Open access • Journal Article • DOI:10.1017/S003329172000104X

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Philip Hyland, Jamie Murphy, Mark Shevlin, Richard P. Bentall ...+6 more authors

Institutions: Maynooth University, Ulster University, University of Sheffield, Edinburgh Napier University ...+5 more institutions

Published on: 01 Oct 2021 - Psychological Medicine (Cambridge University Press)

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On top or underneath: Where does the general factor of psychopathology fit within a dimensional model of psychopathology?

Philip Hyland[1], Jamie Murphy[2], Mark Shevlin[2], Richard P. Bentall[3], Thanos Karatzias[4,5], Grace W.K. Ho[6], Daniel Boduszek[7,8], & Eoin McElroy[9]

[1]Department of Psychology, Maynooth University, Kildare, Ireland

[2]School of Psychology, Ulster University, Derry, Northern Ireland

[3]Department of Psychology, University of Sheffield, Sheffield, England

[4]Edinburgh Napier University, School of Health & Social Care, Edinburgh, Scotland

[5]NHS Lothian, Rivers Centre for Traumatic Stress, Edinburgh, Scotland

[6]The Hong Kong Polytechnic University, School of Nursing, Hong Kong

[7]School of Human and Health Sciences, University of Huddersfield, England

[8]SWPS University of Social Sciences and Humanities, Katowice, Poland

[9]Department of Neuroscience, Psychology and Behaviour, University of Leicester, England

Corresponding Author: Philip Hyland, Department of Psychology, Maynooth University, Kildare, Ireland. Philip.hyland@mu.ie

Word count: 4992

Abstract

Background: Dimensional models of psychopathology are increasingly common, and there is evidence for the existence of a general dimension of psychopathology ('*p*'). The existing literature presented two ways to model *p*: as a bifactor or as a higher-order dimension. Bifactor models typically fit sample data better than higher-order models, and are often selected as better fitting alternatives but there are reasons to be cautious of such an approach to model selection. In this study, the bifactor and higher-order models of *p* were compared in relation to associations with established risk variables for mental illness.

Methods: A trauma-exposed community sample from the United Kingdom (N = 1,051) completed self-report measures of 49 symptoms of psychopathology.

Results: A higher-order model with four first-order dimensions (Fear, Distress, Externalizing, and Thought Disorder) and a higher-order *p* dimension provided satisfactory model fit, and a bifactor representation provided superior model fit. Bifactor *p* and higher-order *p* were highly correlated (r = .97) indicating that both parametrizations produce near equivalent general dimensions of psychopathology. Latent variable models including predictor variables showed that the risk variables explained more variance in higher-order *p* than bifactor *p*. The higher-order model produced more interpretable associations for the first-order/specific dimensions compared to the bifactor model.

Conclusions: The higher-order representation of *p*, as described in the Hierarchical Taxonomy of Psychopathology, appears to be a more appropriate way to conceptualise the general dimension of psychopathology than the bifactor approach. The research and clinical implications of these discrepant ways of modelling *p* are discussed.

Key words: psychopathology; HiTOP; childhood trauma; trauma; mental illness.

On top or underneath: Where does the general factor of psychopathology fit within a dimensional model of psychopathology?

Dimensional models of psychopathology have been shown to be superior to categorical (i.e., diagnostic) models in terms of identifying genetic and environmental risk (Taylor *et al.,* 2018), underlying neurology (Goodkind *et al.,* 2015), chronicity (Vollebergh *et al.,* 2001), developmental change (McElroy *et al.,* 2018), functional impairment (Waszczuk *et al.,* 2017a), treatment planning (Waszczuk *et al.,* 2017b), and treatment response (Andrews *et al.,* 2009). Initially comprising 'Internalizing' and 'Externalizing' dimensions (Krueger *et al.,* 1998), and then a 'Thought Disorder' (psychosis) dimension (Kotov *et al.,* 2011), more recent models have introduced 'Detachment' and 'Somatoform' dimensions, and bifurcated Internalizing into 'Fear' and 'Distress' (Lahey *et al.,* 2012) sub-factors, and Externalizing into 'Disinhibited' and 'Antagonistic' sub-factors (Wright & Simms, 2015). A general dimension of psychopathology, termed '*p*' (Lahey *et al.*, 2012; Caspi *et al*., 2014), was introduced to explain the covariation between all lower-order dimensions and has been evidenced in nationally representative samples of adults (Lahey *et al.,* 2012; Caspi *et al.,* 2014; Martel *et al.,* 2017), children and adolescents (Tackett *et al.,* 2013; Laceulle *et al.,* 2015; Lahey *et al.,* 2015; Patalay *et al.,* 2015; Carragher *et al.,* 2016; Martel *et al.,* 2017; Waldman *et al.,* 2016; McElroy *et al.,* 2018), and among clinical patients (Hyland *et al.,* 2018a; Reininghaus *et al.*, 2013; Reininghaus *et al.*, 2016). In each of these studies, *p* was modelled as a bifactor dimension (see Figure 1a).

The dimensional approach to psychopathology achieved prominence with the publication of the *Hierarchical Taxonomy of Psychopathology* (HiTOP: Kotov *et al.,* 2017). HiTOP proposes that 'symptoms' cluster together into correlated 'syndromes', and these syndromes are manifestations of higher-order 'sub-factors' (e.g., Fear and Distress). All sub-factors are subsumed under a small number of broad 'spectra' dimensions (e.g., Internalizing, Externalizing, Thought Disorder), and *p* sits at the top of this hierarchy capturing the

covariation between the spectra-level dimensions. Considerable evidence has accumulated in support of the hierarchical structure proposed by HiTOP (Conway *et al.,* 2019a; Forbes *et al.,* 2017; Kim & Eaton, 2015; Kotelnikova *et al.,* 2019). Consequently, two approaches to modelling a general dimension of psychopathology exist, and they make different assumptions about the fundamental nature of psychopathology (van Bork, Epskamp, Rhemtulla, Borsboom, & van der Maas, 2017); one models *p* as a bifactor dimension, and the other models *p* as a higher-order dimension.

In the bifactor model, symptom variation and covariation are explained by one general dimension (*p*) and multiple specific dimensions (e.g., Internalizing, Externalizing, Thought Disorder) that are orthogonal to the general dimension (Figure 1a). The general and specific dimensions directly affect symptoms, and thus 'compete' to capture symptom variation and covariation. In the higher-order model, symptom variation and covariation are explained by multiple lower-order dimensions (e.g., Internalizing, Externalizing, Thought Disorder) and the correlations between these dimensions are explained by one superordinate dimension (Figure 1b). In this model, the general and specific dimensions do not 'compete' to capture symptom variation/covariation, nor are they orthogonal to one another. Rather, *p* causes variation in the lower-order dimensions and indirectly affects symptoms via these subordinate factors.

Greene *et al.* (2019) showed that between 2010 and 2017, 95% of studies comparing these representations of psychopathology found that the bifactor model had superior overall model fit. However, using simulated data, they demonstrated that standard indices of model fit, and model comparison, exhibit a 'pro-bifactor' bias. Greene *et al.* showed that when the true underlying model was a correlated factor model, standard model fit, and comparison indices consistently favoured a bifactor model. These and other results (Reise *et al.,* 2016; Markon, 2019) demonstrate that researchers should not rely solely on estimates of model fit in order to 'pick the right model' when comparing bifactor models to correlated factor models or higher-

order models. Rather, it is necessary that models be subjected to 'riskier' tests of validity (Meehl, 1978), including how they perform in relation to external variables. Moreover, as there is evidence that bifactor models produce spurious evidence of superior model fit because of their ability to accommodate model misspecifications (Reise *et al.,* 2016), and randomness in the data (Bonifay & Cai, 2017), bifactor dimensions should be assessed in terms of their reliability and replicability (Rodriguez *et al.*, 2016). Existing data shows that when *p* is modelled as a bifactor, it is correlated with - and predictive of - an array of exogenous variables (Caspi & Moffitt, 2018). However, fewer studies have examined the reliability and replicability of the dimensions of psychopathology in a bifactor model. In those that have, there is consistent support for the reliability and replicability of *p,* however, less consistent support has been obtained for the specific dimensions (Murray *et al.,* 2016; Martel *et al.,* 2017; McElroy *et al.,* 2018; Constantinou *et al.,* 2019; Watts *et al.,* 2019).

Current study

The goal of this study was to evaluate whether *p* is better represented as a bifactor dimension or as a higher-order dimension of psychopathology. We followed the recommendations of Green *et al.* (2019) and Watts *et al.* (2019) and extended our assessments beyond tests of overall model fit to also include 'riskier' tests of model performance. Thus, we first assessed the overall model fit of bifactor and higher-order models of psychopathology (along with a unidimensional model and multiple correlated factor models). Based on the existing literature (Caspi & Moffitt, 2018), we hypothesised that all models would provide a satisfactory representation of the data, however, given the pro-bifactor bias associated with standard model fit and comparison indices (Greene *et al.,* 2019), we hypothesised that a bifactor model would 'best' fit the data. The reliability and replicability of the general and specific dimensions of psychopathology from the best-fitting bifactor model were then assessed, as per the recommendations of Rodriguez *et al.* (2016). Based on existing evidence, it was

hypothesised that *p* would have excellent reliability and replicability, however, the specific dimensions would yield less robust results.

Second, we evaluated how the dimensions of psychopathology – *p* and the specific/first-order dimensions – estimated within the bifactor and higher-order models of psychopathology were correlated with one another. Based on Kim and Eaton's (2015) findings, we hypothesised that (a) bifactor *p* and higher-order *p* would be nearly perfectly correlated, and (b) the specific and first-order dimensions would be highly correlated when modelled within the bifactor and higher-order models, respectively.

Third, the associations between multiple external variables for mental illness and *p*, modelled as a bifactor dimension and as a higher-order dimension, were assessed using structural equation modelling (SEM). Under the assumption that *p* is almost identical when modelled as a bifactor dimension or as a higher-order dimension, it was hypothesised that the observed patterns of association with the external variables would be similar within both modelling approaches. The associations between the external risk variables and the specific (bifactor model) and first-order (higher-order model) dimensions were also assessed. As there is limited evidence regarding the relative associations between specific and first-order dimensions and external risk variables, no hypotheses were formed for this part of the analyses.

Methods

Participants and procedure

The sample for this study was drawn from a panel of research participants that is representative of the general adult population of the United Kingdom (UK), as per the most recent 2011 census. A survey company, Qualtrics, was employed and quota sampling was used to gather a sample that was representative of the UK adult population in terms of age and geographical distribution (England, Wales, Scotland, and Northern Ireland). These data were collected in 2017 as part of a larger project examining trauma-related psychopathology. There

were three inclusion criteria: participants had experienced a traumatic life event, were born in the UK, and were 18 years of age or older. In total, 2,653 panel members were contacted by Qualtrics via email and asked to participate, and 1,051 consented and met the inclusion criteria. Ethical approval was granted by the ethics committee of the institution to which the first author was affiliated at the time of the data collection. The mean age was 47.18 years (*SD* = 15.00, *range* = 18-90 years), and 68.4% were female. Nearly half 'grew up in an urban/large city area' (45.3%), 70.4% were 'in a committed relationship', 32.5% had 'children under 16', 62.7% completed a college/university education, 68.5% were 'employed', and 17.8% had emigrated at some point in their life.

Measures

The 49 symptoms of psychopathology measured in this study are presented in Supplementary Table 1. These were taken from self-report questionnaires that mixed binary and Likert-scale response options. While the analysis could have been conducted on the basis of polyserial correlations, this would have meant that variables were measured on different conceptual/clinical levels. In order to harmonise all variables, it was decided to make all variables binary, and employ cut-off scores that represented what would be clinically meaningful. Thus, all items were dichotomised to reflect the 'presence' (1) or 'absence' (0) of a symptom and these transformations were based on scoring guidelines and standard research procedures.

Internalizing: There were 37 symptoms of internalizing psychopathology. Twelve were taken from the International Trauma Questionnaire (Cloitre *et al.,* 2018), a measure of ICD-11 Complex Posttraumatic Stress Disorder (CPTSD). Six items measure PTSD symptoms and six measure 'Disturbances in Self-Organization' symptoms. All items were answered on a five-point Likert scale (0 = 'Not at all' to 4 = 'Extremely'), and symptom endorsement was based on a score of $\geq$ 2 ('Moderately'). Nine Major Depression and seven Generalized Anxiety

Disorder symptoms were measured using the Patient Health Questionnaire-9 (Kroenke *et al.,* 2001) and the Generalized Anxiety Disorder 7-Item Scale (Spitzer *et al.,* 2006), respectively. Both employ a four-point Likert scale (0 = 'Not at all' to 3 = 'Nearly every day'), and symptom endorsement was based on score $\geq$ 1 ('Several days'). Nine Borderline Personality Disorder symptoms were assessed using a self-report measure based on the BPD screening module of the Structured Clinical Interview for DSM-IV Axis II disorders (Hyland et al., 2018b). Respondents indicated whether each symptom was 'true' (1) or 'not true' (0) of them.

Externalizing: There were five indicators of externalizing psychopathology. The three-item AUDIT Alcohol Consumption Questionnaire (Bush *et al.,* 1998) was used to assess frequency of alcohol use (0 = 'Never or less than monthly', 1 = '2-3 times per month or more frequently'), daily consumption of alcohol (0 = 'Less than 2 units per day', 1 = 'More than 2 units per day'), and frequency of binge drinking (0 = 'Never', 1 = 'Sometimes or regularly'). Two questions measuring frequency of cannabis use (0 = 'Never/once or twice in my life', 1 = 'A few times a year to every day') and use starting before 18 (0 = 'No', 1 = 'Yes') were taken from the UK's 2007 Adult Psychiatric Morbidity Survey (Mc Manus *et al.,* 2009).

Thought Disorder: The Adolescent Psychotic-Like Symptom Screener (Kelleher *et al.,* 2011) includes seven items measuring the frequency of different 'positive' psychosis experiences. A four-point Likert-scale (0 = 'Never' to 3 = 'Nearly always') was used and scores $\geq$ 1 ('Sometimes') indicated the presence of a psychotic-like symptom.

Traumatic exposure: The Adverse Childhood Experiences questionnaire (ACE: Felitti *et al.,* 1998) and the Life Events Checklist for DSM-5 (LEC-5; Weathers *et al.,* 2013) were used to measure childhood ('before 18') and adulthood ('18 or older') interpersonal and non-interpersonal trauma, respectively. Five ACE (verbal abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect; all by a caregiver) and six LEC-5 (physical assault, assault with a weapon, sexual assault, other sexual experiences, captivity, and causing serious

injury/death to another person) events were used to measure childhood interpersonal trauma. Adulthood interpersonal trauma was measured using the same six LEC-5 events. Five ACE (parental divorce, witnessing domestic violence, family member with a drug/alcohol problem, family member with a serious mental illness, and a family member in prison) and seven LEC-5 (natural disaster, fire/explosion, transportation accident, serious accident, exposure to toxic substance, life-threatening illness/injury, and sudden/unexpected death of a loved one) events were used to measure childhood non-interpersonal trauma. Adulthood non-interpersonal trauma was measured using the same seven LEC-5 events.

Data analysis

The latent structure of the 49 symptoms of psychopathology was assessed using confirmatory factor analysis (CFA) and confirmatory bifactor modelling. Six models were tested: (1) a unidimensional model with one general factor (*p*); (2) a correlated three-factor model including dimensions of 'Internalizing', 'Externalizing', and 'Thought Disorder'; (3) a correlated four-factor model including dimensions of 'Fear' (PTSD and anxiety symptoms), 'Distress' (depression, disturbances of self-organization, and borderline personality symptoms), 'Externalizing', and 'Thought Disorder'; (4) a higher-order model with four first-order factors ('Fear', 'Distress', 'Externalizing', and 'Thought Disorder') and one second-order factor (*p*); (5) a bifactor model with one general factor (*p*) orthogonal to three correlated specific factors ('Internalizing', 'Externalizing', and 'Thought Disorder'); and (6) a bifactor model with one general factor (*p*) orthogonal to four correlated specific factors ('Fear', 'Distress', 'Externalizing', and 'Thought Disorder'). It was not possible to test a higher-order model with three first-order factors as this is statistically indistinguishable from a correlated first-order model.

Figure 1a and 1b here

Following the identification of the best-fitting bifactor model, the reliability and replicability of each dimension were assessed in accordance with the recommendations of Rodriguez *et al.* (2016). Omega reliability (ω; proportion of common variance explained by the general and specific factors), omega hierarchical (ωH; proportion of variance within the symptom indicators attributable to the general [or specific] factor[s], controlling for the specific [or general] factors), relative omega (ωR: represents the proportion of reliable variance due to the general factor independent of the specific factors, and each specific factor independent of the general factor), and index H (the extent to which a set of items represents a latent variable and the likelihood of that latent variable replicating across studies) were calculated. Omega coefficients and index H values range from 0-1, and values $\geq$ .80 reflect satisfactory reliability and replicability (Rodriguez *et al.,* 2016). These indices were calculated using Dueber's (2017) software.

Factor scores were saved for each dimension in the best fitting bifactor model and the higher-order model, and the correlations between these factor scores were assessed.

SEM was used to determine the multivariate association between the dimensions within the bifactor and higher-order models and nine exogenous risk variables: sex (0 = male, 1 = female), age, urbanicity (0 = grew up in a rural area, 1 = grew up in an urban area), employment status (0 = employed/retired/student/homemaker, 1 = unemployed), number of different childhood interpersonal traumas, childhood non-interpersonal traumas, adulthood interpersonal traumas, and adulthood non-interpersonal traumas. These risk variables were treated as observed variables and the latent factors of psychopathology were regressed onto each simultaneously.

Analyses were performed in Mplus 8.2 (Muthén & Muthén, 2017) using the Weighted Least Squares Mean- and Variance-Adjusted (WLSMV) estimator which is appropriate for categorical level indicators (Flora & Curran, 2004). There was minimal missing data (0.19%)

and it was handled using pairwise deletion. Model fit was evaluated by several standard goodness-of-fit indices (Hu & Bentler, 1999): a non-significant chi-square (χ^2) result indicates excellent model fit; Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values $\geq$ .90, and Root Mean Square Error of Approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) values $\leq$ .08, indicate acceptable mode fit, respectively. All models were re-estimated each model using the Maximum Likelihood estimator to generate Bayesian Information Criterion (BIC) values which can be used to compare nested and non-nested models. The model with the lowest BIC value is considered to be statistically superior, and a difference of 10 points is considered evidence for the superiority of the model with the lower value (Raftery, 1995). However, simulation studies have shown that the BIC favours bifactor models even when the true underlying model is not a bifactor (Greene *et al.,* 2019).

Results

Descriptive statistics

Symptom endorsement rates are presented in Supplementary Table 1, and these ranged from 8.1% ('*Have you ever had messages sent just to you through the TV or radio?*') to 71.4% ('*Feeling tired or having little energy*'). The distributions of childhood interpersonal traumas (*M* = 2.14, *SD* = 2.38), childhood non-interpersonal traumas (*M* = 1.72, *SD* = 1.86), adulthood interpersonal traumas (*M* = 0.78, *SD* = 1.18), and adulthood non-interpersonal traumas (*M* = 1.31, *SD* = 1.28) were positively skewed.

The latent structure of psychopathology

Model fit results are presented in Table 1. The unidimensional model (Model 1) had acceptable fit according to the CFI, TLI, and RMSEA results, however, the SRMR result indicated poor fit. The three- and four-factor correlated models (Models 2 and 3) had acceptable fit across all indices, and both were superior to the unidimensional model. The BIC was lower for the four-factor model than the three-factor model, indicating improvement in fit when the

Internalizing dimension was divided between Fear and Distress. The higher-order model of *p* (Model 4) also had acceptable fit, however, the BIC was higher than for the correlated four-factor model. The bifactor models had superior fit to all other models, and the BIC was lowest for the model with one general factor and four specific factors (Model 6).

Table 1 here

The model parameters for the bifactor and higher-order models are presented in Table 2. In the bifactor model, all symptoms bar one loaded positively and significantly onto *p*. Eight of the 13 fear symptoms loaded onto the Fear dimension; 21 of the 24 distress symptoms loaded onto the Distress dimension; four of the five externalizing symptoms loaded onto the Externalizing dimension; and all of the psychosis symptoms loaded onto the Thought Disorder dimension. In general, the majority of the Fear and Distress symptoms loaded more strongly onto *p* than onto their respective specific dimension, while the opposite was the case for the Externalizing and Thought Disorder symptoms. The correlations between the specific dimensions were all weak.

In the higher-order model, every symptom loaded positively and significantly onto its respective first-order factor, and the four first-order factors loaded positively and significantly onto the second order *p* factor.

Table 2 here

Table 3 includes the reliability and replicability estimates for the bifactor dimensions. Each dimension had satisfactory – or near satisfactory - construct replicability (i.e., index H values $\geq$ .80), however, only *p* exhibited satisfactory reliability (i.e., ω values $\geq$ .80). Fear and Distress, in particular, had extremely low levels of reliability indicating that these dimensions accounted for very little reliable item variance, adjusting for *p*.

Table 3 here

Associations between bifactor and higher-order dimensions

The correlations between the factor scores of each dimension in the bifactor and higher-order models are presented in Table 4. The correlation between the bifactor and higher-order representations of *p* was almost perfect. Similarly, bifactor *p* was nearly perfectly correlated with the higher-order Fear and Distress dimensions. Contrastingly, higher-order *p* was very weakly associated with the specific factors in bifactor model. The Externalizing and Thought Disorder dimensions were strongly associated across the two models, whereas, the Fear and Distress dimensions were very weakly associated across the two models.

Table 4 here

Associations with exogenous variables

The multivariate associations between the nine external risk variables and the dimensions of psychopathology in the bifactor and higher-order models of psychopathology are presented in Table 5. The SEM model based on the bifactor representation of *p* provided an acceptable fit of the data (χ^2 (1468) = 3001, $p < .001$; CFI = .971; TLI = .969; RMSEA = .032 [90% CI = .030, .033], SRMR = .061; BIC = 41,069), as did the second-order model of *p* (χ^2 (1555) = 4920, $p < .001$; CFI = .937; TLI = .935; RMSEA = .045 [90% CI = .044, .047], SRMR = .092; BIC = 42,839). To generate the associations between the external risk variables and the four first-order dimensions, the SEM model was rerun without the second-order *p* factor, and this model also provide a satisfactory representation of the data (χ^2 (1526) = 4863, $p < .001$; CFI = .938; TLI = .934; RMSEA = .046 [90% CI = .044, .047], SRMR = .085; BIC = 42,769).

Table 5 here

The nine risk variables explained 30.8% of the variance in *p* when modelled as a bifactor dimension, and 40.7% of variance in *p* when modelled as a higher-order dimension. Furthermore, the nine risk variables explained substantially more variance in the Fear, Distress, and Thought Disorder dimensions in the correlated-factors model compared to these specific

dimensions in the bifactor model. The risk variables explained a similar proportion of variance in the Externalizing dimension within the bifactor and correlated-factor models.

The strength and direction of the associations between the external risk variables and bifactor *p* and higher-order *p* were similar. In general, however, the associations were marginally stronger when *p* was modelled as a higher-order dimension. In both cases, *p* was most strongly associated with childhood interpersonal traumas (bifactor *p*, $\beta = .27$, and, higher-order *p*, $\beta = .32$). Bifactor and higher-order *p* were also positively correlated with all other forms of trauma, and younger age.

Some notable differences emerged between the specific dimensions in the bifactor model and the first-order dimensions in the correlated model, especially for the Fear and Distress dimensions. In the bifactor model, Fear was associated with growing up in an urban area, and higher levels of childhood and adulthood interpersonal trauma. In the correlated model, Fear was associated with all forms of trauma, younger age, and female sex. In the bifactor model, Distress was associated with male sex, younger age, higher levels of childhood and adulthood interpersonal trauma, and lower levels of adulthood non-interpersonal trauma. In the correlated model, however, Distress was associated with younger age, higher levels of childhood and adulthood interpersonal trauma, and higher levels of childhood non-interpersonal trauma. The associations for the Externalizing and Thought Disorder dimensions were similar across the two models although some difference did emerge. Externalizing was associated with younger age in the correlated model, but not the in the bifactor model; and Thought Disorder was correlated with childhood interpersonal trauma and childhood non-interpersonal trauma in the correlated model, but not in the bifactor model.

Discussion

The existing literature describes two ways in which a general dimension of psychopathology (*p*) may be incorporated into a comprehensive account of the latent structure

of psychopathology. Although the majority of studies have found that the bifactor approach to modelling *p* provides superior model fit to the hierarchical approach favoured by the HiTOP theory, there is compelling evidence to be sceptical of these findings (Greene *et al.,* 2019). As such, the primary objective of this study was to compare how the bifactor and hierarchical approaches to modelling *p* performed when assessed in relation to a set of well-established risk variables for mental illness. Whether *p* should be modelled as a higher-order dimension or as a bifactor dimension might appear to be a niche statistical question with little relevance to clinical reality, however, this is not the case. These models refer to the same constructs (*p*, Internalizing, Externalizing, Thought Disorder) and this can provide the illusion that the constructs contained therein reflect the same underlying psychological phenomena, but the reality is quite different (see van Bork *et al.,* 2017 for full discussion). In the bifactor model, the general dimension of psychopathology is orthogonal to the specific dimensions whereas in the higher-order model the general dimension is causally related to the specific dimensions. This means that clinicians and researchers would have to think in very different ways about what these constructs reflect, how they relate to one another, how best to assess them, how to approach treatment interventions, and how exogeneous risk variables affect each dimension, depending upon which model is more accurate. Thus, determining the correct approach to modelling *p* is a matter of utmost importance for clinicians, researchers, and patients.

We modelled the latent structure of 49 symptoms of psychopathology from a trauma-exposed community sample, and consistent with the existing evidence (Caspi & Moffitt, 2018; Conway *et al.,* 2019b), the multidimensional, higher-order, and bifactor models yielded satisfactory model fit results. Our findings showed that there was value in bifurcating the Internalizing dimension between its Fear and Distress components, similar to previous findings (e.g., Lahey *et al.,* 2012). However, such findings are likely to be dependent upon the specific indicators available in any given study. Presumably, had we a larger set of indicators of

Externalizing psychopathology, we may have found evidence to make a distinction between its Disinhibited and Antagonistic sub-factors. Regardless, the addition of a higher-order *p* factor resulted in a plausible representation of the data, and all first-order factors loaded significantly onto *p*. Higher-order *p* captured a substantial proportion of variance in each of the first-order factors, with the exception of Externalizing. As predicted, the bifactor models provided the closest fit to the data, and one notable finding from Green *et al.'s* (2019) simulation work is worth highlighting here. They showed that pro-bifactor bias in all fit indices was common under conditions of unmodelled cross-factor loadings. Inspection of the modification indices for the correlated and higher-order models showed numerous instances of very strong unmodelled cross-factor loadings. The superior fit for the bifactor models in this study is, therefore, consistent with Greene *et al.'s* (p. 756) conclusion that "the mistaken inference of bifactor superiority seems to be driven by the general dimension's erroneous accommodation of misspecifications through capturing theoretically unexplained variance and repackaging it as common variance, even though it is not."

The reliability and replicability analyses provided additional evidence to be cautious of the favourable model fit results for bifactor model. The general dimension accounted for 92% of reliable variance among the symptoms of psychopathology, independent of the variance accounted for by the specific dimensions. These findings add to similar observations from child, adolescent, and adult samples (Murray *et al.,* 2016; Martel *et al.,* 2017; McElroy *et al.,* 2018; Constantinou *et al.,* 2019; Watts *et al.,* 2019). However, when the variance attributable to the general dimension was partitioned out, the Fear (11%) and Distress (14%) dimensions explained little reliable variances in their respective symptoms, while Externalizing (70%) and Thought Disorder (66%) explained a higher, but less than satisfactory, level of reliable variance in their symptoms. These findings suggest that the vast majority of the Internalizing-based symptoms are saturated by *p* and call into question the conceptual integrity of the Fear and

Distress dimensions. Given that Fear and Distress reflect little of the variance in their respective symptom indicators, one may reasonably wonder if these dimensions are truly reflective of Fear and Distress based psychopathology.

This concern was heightened by the correlations observed between the bifactor dimensions and their counterparts from the higher-order model. The two Fear dimensions shared just 3.6% of variance, and the two Distress dimensions shared 15.2% of variance. It is difficult to see how these dimensions can be considered equivalent despite the same names being used to describe the constructs. On the other hand, the general dimension of psychopathology in the bifactor and higher-order models shared 94.1% of variance; a result consistent with Kim and Eaton's (2015). Thus, current and past findings indicate that whether *p* is modelled as directly affecting psychopathology symptoms (as in the bifactor model) or indirectly affecting these symptoms via subordinate dimensions (as in the higher-order model), the two parameterization methods produce near equivalent results.

The SEM findings indicated that *p* may operate in a slightly more advantageous manner when modelled within a hierarchical framework. The mental health risk variables explained 10% more variance in higher-order *p* compared to bifactor *p*. Additionally, while both parameterizations of *p* produced consistent correlations with the external variables, the strength of some of these associations – notably with age and interpersonal traumas – were slightly stronger for higher-order *p*. Additionally, all associations between the risk variables and the first-order dimensions of psychopathology in the higher-order model were easily interpretable, and consistent with the wider mental health literature; whereas, some odd and counterintuitive findings emerged for the specific factors in the bifactor model. For example, higher levels of Distress were associated with *lower* levels of adulthood non-interpersonal traumas, and Thought Disorder was not associated with childhood interpersonal, or non-interpersonal, trauma. The latter is a particularly perplexing result given the extensive literature

demonstrating that childhood trauma is strongly – and probably causally – related to psychotic illness (Varese *et al.,* 2012). These results not only provide support for the higher-order model over the bifactor model of psychopathology in terms of explaining psychopathology risk, but they also highlight how trauma exposure – in childhood and in adulthood - is a critical risk-factor for transdiagnostic and transdimensional psychopathology.

Focusing on the higher-order model, some interesting associations emerged between the sociodemographic variables and the dimensions of psychopathology. Younger age was associated with all of the first-order dimensions, and *p*. There was no sex difference on *p*, but women had higher levels of Fear and men had higher levels of Externalizing and Thought Disorder. Growing up in an urban area was only associated with Thought Disorder, consistent with previous research about the importance of exposure to urban environments in psychosis (Vassos *et al.*, 2012). Continuing to identify which aspects of the urban environment impact on the Thought Disorder dimension is important given that human beings are becoming an increasingly urban species (United Nations, 2019). Unemployment status was only associated with the Externalizing dimension, and may suggest that Externalizing psychopathology brings about higher levels of impairment than other forms of psychopathology. Additional research is required to quantify the degree of impairment associated with the different dimensions of psychopathology.

Several limitations should be noted. First, our data were derived from trauma-exposed members of the general population therefore they do not generalise to the entire population. Second, we were only able to use a limited number of symptom indicators for the Externalizing and Thought Disorder dimensions, and had no items to model other dimensions such as 'Somatoform' and 'Detachment'. Having additional measures to represent these dimensions would have better approximated the full HiTOP model. The development of a comprehensive method of measuring all aspects of the HiTOP model remains an important objective (Conway

et al., 2019b). Third, we relied on questionnaire guidelines and standard research practices to dichotomise symptoms as being 'present' or 'absent', thus the endorsement rates are likely biased due to measurement error. Replication of these results using ordinal and continuous indicators of psychopathology symptoms will be important.

Conclusion

Categorical models of psychopathology have dominated the empirical and clinical landscape for the last century, and as their limitations have become increasingly well recognized, dimensional models of psychopathology offer promise in more accurately describing the fundamental nature of psychopathology. A such, dimensional models of psychopathology may lead to important advances regarding the causes and consequences of mental illness, and how best to prevent and treat mental illness (Conway *et al.,* 2019b; Ruggero *et al.,* 2019). The empirical literature supports the existence of a general dimension of psychopathology that captures variance and covariance shared across all forms of mental illness, however, alternative approaches to incorporating *p* into a dimensional theory of psychopathology have been proposed. These alternative approaches have important implications for clinical theory and practice, and it is essential that psychological science determines the most appropriate way to incorporate *p* within a theory of psychopathology. Our findings indicate that the hierarchical approach outlined by the HiTOP theory is the better approach to modelling *p*. More work is needed to determine the psychological mechanisms that underlie *p* but Craver *et al.* (2018) suggest that it may be explained within a dual process framework as over-reactivity of associative processes to emotion-triggering events; a hypothesis that might help to explain why *p* is so strongly associated with childhood interpersonal trauma. The specification of mechanisms involved in *p* might aid clinicians in identifying (a) who is most at risk for different forms of psychopathology, and (b) how best to intervene to mitigate different mental health problems.

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Supplementary Table 1. Endorsement rates for all indicators of psychopathology (N = 1,051).

	Scale	Dimension	Endorsement %
Nightmares	PTSD1	Internalizing/Fear	26.8
Re-experiencing in the here and now	PTSD2	Internalizing/Fear	31.8
Internal avoidance	PTSD3	Internalizing/Fear	37.7
External avoidance	PTSD4	Internalizing/Fear	34.6
Hypervigilance	PTSD5	Internalizing/Fear	36.0
Hyperarousal	PTSD6	Internalizing/Fear	39.5
Nervous feelings	Anx1	Internalizing/Fear	56.0
Can't control worry	Anx2	Internalizing/Fear	51.8
Worrying too much	Anx3	Internalizing/Fear	62.1
Trouble relaxing	Anx4	Internalizing/Fear	60.1
Restlessness	Anx5	Internalizing/Fear	40.1
Easily annoyed/ irritable	Anx6	Internalizing/Fear	52.5
Afraid something awful will happen	Anx7	Internalizing/Fear	45.9
Difficulty calming down	DSO1	Internalizing/Distress	42.8
Feeling numb	DSO2	Internalizing/Distress	36.1
Self as failure	DSO3	Internalizing/Distress	36.3
Self as worthless	DSO4	Internalizing/Distress	34.5
Feeling cut off from people	DSO5	Internalizing/Distress	40.3
Difficulty staying close to people	DSO6	Internalizing/Distress	39.6
Fear of abandonment	BPD1	Internalizing/Distress	44.5
Relationships have ups and downs	BPD2	Internalizing/Distress	44.1
Unstable sense of self	BPD3	Internalizing/Distress	29.4

Impulsiveness	BPD4	Internalizing/Distress	41.6
Suicide attempt/self-injurious behaviours	BPD5	Internalizing/Distress	26.5
Mood changes	BPD6	Internalizing/Distress	43.3
Empty	BPD7	Internalizing/Distress	51.7
Temper outbursts	BPD8	Internalizing/Distress	28.5
Dissociation	BPD9	Internalizing/Distress	38.0
Diminished interest/pleasure	Dep1	Internalizing/Distress	49.2
Feelings of depression	Dep2	Internalizing/Distress	56.1
Trouble with sleep	Dep3	Internalizing/Distress	63.5
Tiredness/ lack of energy	Dep4	Internalizing/Distress	71.4
Eating problems	Dep5	Internalizing/Distress	53.9
Feeling bad about self	Dep6	Internalizing/Distress	49.7
Trouble concentrating	Dep7	Internalizing/Distress	47.8
Moving or speaking slowly	Dep8	Internalizing/Distress	25.6
Suicidal thoughts	Dep9	Internalizing/Distress	28.1
Using alcohol monthly or more frequently	Alc1	Externalizing	51.1
More than two units of alcohol per day	Alc2	Externalizing	21.0
Binge drinking monthly/more frequently	Alc3	Externalizing	43.9
Cannabis use before 18	Drug1	Externalizing	17.2
Using cannabis more than occasionally	Drug2	Externalizing	20.2
Thoughts are being read by other people	TD1	Thought Disorder	22.5
Special messages sent just for you	TD2	Thought Disorder	8.1
People spying on you	TD3	Thought Disorder	25.9
Auditory hallucinations	TD4	Thought Disorder	20.2
Controlled by an outside force	TD5	Thought Disorder	10.8

Visual hallucinations	TD6	Thought Disorder	18.4
Have extra special powers	TD7	Thought Disorder	12.9

Note: PTSD = posttraumatic stress disorder; DSO = disturbances in self-organization; BPD = borderline personality disorder; Dep = Depression; Anx = Anxiety; Alc = Alcohol use; Drug = Cannabis use; TD = Thought Disorder.

Table 1. Model fit results for the alternative dimensional models of the structure of psychopathology.

	χ^2	df	CFI	TLI	RMSEA (90% CI)	SRMR	BIC
Model 1: Unidimensional model (*p*)	8394*	1127	.916	.912	.078 (.077, .080)	.107	46281
Model 2: Three-factor model (I, E, TD)	5788*	1124	.946	.943	.063 (.061, .064)	.085	43900
Model 3: Four-factor model (F, D, E, TD)	5047*	1121	.955	.952	.058 (.056, .059)	.082	43320
Model 4: Second-order four-factor model (*p*, F, D, E, TD)	5062*	1123	.954	.952	.058 (.056, .059)	.083	43337
Model 5: Bifactor model with three specific factors (*p*, I, E, TD)	3416*	1075	.973	.970	.046 (.044, .047)	.055	42130
Model 6: Bifactor model with four specific factors (*p*, F, D, E, TD)	2709*	1072	.981	.979	.038 (.036, .040)	.050	41161

Note. N = 1,049; I = Internalizing; D = Distress; F = Fear; E = Externalizing; TD = Thought Disorder; p = General Psychopathology; χ^2 = chi square goodness of fit statistic; df = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker Lewis Index; RMSEA (90% CI) = Root-Mean-Square Error of Approximation with 90% confidence intervals; SRMR = Standardized Root Mean Square Residual; BIC = Bayesian Information Criterion; * Indicates χ^2 test is statistically significant ($p < .001$).

Table 2. Standardized factor loadings and factor correlations for the bifactor and higher-order models of *p*.

	Bifactor model results					**Higher-order model results**			
	p	F	D	E	TD	F	D	E	TD
Nightmares	.58	.64				.74			
Re-experiencing	.58	.64				.74			
Internal avoidance	.66	.66				.84			
External avoidance	.66	.65				.84			
Hypervigilance	.65	.65				.83			
Hyperarousal	.72	.61				.88			
Nervous feelings	.91	-.07^{ns}				.91			
Can't control worry	.96	-.05^{ns}				.96			
Worrying too much	.92	-.12				.91			
Trouble relaxing	.93	-.07^{ns}				.93			
Restlessness	.88	.03^{ns}				.89			
Easily annoyed/ irritable	.87	-.04^{ns}				.87			
Afraid something awful will happen	.90	.09				.92			

Difficulty calming down	.73	.26	.78
Feeling numb	.75	.43	.84
Self as failure	.74	.61	.93
Self as worthless	.75	.63	.94
Feeling cut off from people	.76	.49	.87
Difficulty staying close to people	.71	.47	.82
Fear of abandonment	.62	.33	.68
Relationships have ups and downs	.63	.40	.71
Unstable sense of self	.73	.42	.82
Impulsiveness	.59	.32	.65
Suicide/ self-injurious behaviours	.63	.43	.73
Mood changes	.76	.36	.83
Empty	.78	.34	.85
Temper outbursts	.66	.32	.73
Dissociation	.78	.28	.83
Diminished interest/ pleasure	.87	.19	.89

Feelings of depression	.90	.22			.93			
Trouble with sleep	.83	-.03[ns]			.81			
Tiredness/ lack of energy	.85	-.03[ns]			.83			
Eating problems	.84	.11			.85			
Feeling bad about self	.87	.32			.93			
Trouble concentrating	.88	.10			.90			
Moving or speaking slowly	.87	.05[ns]			.86			
Suicidal thoughts	.82	.25			.86			
Frequent alcohol use	-.08		.79			.31		
Daily alcohol use	.20		.95			.80		
Binge drinking	.22		.80			.78		
Cannabis use before 18	.14		-.04[ns]			.25		
Frequent cannabis use	.42		.28			.99		
Thoughts are being read	.32			.67			.64	
Special messages sent just for you	.46			.85			.91	
People spying on you	.64			.54			.97	

Auditory hallucinations	.56				.69			.92
Controlled by an outside force	.48				.79			.90
Visual hallucinations	.51				.73			.89
Have extra special powers	.41				.79			.82
	Factor correlations				**Second-order factor loadings on *p***			
Fear	1				.93			
Distress	.29	1				.95		
Externalizing	.04[ns]	.04[ns]	1				.34	
Thought Disorder	.27	.21	.28	1				.63

Note: All factor loadings and factor correlations are statistically significant ($p < .05$) except for those marked [ns].

Table 3. Reliability and construct replicability results for the bifactor dimensions of psychopathology.

	p	Fear	Distress	Externalizing	Thought Disorder
ω	.99	.98	.98	.78	.96
ωH	.91	.11	.13	.70	.66
ωR	.92	.11	.14	.70	.66
H	.99	.81	.79	.93	.90

Note: ω = omega reliability; ωH = omega hierarchical reliability; ωR = relative omega reliability; H = construct replicability.

Table 4. Correlations between the dimensions from the bifactor and higher-order models of psychopathology.

	Bifactor dimensions				
	p	Fear	Distress	Externalizing	Thought Disorder
Higher-order dimensions					
p	.97	.13	.29	.03^{ns}	.13
Fear	.96	.19	.14	.01^{ns}	.08
Distress	.95	.08	.38	.00^{ns}	.10
Externalizing	.37	.02^{ns}	.09	.85	.20
Thought Disorder	.72	.17	.22	.13	.69

Note: all correlations are statistically significant ($p < .05$) except for those marked ^{ns}.

Table 5. Standardized regression coefficients between each risk variable and each dimension of psychopathology (N = 1,049).

	Bifactor model				**Higher-order/ correlated factor model^**				
	p	F	D	E	TD	*p*	F	D	E	TD
Female sex	.07*	.07	-.09*	-.20***	-.16***	.04	.08**	.02	-.18***	-.11**
Age	-.25***	-.08	-.26***	-.05	-.17**	-.30***	-.25***	-.30***	-.10*	-.25***
Grew up in an urban area	.01	.11**	-.09	.01	.11**	.02	.04	.00	.01	.09*
History of emigration	-.02	.00	.04	.07	.03	-.00	-.02	.01	.06	.01
Currently employed	.03	.00	.06	-.14***	.02	.04	.03	.05	-.12**	.04
Childhood interpersonal trauma	.27***	.21***	.19***	-.08	.09	.32***	.30***	.30***	-.03	.19***
Adulthood interpersonal trauma	.09*	.11**	.15**	.14**	.13**	.13***	.10**	.13***	.17***	.15***
Childhood non-interpersonal trauma	.11**	-.03	.02	.08	.07	.11**	.09*	.10**	.09	.10*
Adulthood non-interpersonal trauma	.09**	.03	-.11**	.02	.14**	.06*	.08**	.04	.02	.15***
R^2	.31***	.11***	.18***	.10***	.18***	.41***	.33***	.37***	.12***	.30***

Note: *p* = general psychopathology, F = Fear, D = Distress, E = Externalizing, TD = Thought Disorder; ^ Standardized regression coefficients for *p* were derived from the SEM model based on the second-order model, and the effects for F, D, E, and TD were derived from the SEM model based on the first-order model; Statistical significance = *p < .05, **p < .01, ***p < .001; R^2 = the percentage of variance in each dimension explained by the nine risk variables.

Figure 1a. Bifactor order model of psychopathology.

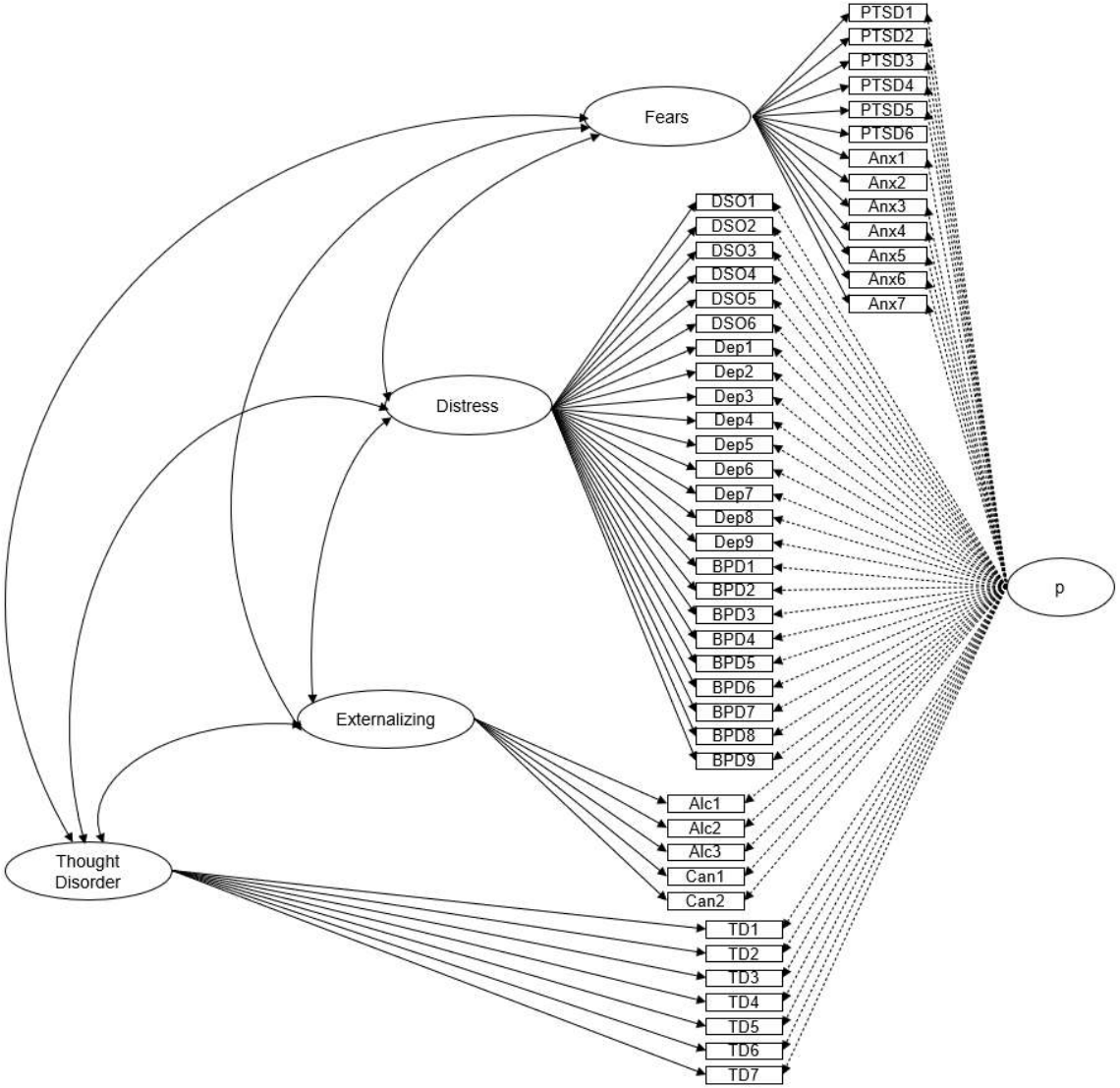

Figure 1b. Higher-order model of psychopathology.