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Validation of the importance of continua in representing delusional ideation in the general population

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ABSTRACT

Background: Previous studies have examined the distribution of psychotic like experiences (PLE) with the aim of informing the debate concerning the categorical versus continuous nature of psychosis. We extend this research by subjecting a number of competing models of delusional ideation to validation analysis to further examine previous findings.
Methods: We constructed latent variable models representing the factor structure of delusional ideation reported previously, using self-reported delusional ideation (Peter's Delusional Inventory; PDI) at age 21 in a general population prospective birth cohort study. After firstly eliminating models which exhibited poor fit we performed a longitudinal validation analyses among the competing models to investigate whether increasing levels of ideation were associated with developmental antecedents, correlates and distal indicators of psychotic disorder.
Results: Four latent variable models were found to adequately represent the delusional ideation data, two comprised exclusively of continua (a multidimensional 5 factor model and a bifactor model with 1 general and 4 specific factors), and two which included both categories and continua (two factor mixture models, each with 3 classes and 1 factor per class, but with varying levels of parameter restrictions). Exclusively categorical latent models obtained poor fit and the categorical components of hybrid models failed to discriminate on psychotic illness, while among the models incorporating continuous latent factors validation analyses did not clearly identify any model as better than the others.
Conclusion: We provide novel evidence of the importance of continua in adequately and validly representing delusional ideation in the general population. Beyond this, our data suggests it is not possible to further refine the structure of delusional ideation in the general population.

1. Introduction

Debate continues as to how psychotic-like experiences (PLEs) in the general population should best be considered in terms of their clinical and psychopathological significance (Lawrie et al., 2010). Some assert evidence of a single-continuum of psychotic-like experiences with psychotic disorders representing one extreme end (Subramaniam et al., 2013), while others have warned against giving too much credence to the continuum model, viewing it as an unhelpful and unproven explanation to the shortcomings of current diagnostic criteria (David, 2010; Lawrie et al., 2010; Sommer, 2010). Between these two extremes lie a number of potentially valid and useful representations of PLEs, including the multiple discontinuous subpopulations as suggested by Linscott and van Os (2010). A better understanding of the PLE distribution may help identify biological and environmental risk factors and phenotypic antecedents relevant to psychotic disorders (Calkins et al., 2017; David and Ajnakina, 2016) improving identification of those most at risk (Freeman, 2016).

Efforts to determine the structure of PLEs have been subject to two major limitations, model restrictions and lack of validation. Regarding the former, the majority of research has utilised modelling strategies in which classes and continua are treated as mutually exclusive, an unsuitable approach should the data consist of two or more subpopulations each with its own PLE continuum (Borsboom et al., 2016), consistent with the aforementioned work of Linscott & van Os. Factor mixture modelling (FMM) offers a powerful solution to this limitation, whereby PLE item correlations are used to derive two or more PLE

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classes, each with their own "severity" continua also defined by the PLE items (see Supplementary text 2).

Recent publications have outlined the theoretical relevance (Borsboom et al., 2016) and practical implementation (Miettunen et al., 2016) of FMM approaches to modelling the structure of PLEs, and a number of research teams have already put these methods to good use, demonstrating both single (Subramaniam et al., 2013) and multidimensional (Miettunen et al., 2016) continua provide the best fit to available data. In contrast, Bebbington identified a more complex structure, whereby delusional ideation was represented by four classes for which each contained a continuum (Bebbington et al., 2013). However, even these analytically advanced studies did not explore the possibility that bifactor structures may provide superior fit compared with FMM. A bifactor model represents the data by allowing all items to load onto one general factor in addition to one of a number of specific factors. With regard to PLE, previous research has identified the bifactor model as providing the "best fit" (Wigman et al., 2012; Wigman et al., 2011).

With regards to validation, almost all previous studies comparing different models have been conducted using cross-sectional data or national surveys and therefore unable to assess whether models were related to antecedents psychotic disorders (e.g., child neurodevelopmental factors and self-reported schizophrenia respectively) and indicators of psychotic disorders at later ages. Validation is an essential step in latent variable modelling and indeed any form of composite variable construction, and allows the assessment of the utility and predictive validity of the model instead of simply relying on fit indices.

In this study we combined the methodological strengths of a 30 year pre-birth cohort study and structural equation modelling to develop a comprehensive framework within which we firstly derive, and then test the validity of categorical, continuous and hybrid models of delusional ideation. We argue that theoretical approaches to understanding the structure of PLEs can be complimented by data driven approaches which compare how competing structures relate to developmental antecedents, correlates and distal indicators of psychotic disorder and severe psychopathology. This study aims to identify patterns of delusional ideation in the general population most closely aligned with serious mental illness and its associated functional deficits.

2. Methods

2.1. Participants

Participants came from the Mater University Study of Pregnancy (MUSP), a prospective pre-birth cohort study following mothers and their children for over 30 years. A total of 7223 mothers attending their first clinic visit at Brisbane's Mater Misericordiae Hospital were recruited between 1981 and 1984, with subsequent follow-ups at birth, and child age 6 months, and 5, 14, 21 and 30 years. Further information can be found elsewhere (Keeping et al., 1989; Najman et al., 2015; Najman et al., 2005).

2.2. Delusional ideation

At 21 years 3738 offspring completed the 21-item Peters Delusional Inventory (PDI) (Peters et al., 2004), providing the primary sample to examine the factor structure of PLE's. Face validity of the PDI was assured by basing delusion items off the Present State Examination (PSE) (Peters et al., 1999; Wing et al., 2012), and the 21-item PDI demonstrated adequate reliability, and concurrent and content validity (Peters et al., 2004). The original PSE questions were softened in the PDI (e.g. "Do you ever feel *as if* things in magazines or on TV were written especially for you") to take an inclusive and continuous approach to delusional ideation in the general population (Peters et al., 2004; Peters et al., 1999). Answers to all questions were recorded as yes/no, and can be found in (Peters et al., 2004).

2.3. Antecedent risk factors

Impairments in cognitive ability, social functioning, attention and motor functioning have been found to predict schizophrenia (Dickson et al., 2012; Erlenmeyer-Kimling et al., 2000) and in the MUSP cohort many related measures have been obtained prospectively. The Peabody Picture Vocabulary Test (PPVT-R) was completed by the offspring at 5 years as a measure of verbal ability (Dunn, 1981) and has been validated against other standardised intelligence tests (Dunn, 1981). Children were also administered the Denver Developmental Screening Test (DDST) (Frankenburg and Dodds, 1967) at this follow-up, which assessed developmental delays in the four key sectors of gross motor, fine motor-adaptive, language and personal-social development. The DDST was administered by trained researchers and a standard algorithm determined if the child's performance on the relevant task was normal, questionable or abnormal (Frankenburg et al., 1973). The four variables for each sector were then dichotomised (1 = normal/

Table 1
Comparison of fit indices for Exploratory Factor Analyses (EFA), Bifactor model, Latent Class Analysis (LCA) and Factor Mixture Models (FMM) of 21 PDI items ascertained among offspring at age 21.

Model	Offspring age 21 (n = 3738)		
	BIC	BIC-SSA	Entropy
Continuous			
EFA			
1 factor	69,416	69,283	
2 factor	68,120	67,923	
3 factor	67,761	67,503	
4 factor	67,538	67,224	
5 factor	67,519	67,150	
6 factor	67,557	67,137	
Bifactor			
2 factor	68,120	67,923	
3 factor	67,761	67,503	
4 factor	67,538	67,224	
5 factor	67,519	67,150	
6 factor	67,557	67,137	
Categorical			
LCA			
2 class	70,791	70,655	0.78
3 class	69,728	69,522	0.75
4 class	68,878	68,602	0.79
5 class	68,683	68,336	0.75
6 class	68,555	68,139	0.78
7 class	68,485	67,999	0.79
8 class	68,451	67,895	0.77
9 class	68,478	67,852	0.77
FMM-2C 1F			
FMM-1	69,422	69,285	0.57
FMM-2	69,428	69,288	0.99
FMM-3	68,255	68,051	0.89
FMM-4	68,347	68,076	0.73
FMM-3C 1F			
FMM-1	69,341	69,195	0.83
FMM-2	69,338	69,186	0.64
FMM-3	67,898	67,625	0.70
FMM-4	68,056	67,649	0.81
FMM-4C 1F			
FMM-1	69,438	69,295	0.11
FMM-2	69,398	69,246	041
FMM-3	–	–	–
FMM-4	68,099	67,556	0.67

Note: Bayesian Information Criterion (BIC); Bayesian Information Criterion – sample size adjusted (BIC-SSA); Factor Mixture Models (FMM – 2C 1F, two classes with one factor in each; 3C 1F, three classes with one factor in each; 4C 1F, four classes with one factor in each). FMM became less restrictive as the numerical index increased: FMM-1 non-invariant factor mean, invariant thresholds and factor loadings, factor variance set to 0; FMM-2 non-invariant factor mean and variances, invariant thresholds and factor loadings; FMM-3 non-invariant item thresholds, invariant factor loadings and variance, factor mean set to 0; FMM-4 non-invariant item thresholds, factor loadings and variance, factor mean set to 0. The 4C 1F FMM-3 could not be estimated reliably.

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