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The Hierarchical Taxonomy of Psychopathology in Clinical High Risk for Psychosis: Validation and Extension

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Abstract

The Hierarchical Taxonomy of Psychopathology (HiTOP) consortium's transdiagnostic dimensional model of psychopathology has considerable support; however, this model has been under-researched in individuals at clinical high risk for psychosis (CHR-P), a population that may advance the model. CHR-P individuals have attenuated psychotic symptoms that vary in severity, but also have many comorbid diagnoses and varied clinical outcomes, including disorders with uncertain relations to HiTOP (e.g., obsessive-compulsive disorder). The present study used self-report and interview data from North American Prodrome Longitudinal Study-3 (710 CHR, 96 controls) to replicate the HiTOP model and test specific hypotheses regarding disorders with

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The pre-registration and data analysis code are available at: https://osf.io/uh9fr. Study data are available through the National Institute of Mental Health Data Archive (https://nda.nih.gov/) and materials can be obtained by contacting the authors. Institutional Review Boards at each site approved the study protocol.

uncertain relations to its dimensions. Additionally, the present study examined the HiTOP model in relation to childhood trauma, declines in social functioning, and development of full psychosis. Confirmatory factor analysis (CFA) indicated that the HiTOP model's fit was nearly adequate (e.g., CFI = .89), though several theory-relevant modifications were indicated. Additionally, specific tests were conducted to gain a more fine-grained perspective on how disorders with less clear prior evidence were related to the HiTOP model. Notable findings from these analyses include bipolar spectrum disorders relating to the psychosis super spectrum (i.e., .39 loading), and obsessive-compulsive disorder showing a complex pattern of loadings (e.g., internalizing and psychosis). The final model parsimoniously accounted for childhood trauma (e.g., super spectra *r*s = .22-.32), associations with current functioning, and predicted future conversion to a psychotic disorder (e.g., super spectra R^2 = .13). Overall, these results inform the HiTOP model and suggest its promise for CHR-P research.

General Scientific Summary:

Individuals at risk of developing psychosis often have multiple psychiatric diagnoses; however, existing diagnostic frameworks poorly describe the reality of the symptoms experienced by individuals at risk for psychosis. The present study supported the validity and utility of an alternative framework for describing psychiatric symptoms—the Hierarchical Taxonomy of Psychopathology—by showing its relevance to both psychosis risk factors and clinical outcomes.

Keywords

psychosis risk; transdiagnostic; dimensions; comorbidity; factor analysis

Introduction

Traditional psychiatric classifications consist of presumably distinct diagnoses (e.g., *Diagnostic and Statistical Manual of Mental Disorders-5* [*DSM-5*]; American Psychiatric Association, 2013), originally defined primarily based on clinical observation and expert consensus (Markon, 2013). Despite the widespread use of such categorical diagnostic systems, numerous concerns have emerged regarding their validity (Kotov et al., 2021). Two of their greatest limitations are (a) high co-occurrence or comorbidity among diagnoses and (b) high symptom heterogeneity within diagnoses. The combination of these problems often means it is unclear whether treatments and etiologic mechanisms are specific to a particular diagnosis or whether they apply to most people with that diagnosis. The Hierarchical Taxonomy of Psychopathology (HiTOP) consortium has emerged to address these issues, through promoting a hierarchical model of transdiagnostic dimensions, grouping highly specific clinical constructs (anhedonia, avolition, etc.) under increasingly broad dimensions (detachment, psychosis, etc.; see Figure 1 for example). Despite the emergence of HiTOP, it remains limited in certain ways, including validation in key populations, coverage of specific disorders, and relations to important mechanisms and outcomes. The present study sought to address limitations to the HiTOP model, through examining it in individuals at clinical high risk for psychosis (CHR-P).

Individuals who meet CHR-P criteria show high rates of comorbidity and significant variability in their premorbid and long-term course. Based on the most recent review of follow-up studies, approximately 25% of CHR-P individuals develop a psychosis spectrum disorder within 3 years of identification (Salazar de Pablo et al., 2021), but even those that do not often experience considerable impairments in functioning (Beck et al., 2019). Defining features of CHR-P syndromes include attenuated positive symptoms (e.g., unformed hallucinations), brief full psychotic symptoms, and declines in functioning coupled with schizotypal personality disorder or a family history of psychosis (Woods et al., 2009). Consistent with HiTOP, CHR-P research conceptualizes psychotic symptoms as being on a continuum with normative experiences (i.e., dimensional) and conceptualizes risk for psychosis as a shared transdiagnostic risk for any psychotic disorder. Despite the emphasis on positive symptoms, CHR-P individuals also have negative, disorganized, and cognitive dysfunction symptoms, as well as high rates (roughly 80%) of comorbid diagnoses (depression, mania, substance use, etc.; Addington et al., 2017; Solmi et al., 2023).

Despite these high rates of comorbidity and HiTOP's utility for comprehensively modeling comorbidity, few studies have examined the HiTOP model in this population. One study examined associations between interview-rated attenuated psychotic symptoms and psychopathology dimensions defined by self-report, finding that interview-rated attenuated psychotic symptoms reflect underlying elevation on both psychosis and internalizing symptom dimensions (Cowan et al., 2023). A smaller study produced similar conclusions, finding internalizing, positive symptom, and negative symptom factors that predicted important outcomes (Cowan & Mittal, 2021). These studies indicate the potential for examining the HiTOP model in CHR-P individuals. Notably, however, their ability to examine the overarching HiTOP model was limited by the range of psychopathology indicators used (e.g., no externalizing factor) and analytic approaches (i.e., exploratory analyses). Put differently, these inquiries made use of data that were too narrow in content coverage to provide an opportunity to empirically validate the overarching model itself in a CHR-P population. A broader examination of HiTOP would advance the CHR-P literature. Additionally, given the wide variation in symptom severity and patterns of comorbidity in CHR-P individuals, such work may also address lingering questions regarding the structure of the HiTOP model.

Some diagnoses and constructs show complex, "provisional" relations to HiTOP dimensions (Kotov et al., 2021), due to limited or inconclusive evidence (Ringwald et al., 2021). The present study examines hypotheses regarding five diagnoses with provisional relations to HiTOP (see Table 1): bipolar spectrum disorder, obsessive compulsive disorder (OCD; Kotov et al., 2020), borderline personality disorder (BPD), avoidant personality disorder (AVPD; Ringwald et al., 2021), schizotypal personality disorder (STPD). In many previous studies, these disorders were not assessed or had limited variability (Ringwald et al., 2021). CHR-P samples may help address these limitations, as their dimensional representation of psychosis risk symptoms ensures relatively high proportions of participants have these diagnoses. Note that in the HiTOP model, *DSM* disorders are not formally used as indicators; HiTOP uses more granular indicators, such as symptom components and maladaptive traits (Kotov et al., 2021). Nonetheless, many previous studies have relied on *DSM* disorders as indicators that may be useful for estimating the dimensions within

HiTOP and such dimensions are conceptualized as accounting for the comorbidity of *DSM* disorders (Forbes et al., 2017; Kotov et al., 2020). Furthermore, being able to translate research literatures on *DSM* disorders into the HiTOP model is essential and testing hypotheses related to the above diagnoses will further this goal.

Another area in which HiTOP and the CHR-P literatures may mutually benefit is through the consideration of how symptoms develop (etiology, course, etc.) and the prediction of important clinical outcomes. Although these areas have been understudied in the HiTOP model, these are focal areas of research in the CHR-P literature (Cannon, 2015). Most CHR-P studies recruit participants in their teenage years and follow them longitudinally, as psychosis spectrum disorders typically have their onset in late adolescence and early adulthood (Addington et al., 2020). In this framework, childhood trauma has emerged as one important risk factor that may precede psychotic symptom development (Gibson et al., 2016; Santesteban-Echarri et al., 2022; Stowkowy et al., 2016). Nonetheless, the specificity of this risk factor is unclear and CHR-P work may benefit from embedding this work in the HiTOP model. Finally, CHR-P research often focuses on functioning as an outcome (Carrión et al., 2019), as well as the onset of psychosis during the study. In particular, psychosis onset has not been directly considered within HiTOP research and may provide additional insight into the ability of the model to capture etiological processes.

Present Study

The present study aimed to both advance research on psychosis risk and to contribute to the improvement of the HiTOP model. HiTOP offers a principled, efficient, and evidence-based model for understanding the extensive comorbidity present in CHR-P. In turn, CHR-P research presents many opportunities to better understand HiTOP, including an explicitly developmental and mechanism-oriented framework, as well as a population that is dimensionally conceptualized and has a wide-range of comorbidities. The present study's primary aims were to (1) examine disorders that are common in CHR-P samples and poorly understood within the context of HiTOP (e.g., bipolar spectrum disorders) and (2) leverage the HiTOP model to test antecedents of psychosis risk (i.e., trauma) and psychosis risk outcomes (functioning, conversion, etc.). These aims were pursued with an innovative and methodologically rigorous approach, which made use of holistic model evaluation (Waldman et al., 2023) and a pre-registered analytic plan. Specific hypotheses are summarized in Table 1 and described in greater depth in the pre-registration[1].

Method

The present study used baseline and outcome data from the North American Prodrome Longitudinal Study-3 (NAPLS-3), a recently completed multi-site, three-year longitudinal study of CHR-P individuals. Details about this project and its background are described by Addington and colleagues (2021). Institutional Review Boards at each site approved the study protocol.

[1]The pre-registered analyses and hypotheses can be viewed here: https://osf.io/uh9fr.

Participants and Procedures

Participants (N = 806) were recruited and completed screenings, then more detailed interviews. CHR-P participants (n = 710) had to meet criteria for a psychosis-risk syndrome on the Structured Interview for Psychosis Risk Syndromes and be between 12 and 30 years old, have no history of psychotic disorder, an IQ ≥ 70, and have no history of neurological disorders. Additionally, the sample was enriched by emphasizing recruitment of CHR-P participants that met criteria from the NAPLS risk calculator (n = 506), specifically: (a) moderately severe or higher unusual thought content (SIPS P1 ≥ 4) or suspiciousness (SIPS P2 ≥ 4), or (b) both moderate unusual thought content and suspiciousness (SIPS P1 and P2 = 3), or (c) demonstrate impaired performance (≤ 10th percentile) on either the Hopkins Verbal Learning Test-Revised (HVLT-R) or the Brief Assessment of Cognition in Schizophrenia (BACS) symbol coding. Control participants (n = 96) could not: (a) meet criteria for a psychosis risk syndrome or any disorder involving psychotic symptoms, (b) report a family history of psychotic disorder or Cluster A personality disorder diagnoses, or (c) currently use psychotropic medication. Participants were on average 18.24 years old (SD = 4.06), 53.72% indicated their sex at birth was male (22 participants reported identifying as transgender), 53.85% identified their racial background as White, 11.91% as Black, 11.41% as Asian, 12.90% as multiracial, and the remaining 10.03% as other racial groups (First Nations, Central/South American, Native Hawaiian, Middle Eastern).

Measures

Structured Interview for Psychosis Risk Syndromes (SIPS).—The SIPS is a semi-structured interview that dimensionally assesses symptoms (i.e., positive, negative, disorganization) and identifies psychosis syndromes (McGlashan et al., 2010). Symptoms are rated on a 0 (Absent) to 6 (Psychosis) scale, within which 3-5 represents attenuated positive symptoms consistent with a psychosis risk syndrome. The SIPS was used to determine participant eligibility and symptom ratings provided factor indicators, as listed in the following sentences and displayed in Figure 1. Reality Distortion: Unusual Thought Content/Delusional Ideas (P1), Suspiciousness/Persecutory Ideas (P2), Grandiose Ideas (P3), and Perceptual Abnormalities/Hallucinations (P4). SIPS ratings specified as indicators of Detachment: Social Anhedonia (N1), Avolition (N2), Decreased Expression of Emotion (N3), Decreased Experience of Emotions and Self (N4), and Decreased Ideational Richness (N5). SIPS indicators of Disorganization: Disorganized Communication (P5), Odd Behavior or Appearance (D1), Bizarre Thinking (D2), Trouble with Focus and Attention (D3), and Impairment in Personal Hygiene (D4).

Structured Clinical Interview for DSM-5 (SCID-5).—The SCID-5-RV is a semi-structured interview that identifies the presence of *DSM-5* diagnoses (First, 2015). SCID diagnoses (code 0-Absent, 1-Present) were used as indicators in factor analyses, with their factor assignment listed in the following sentences and displayed in Figure 1. Distress: persistent depressive disorder, major depressive disorder, generalized anxiety disorder, post-traumatic stress disorder, and other-specified/unspecified depressive disorder. Fear: panic disorder, agoraphobia, specific phobia, social anxiety disorder, and other-specified/unspecified anxiety disorder. Substance-Use/Disinhibition: alcohol use disorder, cannabis use disorder, other substance use disorder, attention-deficit hyperactivity disorder.

Additionally, OCD, STPD, AVPD, BPD, and bipolar spectrum disorder diagnoses were assessed, but their use as indicators within models was subject to hypothesis driven tests (see Table 1).

Structured Assessment of Violence Risk in Youth (SAVRY).—The SAVRY is an interviewer rated measure that predicts risk of violence in adolescents (Borum et al., 2006). It consists of 30 risk factors, rated as Low, Moderate, or High. In the present study, a subset of ratings were used as factor indicators. Specifically, Risk Taking/Impulsivity, Substance Use Difficulties, and Attention-Deficit/Hyperactivity Difficulties were used as indicators of Substance Use/Disinhibition and History of Violence, Anger Management Problems, and Low Empathy/Remorse were used as indicators of the Antisocial/Antagonistic factor.

Documentation of Trauma.—Six trauma categories were assessed: psychological bullying, physical bullying, emotional neglect, psychological abuse, physical abuse, sexual abuse. Each category was scored from 0 (has not occurred) to 1 (has occurred). A childhood trauma composite was created by averaging the 6 categories. The composite ranges from 0 (*no trauma has occurred*) to 1 (*trauma in all 6 categories occurred*). Participants in the current sample experienced on average between 1 and 2 of the types of trauma (M = .28, SD = .27), and 68% of participants endorsed at least 1 type of trauma.

Functional Impairment.—The *DSM-5* Global Assessment of Functioning (GAF) was rated by interviewers based on symptoms and associated dysfunction. The Global Functioning Scale Social (GFS) and Role (GFR) were rated based on outcomes and behavior associated with social relationships and work/school/role activities (Carrión et al., 2019).

Conversion to Psychosis Spectrum Disorder.—The SIPS and SCID were used to confirm whether or not a participant had developed a psychosis spectrum disorder. Conversions status was assessed yearly throughout the study (i.e., all three time points).

Analyses

All analyses were conducted in Rstudio (RStudio Team, 2020) using the lavaan package (Rosseel, 2012). Our preregistration (https://osf.io/uh9fr) provides a detailed description of each step of our analytic plan, including data cleaning and model re-specification procedures. A discussion of data cleaning results can be found in the supplement. Confirmatory factor analyses were run using a robust weighted least square estimator (WLSMV). Models were evaluated in terms of absolute fit, relative fit, and factor loadings, using pre-registered benchmarks. Adequate absolute fit was determined based on models meeting 2 of 3 criteria: (1) CFI ≥. 90, (2) RMSEA ≤. 06, (3) SRMR ≤ .08 (Hu & Bentler, 1999). Factors with at least three significant loadings were considered adequately represented. The following criteria were used to compare models: (1) a significant chi-square difference test and (2) 2 of the 3 present ΔCFI ≥. 01, ΔRMSEA ≥ .015, ΔSRMR ≥ .015 (Kelley et al., 2019). These criteria were initially applied to established HiTOP models, which only included indicators with undisputed mappings to factors (see Figure 1 and measure descriptions). In the case of inadequate overall fit, explicit pre-registered re-specification procedures were followed, which allowed for two rounds of re-specification.

After examining well-validated indicators, factor loadings for diagnoses with unclear relations to HiTOP were specified by allowing each diagnosis to load on all relevant super spectra in one model, then comparing these models to models in which the diagnosis loaded on only one super spectrum. This approach was also applied to spectra/subfactors on an exploratory basis. Evidence of a diagnosis being related to a specific factor was based on both (a) non-significant chi-square difference test (i.e., equal fit to model with diagnosis loading on multiple factors) and (b) significant factor loading in model where diagnosis loads on multiple factors.[2] Based on the results of these models, a final model containing all diagnoses was tested and evaluated for absolute fit.

Factor scores from the final model were exported to examine relations to trauma, functioning, and conversion to a psychosis spectrum disorder. Given the considerable literature comparing trauma history to transdiagnostic dimensions (Caspi & Moffitt, 2018), an equivalence testing approach was used to test whether we could reject the possibility of effects that reached or exceeded a certain magnitude. Findings from equivalence tests complement those of traditional hypothesis testing by statistically testing whether the possibility of a certain effect size (or greater) can be rejected. For these tests, we used a correlation effect size of |.18| (e.g., versus a null hypothesis of 0; Lakens et al., 2018). This effect size is the same as the significant external correlation between the internalizing spectrum and childhood maltreatment reported in Caspi and colleagues (2014). We believe it provides a reasonable benchmark for testing the effect of trauma history in a similar factor analytic framework. Correlation and multiple regression were used to examine relation to continuous outcomes, whereas logistic regression was examined for conversion to psychosis as a binary outcome.

Results

Examining the Established Model

First, the best-validated aspects of the HiTOP model were tested in 5 models: (M1) p-factor only, (M2) 3 super-spectra factors only, (M3) 7 spectra/subfactors, (M4) spectra/subfactors with higher-order spectra factors (two-levels), and (M5) a three-level model with the p-factor added. The most complex initially specified model attained near adequate fit (i.e., three-level model CFI = .893, RMSEA = .051, SRMR = .110), though was below pre-established benchmarks. The re-specification procedure was thus pursued to produce final models and inform future research. This included: (a) allowing error covariances between near-identical indicators (see Figure 1 superscripts) and (b) allowing cross-loadings (see italicized variables in Figure 1 and supplement). Following these modifications, final models were directly compared (see Table 2).

Multifactor models improved upon the p-factor model (e.g., $\chi_D^2[8] = 647.41$, $p < .001$; $\Delta CFI \geq .211$, $\Delta RMSEA \geq .022$); however, evidence for improvements beyond this were mixed. Despite a significant chi-square difference test ($\chi_D^2[20] = 257.68$, $p < .001$) between the super spectra and spectra/subfactor models, as well as a clear CFI increase (ΔCFI

[2]These criteria reflect a deviation from pre-registered analyses, which also included changes in relative fit statistics; however, these did not differentiate any models, likely because they were insensitive to adding/removing a single parameter.

≥ .033), changes in other fit statistics did not meet pre-established benchmarks, thus not indicating a clear difference between any of these models. All factor loadings were significant as specified and the average factor loading across models did not differ (i.e., super spectra *M* loading = .52, spectra/subfactor *M* loading = .54). Notably, models with higher order factors (two-level, three-level), fit similarly to the spectra/subfactor model. Thus, our pre-registered criteria for identifying differences between models (see Analyses) did not indicate one "best model". Given this result, we elected to follow the recently published advice of the HiTOP consortium (Waldman et al., 2023) and use the remainder of the analyses in the present study to compare the utility of these models. We chose to move forward examining the most conceptually simple and complex models: the super spectra only model and the three-level hierarchical model (i.e., containing P-factor, super spectra, and spectra/subfactors)[3].

Testing Hypotheses Regarding Complex Disorders

For both the super spectra and three-level models, mixed evidence emerged regarding H2 hypotheses, which focused on diagnoses with uncertain relations to HiTOP dimensions. First (H2a), for bipolar spectrum disorder, clear evidence emerged for relations to the psychosis super spectrum[4], with factor loadings on psychosis of .39 (super spectra) and .29 (three level hierarchical). Second (H2b), mixed evidence emerged for OCD; the super spectra model indicated OCD is most related to psychosis (.20 factor loading), whereas the three-level hierarchical model indicated OCD is most related to emotional dysfunction (.33 factor loading). Third (H2c), BPD similarly showed discrepancies across models, with the super spectra model suggesting that BPD should load both on emotional dysfunction (.21) and externalizing (.36), whereas the three-level model results indicated that it only loaded on externalizing (.38 loading). Fourth (H2d), for AVPD there were similar findings across models, indicating AVPD is most related to the psychosis super spectrum (.24 and .30 loadings). Finally (H2e), for STPD clear evidence emerged across models that the diagnosis strongly and exclusively loaded on the psychosis super spectrum (.86-.89 factor loading).

Exploratory analyses built upon these results, examining the relation of these diagnoses to the three-level hierarchical model, at the spectra/subfactor level. These results indicated that bipolar spectrum disorder loaded on the reality distortion subfactor, OCD loaded on both the fear and reality distortion subfactors, BPD loaded on the substance use-disinhibition subfactor exclusively, AVPD loaded on the detachment subfactor, and STPD loaded on the reality distortion subfactor. Factor loadings for these results were essentially identical to those in the final model in Figure 1.

Final models were specified based on the results of above analyses. For the super spectrum model, the results of the hypothesis tests above were used to assign disorders as indicators to super spectra, resulting in an adequately fitting model (CFI = .90, RMSEA = .04, SRMR = .11). For the three-level model, the final model was specified based on the results of

[3]The spectra/subfactor model was also considered; however, this model produced a not positive definite latent variable covariance matrix. All factor correlations were < .80, suggesting a more complex linear dependency, which disappeared when modeling higher-order factors. Nonetheless, this precluded estimating the factor scores needed for later analyses.

[4]It was necessary to remove depression diagnosis as an indicator from the models testing bipolar disorder's placement, due to diagnostic exclusion rules between depression and bipolar disorder within the SCID.

the exploratory analyses, which allowed disorders to be assigned to subfactors/spectra. This final three-level model fit adequately (CFI = .92, RMSEA = .04, SRMR = .11) and the factor loadings from this model are displayed in Figure 1. Factor scores from these models were output for further analyses.

Relations to Etiological Factors and Outcomes

First, correlations between childhood trauma and factor scores from both the super spectrum and three-level model were examined. In the super spectrum model, the emotional dysfunction (r = .22), thought disorder (r = .22), and externalizing (r = .32) spectra all were positively correlated with childhood trauma (p < .05). Equivalence tests (see Analyses section; Lakens et al., 2018) reinforced these positive findings by suggesting there was no basis for rejecting the null hypothesis of an effect at least as large as r = |.18|. Moving to the three-level model, consistent with hypotheses, the p-factor was correlated with childhood trauma (r = .27). Following this, correlations between the uniquenesses of super spectra and trauma were examined. Factor uniquenesses reflect the variance in the factor that is not explained by the p-factor. The externalizing super spectrum uniqueness positively correlated trauma (r = .19), whereas the thought disorder uniqueness correlated negatively with trauma (r = −.18). For all the correlations tested in the three-level model, equivalence tests showed that a correlation at least as extreme as r = |.18| could not be rejected. The emotional dysfunction uniqueness was uncorrelated with trauma history (r = .04). In this case, the equivalence test showed that the hypothesis that the true correlation between trauma history and the emotional dysfunction uniqueness is as or more extreme than r = |.18| could be rejected.

Second, correlations with functioning were examined, as was the prediction of whether participants developed a psychosis spectrum disorder during the follow-up period. Given that results for the super spectra were nearly identical across the three-level model and the super spectra only models, results are presented for only the three-level model (see Table 3). Overall, outcomes varied in terms of which level of the hierarchy were most predictive, with some being well-predicted by the p-factor (e.g., GAF) and others showing more substantial improvement when more narrow symptom dimensions were used as predictors (e.g., GFS). In general, dimensions from the psychosis super spectra (i.e., detachment and reality distortion) showed the most unique predictive value, though the distress subfactor uniquely predicted worse overall function and better social functioning in this sample. Relatedly, although the p-factor significantly predicted conversion to a psychosis spectrum disorder, at the super spectra level only psychosis predicted conversion and at the spectra/subfactor level only reality distortion was uniquely predictive.

Discussion

The present study examined how the HiTOP and psychosis risk research paradigms may be mutually informative. The present study broadly supported the HiTOP model in a CHR-P sample, though several findings suggest modifications to HiTOP and potentially reconceptualizing psychosis risk symptoms. Additionally, relations to trauma, functioning,

and conversion to psychosis indicated the value of the HiTOP model for understanding psychosis risk, while simultaneously building HiTOP's nomological network.

Informing HiTOP and Understanding Comorbidity in Psychosis Risk

The present study found evidence for a hierarchical model that integrates *DSM* diagnoses, clinical features, and psychosis risk symptoms, and thus has implications for both the HiTOP model and conceptualizing comorbidity in CHR-P populations. First, although the HiTOP model approached adequate fit without modifications, a number of indicated modifications appeared necessary. The fact that these three measures had never previously been jointly factor analyzed explains some of these modifications (e.g., substance use error covariances), whereas other modifications may have implications for both theory and measurement. For instance, SIPS Grandiosity is intended to measure subclinical grandiose delusions, which are theoretically distinct from the narcissistic grandiosity that is more characteristic of antagonism (Miller et al., 2016; Mullins-Sweatt et al., 2022). Nonetheless, the present study found that SIPS Grandiosity loaded on both antagonism and reality distortion factors, indicating either that grandiosity was measured imprecisely or that antagonistic and psychotic grandiosity are less distinct than previously thought. Similarly, SIPS Concentration (i.e., Trouble with Focus and Attention) loaded not only on disorganization, but also on the internalizing-distress factor, which is consistent with broad disruptions to attention being a transdiagnostic symptom (Huang-Pollock et al., 2017). SCID social phobia loading on detachment, in addition to fear, is consistent with some ambivalence within HiTOP about whether social anxiety should be considered as solely reflecting detachment (Zimmermann et al., 2022) and meta-analytic results suggesting it cross-loads between internalizing and detachment (Ringwald et al., 2021). These three findings reflect important areas for further research and should be considered in the model revision process for HiTOP, as well as potentially informing studies that use the SIPS to measure psychosis risk.

Additionally, the present study tested hypotheses regarding five diagnoses that have uncertain relations to the HiTOP model: bipolar spectrum disorders, OCD, and three personality disorders (BPD, AVPD, and STPD). Counter to the current HiTOP model viewing bipolar disorders reflecting both internalizing and psychosis super spectra (H2a), clear evidence emerged for these diagnoses being solely related to psychosis, consistent with etiological research that indicates overlap between bipolar and psychosis spectrum disorders (Brainstorm Consortium et al., 2018). Similarly, counter to what the HiTOP model currently suggests (H2d), AVPD was clearly linked to the detachment spectrum of psychosis, as opposed to being linked to both detachment and emotion dysfunction. More consistent with the HiTOP model (H2e), STPD was clearly linked to the reality distortion spectrum of psychosis. In all three of these cases, the results are theoretically consistent with psychosis risk research and bolstered by the fact that there is substantial variation in these diagnoses in this CHR-P samples. Thus, these results are likely to be highly relevant for the HiTOP consortium during the HiTOP model revision process. Less consistent results emerged for OCD and BPD, indicating that further work is needed to understand how these diagnoses can be understood within HiTOP. More generally, for all of these complex diagnoses, further

clarity may be obtained through examining how individual symptoms of these diagnoses relate to HiTOP dimensions.

Additionally, these findings may have clinical implications for understanding psychosis risk symptoms and their relation to comorbid conditions. As noted above, the present results suggest that it may be challenging to assess grandiosity as a symptom of psychosis risk (e.g., may reflect antagonism), indicating that practitioners should take care in making prognoses or predictions based solely on this symptom. In contrast, overall psychopathology (e.g., p-factor) may be an important risk factor that practitioners can attend to, as the overlap of internalizing, externalizing, and psychosis symptoms accounted for a significant proportion of variance in conversion outcomes. More broadly, through showing links to both functional and clinical outcomes, the present study supports previous work suggesting that psychosis risk can be usefully conceptualized using hierarchical models of symptom dimensions (Cowan et al., 2023; Johns & van Os, 2001), which is in contrast to the traditionally used categorical approach (McGlashan et al., 2010).

Psychosis Risk Etiology and Outcomes

Consistent with previous research, the p-factor was associated with a childhood trauma history (Caspi & Moffitt, 2018) and externalizing symptoms may have a unique relation to trauma beyond the p-factor (Snyder et al., 2019). The finding that the psychosis super spectrum uniqueness was negatively associated with childhood trauma contradicts a substantial literature suggesting a positive association (Gibson et al., 2016). One possible explanation for the present finding is the strong association between the general factor and psychosis in the present study (i.e., .84 loading), which suggests that the psychosis uniqueness may have contained limited reliable variance separate from the p-factor. However, two recent studies in non-CHR-P samples with somewhat less overlap between the general factor and psychosis (e.g., .63 loading) also found that psychosis was not associated with childhood trauma history (Hyland et al., 2018, 2021). It may be that previous research has not adequately accounted for comorbid diagnoses when analyzing the psychosis-trauma association. Interestingly, Hyland and colleagues (2021) did find that psychosis was associated with other environmental factors (i.e., adult trauma and urbanicity). Finally, the lack of evidence for a correlation between the uniqueness of emotional dysfunction and childhood trauma history suggests that childhood trauma may be better conceptualized as a general versus specific liability for mental health problems. To some extent, our pattern of findings reinforced the general principle that broader dimensions tend to outperform narrower ones in criterion validity tests, particularly in examinations of environmental risk (Conway et al., 2019). Overall, the HiTOP model may challenge psychosis risk researchers to examine etiology with greater nuance and, in so doing, present opportunities to advance risk models.

Examining relations to outcomes further illustrates the role of comorbidity, but also demonstrates the utility of a hierarchical approach to conceptualizing psychopathology. Consistent with the recommendations of (Waldman et al., 2023), we found that examining relations to outcomes helped with evaluating models and demonstrating the value of different levels of HiTOP. For instance, social functioning and conversion to a psychotic

disorder appeared best predicted by the 7-factor spectra/subfactor model. In contrast, more complex models showed limited value beyond the p-factor for predicting global functioning (GAF). These results also may inform psychosis risk research, in that changes in global functioning may indicate CHR-P status, while further changes in social functioning may precede conversion to psychosis (Carrión et al., 2021). Research seeking to understand these trajectories of functioning will do well to consider comorbidity at the appropriate level of granularity.

Future Directions, Limitations, and Conclusions

The present study benefited from a large sample composed of CHR-P and HC participants, coverage of three HiTOP super spectra, longitudinal follow-up data, and pre-registered analyses. Nonetheless, there are several limitations that may prompt further inquiry. First, the pre-registered benchmarks for evaluating the relations of individual diagnoses to HiTOP were ineffective, because relative fit indices changed very little across models, even when Chi-Square difference tests and an examination of factor loadings suggested otherwise. One explanation for this is that the relative fit index change benchmarks were based on a study focused on measurement invariance and were designed to be sensitive to model comparisons in which more parameters are changed (Kelley et al., 2019). Future work would do well to focus on either the approach ultimately used in the present study (i.e., algorithm combining chi-square difference tests and factor loadings) or use simulations to examine more suitable relative fit index cut-offs. Second and related, the present study was limited by the use of categorical SCID diagnoses, which prevented the use of information criteria to compare models and also reduces the symptom-level heterogeneity of diagnoses to single data points. Using dimensionally rated symptom measures (e.g., IMAS; Watson et al., 2007) will allow for stronger tests of models and provide a more detailed assessment of the HiTOP model. Third, the present study included mostly CHR-P individuals, potentially reducing the positive manifold that might otherwise be present among indicators. Although this may allow for more nuanced factors to be recovered, it is also open to question whether the present results would replicate when sampling psychosis risk more continuously. Finally, the long-term follow-up of the NAPLS samples that is currently underway is expected to reveal more conversions to psychosis and broadening the scope to also consider longitudinal change in severe negative, disorganization, and cognitive symptoms may yield additional insights. Similarly, comparing symptom-assessed psychosis risk and polygenic risk scores may yield further insights into etiology.

Overall, the present study provided evidence that the HiTOP model broadly replicates in a CHR-P sample and that CHR-P research can inform how diagnoses should be understood in relation to HiTOP. In addition, HiTOP can contribute to understanding psychosis risk, through providing a more accurate and parsimonious understanding of comorbid psychopathology, whereas the CHR-P literature can offer HiTOP a window into important mechanisms underlying disease progression.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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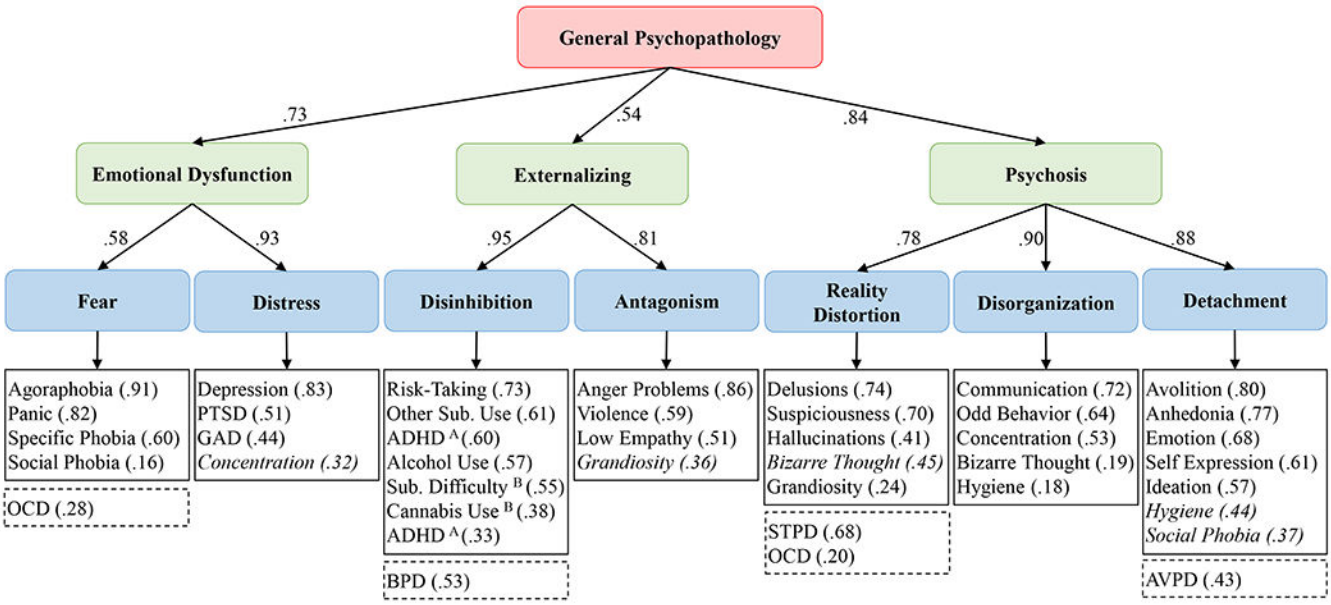

Figure 1.

Factor Loadings for the Final Three-Level Hierarchical Confirmatory Factor AnalysisNote. This includes all diagnoses with debated placements in dashed boxes (H2), with the exception of bipolar spectrum disorder, which had to be excluded due to a dependency with depression. This model also includes modifications to the hypothesized baseline HiTOP model (H1), with italicized loadings reflecting post hoc cross-loadings, and superscripts (A, B) reflecting post hoc error covariances. H = hypothesis; OCD = obsessive-compulsive disorder; PTSD = posttraumatic stress disorder; GAD = generalized anxiety disorder; ADHD = attention deficit hyperactivity disorder; BPD = borderline personality disorder; STPD = schizotypal personality disorder; AVPD = avoidant personality disorder. See the online article for the color version of this figure.

Table 1.

Pre-registered hypotheses and models

Hypothesis 1: Established HiTOP three-level (p-factor, super spectra, spectra/subfactors) would adequately fit
Hypothesis 2: Examining diagnoses with preliminary and unclear relations to HiTOP spectra
H2a: Bipolar Spectrum Disorder relates to emotional dysfunction and psychosis
H2b: Obsessive Compulsive Disorder relates to emotional dysfunction and psychosis
H2c: Borderline Personality Disorder relates to emotional dysfunction and externalizing
H2d: Avoidant Personality Disorder relates to emotional dysfunction and psychosis
H2e: Schizotypal Personality Disorder relates to the psychosis
Hypothesis 3: P-factor and psychosis uniqueness will be positively related to childhood trauma (null hypothesis = |.18|)

Note. More detailed articulations of hypotheses can be found in the pre-registration (https://osf.io/uh9fr)

Table 2.

Fit statistics for final models

	k	CFI	RMSEA	SRMR	χ_D^2
M1: p-Factor only	133	.790	.070	.141	
M2: Super Spectra only	141	.901	.048	.108	M2 > M1 ($p < .001$)
M3: Spectra/Subfactor only	161	.934	.040	.095	M3 > M2 ($p < .001$)
M4: Two-Level Model	149	.924	.043	.102	M4 < M3 ($p < .001$)
M5: Three-Level Model	149	.924	.043	.102	M5 < M4 ($p < .001$)

Note. Indicator-factor assignments are portrayed in Figure 1 and further described in the pre-registration and supplement. Absolute model thresholds: CFI ≥ .90, RMSEA ≤ .06, and SRMR ≤ .08. Model comparison thresholds: ΔCFI ≥ .01, ΔRMSEA ≥ .015, and ΔSRMR ≥ .015.

Table 3.

Relations between three-level model and outcome variables

Dimension	GFS *r*	GFS *β*	GFR *r*	GFR *β*	GAF *r*	GAF *β*	Conv. OR
p-factor	−.61	−0.61***	−.51	−.51***	−.76	−.76***	8.18***
R^2		0.37		0.25		0.57	0.11
Super Spectra							
Emotional Dys.	−.47	0.27***	−.40	0.15**	−.68	−0.17***	0.99
Externalizing	−.38	0.04	−.39	−0.10**	−.51	−0.02	0.44
Psychosis	−.65	−0.91***	−.52	−0.58***	−.76	−.60***	8.33***
R^2		0.45		0.28		0.58	0.13
Spectra/Subfactors							
Distress	−.42	0.21*	−.37	0.00	−.65	−.12**	1.22
Fear	−.30	−0.01	−.26	0.09	−.52	−0.06	0.91
Substance-Dis	−.36	0.04	−.37	0.01	−.48	0.01	1.13
Antagonism	−.35	−0.07	−.37	−0.15	−.45	−0.07	0.59
Reality Distort	−.57	−0.10*	−.43	0.07	−.72	−.32***	3.74***
Disorganized	−.62	0.06	−.50	−0.09	−.72	0.00	1.61
Detachment	−.69	−0.80*	−.53	−0.51***	−.73	−.31***	1.03
R^2		0.49		0.30		0.60	0.15

Note. GFS = Global Function Scale-Social, GFR = Global Functioning Scale-Role, GAF = Global Assessment of Functioning, and Conv. OR = odds ratios from logistic regressions predicting conversion to a psychosis spectrum disorder. Nagelkerke's R^2 was used for logistic regressions. All zero-order correlations are significant, for *β* coefficients:

* = p < .05,

** = p < .01,

***, and = p < .001.