
3	0.68	0.09		
4	0.86		0.14	
5	0.59		0.25	
6	0.87		0.19	
7	0.55			0.31
8	0.91			0.06

Note: All factor loadings are statistically significant ($p < 0.001$)

the general factor, this is evidence suggesting that the grouping factors are of primary importance (see Table II for such an example). In some situations the factor loadings may be somewhat ambiguous and it will not be obvious which factor is of greatest importance. As is commonly the case in such situations, researchers should guide their decision making process on sound theoretical indications.

Should researchers wish to include these latent factors in a structural model upon discovery of a bifactor solution, all they need do is regress the outcome variable, or variables, onto whichever factor(s) is deemed appropriate. For example, say we modelled the MCSI and discovered that a bifactor solution (Figure 1, Model D) was the best fit, and additionally, that the general factor was more important than the grouping factors. We would then regress our dependent variables of interest onto criminal social identity (the general factor) as modelled in the bifactor solution (see Figure 3).

Conclusion

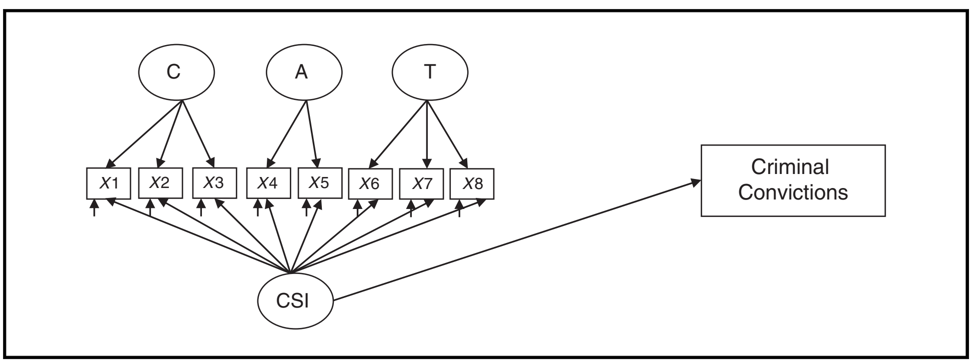
Bifactor modelling offers criminal psychology researchers a highly effective analytical method of investigating complex research questions, however this approach is very rarely utilised. Bifactor modelling is extremely beneficial as it affords researchers the ability to model and assess the validity of a single (or multiple) general factor(s) while also acknowledging and incorporating aspects of multidimensionality. Additionally, through the use of this methodology, researchers can ask (and answer!) interesting research questions such as; what happens to the associations between grouping factors once the effects of the general factor have been controlled for? Is this construct primarily unidimensional or best represented as a

Table II Example of standardized factor loadings for a general factor and three grouping factors that suggests the primacy of the three grouping factors

Items	*General factor*	*Grouping Factor 1*	*Grouping Factor 2*	*Grouping Factor 3*
1	0.12	0.77		
2	0.21	0.59		
3	0.08	0.91		
4	0.44		0.56	
5	0.33		0.61	
6	0.27		0.59	
7	0.25			0.81
8	0.42			0.64

Note: All factor loadings are statistically significant ($p < 0.001$)

Figure 3 Bifactor solution to the measure of criminal social identity predicting an outcome variable "criminal convictions"



multidimensional construct? How best should this particular questionnaire be scored? Are there method effects that need to be accounted for in order to derive a trustworthy scoring scheme? Will the predictive power of a given construct be improved through the modelling (controlling) of methodological effects?

In the Appendix that follows, an annotated Mplus syntax input file is provided to guide interested researchers in specifying a bifactor model.

Note

1. In this case the bifactor model best represented the structure of the RSES within the general population, while the multidimensional structure best represented the structure of the RSES within the criminal population.

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Appendix. Mplus syntax input file for confirmatory bifactor modelling

TITLE: Confirmatory bifactor model with one general factor

DATA: file is example.dat;

VARIABLE: names are *x*1-*x*8;

ANALYSIS: estimator = MLR;

MODEL: *General Factor by x1* x2x3 x4x5 x6x7 x8*;

Grouping Factor 1 by x1 x2 x3*;

Grouping Factor 2 by x4 x5*;

Grouping Factor 3 by x6 x7 x8*;

(Note that the first item in each congeneric set should contain an *. By default Mplus fixes the factor loading of the first item to 1.0. The inclusion of the * overrides the default command)

General Factor@1;

Grouping Factor 1@1;

Grouping Factor 2@1;

Grouping Factor 3@1;

(These four commands instruct Mplus to constrain the variances of each factor to 1.0. This is necessary for model estimation since the fixed factor loading of the first item in each congeneric set was freely estimated)

General Factor with Grouping Factor 1-Grouping Factor 3@0;

(This command sets the correlation between the general factor and each of the grouping factors to be 0. If you wish to run an unrestricted bifactor model disregard this command.)

Grouping Factor 1 with Grouping Factor 2@0;

Grouping Factor 1 with Grouping Factor 3@0;

Grouping Factor 2 with Grouping Factor 3@0;

(These commands set the correlations between the three grouping factors to 0. If running an unrestricted model, disregard this command.)

OUTPUT: STDYX MODINDICES;

(The STDYX command produces standardised model parameter results, while the MODINDICES produces modification indices which can help to explain where the model may be mis-specified).

About the author

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