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The Hierarchical Taxonomy Of Psychopathology (HiTOP):

A Dimensional Alternative to Traditional Nosologies

Roman Kotov[1]
Robert F. Krueger[2]
David Watson[3]
Thomas M. Achenbach[4]
Robert R. Althoff [4]
Michael Bagby [5]
Timothy A. Brown[6]
William T. Carpenter[7]
Avshalom Caspi[8,9]
Lee Anna Clark[3]
Nicholas R. Eaton[10]
Miriam K. Forbes[2]
Kelsie T. Forbush[11]
David Goldberg[12]
Deborah Hasin[13]
Steven E. Hyman[14]
Masha Y. Ivanova[4]
Donald R. Lynam[15]
Kristian Markon[16]
Joshua D. Miller[17]
Terrie E. Moffitt[8,9]
Leslie C. Morey[18]
Stephanie N. Mullins-Sweatt[19]
Johan Ormel[20]
Christopher J. Patrick[21]
Darrel A. Regier[22]
Leslie Rescorla[23]
Camilo J. Ruggero[24]
Douglas B. Samuel[15]
Martin Sellbom[25]
Leonard J. Simms[26]
Andrew E. Skodol[27]
Tim Slade[28]
Susan C. South[15]
Jennifer L. Tackett[29]
Irwin D. Waldman[30]
Monika A. Waszczuk[1]
Thomas A. Widiger[31]

Aidan G. C. Wright[32]
Mark Zimmerman[33]

[1]Stony Brook University, Department of Psychiatry, Stony Brook, NY, United States
[2]University of Minnesota, Department of Psychology, Minneapolis, MN, United States
[3]University of Notre Dame, Department of Psychology, South Bend, IN, United States
[4]University of Vermont, Department of Psychiatry, Burlington, VT, United States
[5]University of Toronto, Departments of Psychology and Psychiatry, Scarborough, ON, Canada
[6]Boston University, Department of Psychology, Boston, MA, United States
[7]University of Maryland School of Medicine, Department of Psychiatry, Baltimore, MD, United States
[8]Duke University, Department of Psychology and Neuroscience, Durham, NC, United States
[9]Social, Genetic, and Developmental Psychiatry Research Centre, Institute of Psychiatry, Psychology & Neuroscience, King's College, London, United Kingdom
[10]Stony Brook University, Department of Psychology, Stony Brook, NY, United States
[11]University of Kansas, Lawrence, KS, United States
[12]Institute of Psychiatry, Psychology & Neuroscience, King's College, London, United Kingdom
[13]Columbia University, Department of Psychiatry, College of Physicians and Surgeons, New York, NY, United States
[14]Stanley Center for Psychiatric Research, Broad Institute of MIT and Harvard, Cambridge, MA, United States
[15]Purdue University, Department of Psychological Sciences, West Lafayette, IN, United States
[16]University of Iowa, Department of Psychological and Brain Sciences, Iowa City, IA, United States
[17]University of Georgia, Department of Psychology, Athens, GA, United States
[18]Texas A&M University, Department of Psychology, College Station, TX, United States
[19]Oklahoma State University, Department of Psychology, Stillwater, OK, United States
[20]University of Groningen, Department of Psychiatry, Groningen, The Netherlands
[21]Florida State University, Department of Psychology, Tallahassee, FL, United States
[22]Uniformed Services University, Department of Psychiatry, Bethesda, MD, United States
[23]Bryn Mawr College, Department of Psychology, Bryn Mawr, PA, United States
[24]University of North Texas, Department of Psychology, Denton, TX, United States
[25]University of Otago, Department of Psychology, Dunedin, New Zealand
[26]University at Buffalo, The State University of New York, Department of Psychology, Buffalo, NY, United States
[27]University of Arizona, Department of Psychiatry, Tucson, AZ, United States
[28]University of New South Wales, Nation Drug and Alcohol Research Centre, Randwick, NSW, Australia
[29]Northwestern University, Department of Psychology, Evanston, IL, United States
[30]Emory University, Department of Psychology, Atlanta, GA, United States
[31]University of Kentucky, Department of Psychology, Lexington, KY, United States
[32]University of Pittsburgh, Department of Psychology, Pittsburgh, PA, United States
[33]Brown Alpert Medical School, Department of Psychiatry and Human Behavior, Providence, RI, United States

Corresponding author:

Roman Kotov
Department of Psychiatry
Stony Brook University
HSC, Level T-10, Room 060H
Stony Brook, NY 11794-8101
phone: 631-638-1923; Fax: 631-638-1935
email: roman.kotov@stonybrook.edu

Author contributions:

Kotov, Krueger, and Watson contributed to the initial composition of the manuscript. All other authors contributed to revision of the manuscript, adding important intellectual content; they are listed in alphabetical order.

Abstract

The reliability and validity of traditional taxonomies are limited by arbitrary boundaries between psychopathology and normality, often unclear boundaries between disorders, frequent disorder co-occurrence, heterogeneity within disorders, and diagnostic instability. These taxonomies went beyond evidence available on the structure of psychopathology and were shaped by a variety of other considerations, which may explain the aforementioned shortcomings. The Hierarchical Taxonomy Of Psychopathology (HiTOP) model has emerged as a research effort to address these problems. It constructs psychopathological syndromes and their components/subtypes based on the observed covariation of symptoms, grouping related symptoms together and thus reducing heterogeneity. It also combines co-occurring syndromes into spectra, thereby mapping out comorbidity. Moreover, it characterizes these phenomena dimensionally, which addresses boundary problems and diagnostic instability. Here, we review the development of the HiTOP and the relevant evidence. The new classification already covers most forms of psychopathology. Dimensional measures have been developed to assess many of the identified components, syndromes, and spectra. Several domains of this model are ready for clinical and research applications. The HiTOP promises to improve research and clinical practice by addressing the aforementioned shortcomings of traditional nosologies. It also provides an effective way to summarize and convey information on risk factors, etiology, pathophysiology, phenomenology, illness course, and treatment response. This can greatly improve the utility of the diagnosis of mental disorders. The new classification remains a work in progress. However, it is developing rapidly and is poised to advance mental health research and care significantly as the relevant science matures.

Key words: Internalizing, Externalizing, Thought Disorder, factor analysis, structure

General scientific summary

This paper introduces a new classification of mental illness, the Hierarchical Taxonomy Of Psychopathology (HiTOP). It aims to address several major shortcomings of traditional taxonomies and provide a better framework for researchers and clinicians.

The Hierarchical Taxonomy Of Psychopathology (HiTOP): A Dimensional Alternative to Traditional Nosologies

The Hierarchical Taxonomy Of Psychopathology (HiTOP; http://medicine.stonybrookmedicine.edu/HITOP) consortium brings together a group of clinical researchers who aim to develop an empirically driven classification system based on advances in quantitative research on the organization of psychopathology. Primary objectives of the consortium are to (a) integrate evidence generated by this research to date and (b) produce a system that reflects a synthesis of existing studies. Our motivation in articulating the HiTOP system is to facilitate translation of findings on quantitative classification to other research arenas and to clinical practice. To that end, we also seek to identify measures that can be used to assess HiTOP dimensions. Moreover, we hope that this system will stimulate and guide new nosologic research. We view the HiTOP as a set of testable hypotheses that would encourage exploration rather than constrain it. Indeed, we seek to avoid reification of the system. This paper is the first publication of the consortium and reviews evidence available to date. We aim to provide regular updates to the HiTOP system as new data become available.

This paper relies on several key terms and concepts, which are important to define upfront. *Structural studies* refer to research that investigates relations among signs, symptoms, maladaptive behaviors, or diagnoses. *Dimensions* are psychopathologic continua that reflect individual differences in a maladaptive characteristic across the entire population (e.g., social anxiety is a dimension that ranges from comfortable social interactions to distress in nearly all social situations); dimensions reflect differences in degree, rather than in kind. These dimensions can be organized hierarchically from narrowest to broadest, as follows. *Homogeneous components* are constellations of closely related symptom manifestations; for example, fears of

working, reading, eating or drinking in front of others form performance anxiety cluster. *Maladaptive traits* are specific pathological personality characteristics, such as submissiveness. *Syndromes* are composites of related components/traits, such as a social anxiety syndrome that encompasses both performance anxiety and interaction anxiety. Of note, the term syndrome can be used to indicate a category, but here we use it to indicate a dimension. *Subfactors* are groups of closely-related syndromes, such as the fear subfactor formed by strong links between social anxiety, agoraphobia, and specific phobia. *Spectra* are larger constellations of syndromes, such as an internalizing spectrum composed of syndromes from fear, distress, eating pathology, and sexual problems subfactors. *Super-spectra* are extremely broad dimensions comprised of multiple spectra, such as a general factor of psychopathology that represents the liability shared by all mental disorders.

We also want to emphasize that although this paper references disorders defined in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2013) in various passages, this only is to facilitate communication in situations wherein HiTOP dimensions parallel DSM diagnoses. The new system does not include any of the traditional diagnoses.

The present paper covers six major topics. First, we review limitations of traditional taxonomies. Second, we discuss the history and principles of the quantitative classification movement that developed in parallel with traditional taxonomies. Third, we outline findings on the quantitative classification and the resulting HiTOP system. Fourth, we review measures currently available to implement this system. Fifth, we discuss the utility of the HiTOP model for research and clinical applications. Sixth, we conclude with an overview of limitations and future directions of this work.

Limitations of Traditional Taxonomies

The third edition of the *DSM* (DSM-III; APA, 1980), along with its subsequent editions and counterpart editions of the International Classification of Diseases [ICD], including the current 10th edition (ICD-10; World Health Organization [WHO], 1992), substantially refined psychiatric classification, greatly reduced national variations in prevalence estimates, improved the diagnostic process, and provided a common language for the field (Kendell & Jablensky, 2003). Nevertheless, these classification systems also have significant limitations.

First, these traditional systems consider all mental disorders to be categories, whereas the evidence to date suggests that psychopathology exists on a continuum with normal-range functioning; in fact, not a single mental disorder has been established as a discrete categorical entity (Carragher et al., 2014; Haslam, Holland, & Kuppens, 2012; Markon & Krueger, 2005; Walton, Ormel, & Krueger, 2011; Widiger & Samuel, 2005; Wright et al., 2013). Importantly, imposition of a categorical nomenclature on naturally dimensional phenomena leads to a substantial loss of information and to diagnostic instability (MacCallum, Zhang, & Preacher, 2003; Markon, Chmielewski, & Miller, 2011; Morey et al., 2012).

Second, traditional diagnoses generally show limited reliability, as can be expected when arbitrary categories are forced onto dimensional phenomena (Chmielewski, Clark, Bagby, & Watson, 2015; Markon, 2013). For example, the *DSM-5* Field Trials found that 40% of diagnoses did not meet even a relaxed cutoff for acceptable interrater reliability (Regier et al., 2013), although the same disorders often showed excellent reliability when operationalized dimensionally (Markon et al., 2011; Shea et al., 2002).

Third, many existing diagnoses are quite heterogeneous and encompass multiple pathological processes (Clark, Watson, & Reynolds, 1995; Hasler, Drevets, Manji, & Charney,

2004; Zimmerman et al., 2015). Traditional taxonomies attempt to address heterogeneity by specifying disorder subtypes. However, most subtypes have been defined rationally rather than being derived from structural research, and fail to demarcate homogenous subgroups (Watson, 2003a).

Fourth, co-occurrence among mental disorders, often referred to as comorbidity, is very common in both clinical and community samples (Andrews, Slade, & Issakidis, 2002; Bijl, Ravelli, & van Zessen, 1998; Brown, Campbell, Lehman, Grisham, & Mancill, 2001; Grant et al., 2004; Kessler, Chiu, Demler, & Walters, 2005; Teesson, Slade, & Mills, 2009; Ormel et al., 2015). Comorbidity complicates research design and clinical decision-making, as additional conditions can distort study results and affect treatment. In terms of nosology, high comorbidity suggests that some unitary conditions have been split into multiple diagnoses, which co-occur frequently as a result, indicating the need to redraw boundaries between disorders.

Fifth, many patients fall short of the criteria for any disorder, despite manifesting significant distress or impairment that indicates the need for care. The *DSM-5* addresses this problem by providing Other Specified/Unspecified (previously Not Otherwise Specified) categories. Importantly, these cases represent a shortcoming of the current system, as such diagnoses provide little information.

The core issue potentially responsible for these five shortcomings is that construction of traditional taxonomies went beyond evidence available on the structure of psychopathology and was shaped by various other considerations. It appears that this rational approach to psychiatric nosology, not grounded in structural research or an understanding of the etiologic architecture of mental disorders, has failed in some instances to represent psychopathology accurately. Indeed, the sluggish pace of discovery in psychiatry has been attributed, in part, to the limited validity

and certain arbitrariness of traditional diagnoses (Cuthbert & Insel, 2013; Gould & Gottesman, 2006; Hasler, LaSalle-Ricci, & Ronquillo, 2005; Hyman, 2010; Merikangas & Risch, 2003). Clinically, diagnosis is expected to help in selection of treatment, but the *DSM* and *ICD* are imperfect guides to care (Beutler & Malik, 2002; Bostic & Rho, 2006; Hermes, Sernyak, & Rosenheck, 2013; Mohamed & Rosenheck, 2008).

The Quantitative Classification Movement

A solution to the shortcomings of traditional taxonomies is emerging in the form of a quantitative nosology, an empirically based organization of psychopathology (e.g., Achenbach & Rescorla, 2001; Forbush & Watson, 2013; Kotov, Ruggero, et al., 2011; Krueger & Markon, 2006; Lahey et al., 2008; Slade & Watson, 2006; Vollebergh et al., 2001; Wright & Simms, 2015). Rather than relying on *a priori* assumptions, a quantitative nosology is defined through the independent work of multiple research groups seeking to understand the organization of psychopathology (Kotov, 2016). In this section, we discuss four aspects of the quantitative approach. First, we review its history. Second, we outline ways in which the quantitative approach addresses the limitations of traditional taxonomies. Third, we respond to common concerns raised about this approach related to (a) methodological choices and (b) applicability to clinical settings. Fourth, we discuss the interface of a quantitative nosology with another dimensional approach to psychopathology, the Research Domain Criteria (RDoC; Cuthbert & Insel, 2010, 2013) framework.

History. The quantitative movement has a long history, beginning with the pioneering work of Thomas Moore, Hans Eysenck, Richard Whittenborn, Maurice Lorr, and John Overall, who developed measures to assess signs and symptoms of psychiatric inpatients, and identified empirical dimensions of symptomatology through factor analysis of these instruments (e.g.,

Eysenck, 1944; Lorr et al., 1963; Moore, 1930; Overall & Gorham, 1962; Whittenborn, 1951). Others have searched for natural categories using such techniques as cluster analysis (Blashfield, 1984; Macfarlane, Allen, & Honzik, 1954). Similarly, research on the structure of affect (Tellegen, 1985) helped to identify dimensions of depression and anxiety symptoms (Clark & Watson, 1991). Factor analytic studies of child symptomatology found dimensional syndromes that remain in use today (Achenbach, 1966; Achenbach, Howell, Quay, Conners, & Bates, 1991; Achenbach & Rescorla, 2001). Finally, factor analyses of comorbidity among common adult disorders revealed higher-order dimensions of psychopathology (Krueger, 1999; Krueger, Caspi, Moffitt, & Silva, 1998; Wolf et al., 1988) that inspired a growing and diverse literature.

Also relevant are factor analytic studies of normal personality. This research has identified a hierarchical taxonomy that spans many levels of generality from specific facets (e.g., 30 dimensions in the work of Costa & McCrae, 1992) to general factors (DeYoung, 2006; Digman, 1997; Markon, Krueger, & Watson, 2005). Among these levels, most attention has been devoted to the five-factor model, consisting of neuroticism, extraversion, openness, agreeableness, and conscientiousness (e.g., Costa & McCrae, 1992; Digman, 1990; Goldberg, 1993; John, Naumann, & Soto, 2008); and the “Big Three” model, consisting of neuroticism, extraversion, and disinhibition (Eysenck & Eysenck, 1975; Clark & Watson, 1999). These general traits show strong links to all common forms of psychopathology (Clark, 2005; Kotov et al., 2010, Saulsman & Page, 2004); in addition, specific facets are highly informative for understanding certain mental disorders (Samuel & Widiger, 2008; Watson, Stasik, Ellickson-Larew, & Stanton, 2015). Although extensive discussion of connections between personality and psychopathology is beyond the scope of the present paper, we should note that the taxonomy of normal personality has played a major role in shaping dimensional models of personality

pathology (Widiger & Mullins-Sweatt, 2009; Widiger & Simonsen, 2005; Widiger & Trull, 2007). Personality models are also important because the scope of a quantitative nosology includes both symptoms, which are relatively transient forms of psychopathology, and maladaptive personality traits that form a more stable core of the clinical picture (Hopwood et al., 2011; Krueger & Markon, 2006).

Addressing limitations of traditional taxonomies. A quantitative psychiatric classification operates on two levels (Kotov, 2016). First, it constructs syndromes from the empirical covariation of symptoms to replace diagnoses that rely on untested assumptions, such as the assumption that mental disorders are categories. Second, it groups syndromes into spectra based on the covariation among them. Intermediate structural elements—such as components within syndromes and subfactors within spectra—are similarly elucidated. In line with existing evidence, all of these constructs have been operationalized dimensionally.

This quantitative approach responds to all aforementioned shortcomings of traditional nosologies. First, it resolves the issue of arbitrary thresholds and associated loss of information (Markon et al., 2011). It also helps to address the issue of instability, as indicated by the high test-retest reliability of dimensional psychopathology constructs (Watson, 2003b). Second, a quantitative approach groups related symptoms together and assigns unrelated symptoms to different syndromes, thereby identifying unitary constructs and reducing diagnostic heterogeneity (Clark & Watson, 2006). Third, comorbidity is incorporated into the classification system with the assignment of syndromes to spectra. Comorbidity conveys important information about shared risk factors, pathological processes, and illness course; a quantitative nosology formalizes this information, making it explicitly available to researchers and clinicians (Brown & Barlow, 2009; Krueger & Markon, 2011; Watson, 2005). Hence, if a question

concerns a clinical feature common to multiple syndromes, the clinician or researcher may focus on the higher-order dimension. Alternatively, if a specific syndrome is of interest, the higher-order dimension can be controlled statistically (or for a given patient, relative elevation of the syndrome can be computed relative to score on the higher-order dimension) to elucidate information unique to this syndrome. This hierarchical organization is an important feature of a quantitative nosology; the multi-level approach (including individual symptoms, components/traits, syndromes, subfactors, and spectra) allows for a flexible description of a patient depending on the desired degree of specificity. This approach parallels established classification frameworks in the study of human individual differences more broadly, such as taxonomies of personality and cognitive abilities (e.g., Markon et al., 2005). Fourth, no patients are excluded or incompletely described by the system, because everyone can be characterized on a set of dimensions, even those with low levels of pathology.

Methods. Development of a quantitative classification relies substantially on factor analysis, a statistical procedure that groups variables (e.g., symptoms, syndromes) based on the pattern of their interrelations. This family of techniques includes exploratory factor analysis, which searches for the optimal organization of variables, and confirmatory factor analysis, which tests the fit of hypothesized structures to data (Brown, 2015; Fabrigar et al., 1999). Other methods have been used to investigate natural classes or hybrid models that allow for both classes and dimensions. Class-based methods have the appeal of clustering people, rather than variables. However, when structural findings are translated to practical application, these results are operationalized as scales or other composites of variables, regardless of whether they were derived by class-based or factor analytic methods. Recent studies that used class-based methods (e.g., latent class analysis) found classes that represent extreme levels of dimensions identified in

factor analytic research (Olino et al., 2012; Vaidyanathan, Patrick, & Iacono, 2011), but older studies produced different sets of clusters (Kessler et al., 2005). Dimensional models have shown better fit to the data than latent classes or hybrid models (Eaton et al., 2013; Carragher et al., 2014; Haslam et al., 2012; Markon & Krueger, 2005; Vrieze, Perlman, Krueger, & Iacono, 2012; Walton et al., 2011; Wright et al., 2013). Individual symptoms also have been found to be dimensions rather than binary absent/present states (Flett, Vredenburg, & Krames, 1997; Strauss, 1969; Van Os et al., 2009).

These findings likely contribute to the wide reliance on factor analysis in quantitative nosology research and the shared assumption that psychopathology can be represented effectively by dimensions. There is no conclusive evidence of categorical entities in mental health to challenge this assumption (Haslam et al., 2012; Markon & Krueger, 2005; Walton et al., 2011; Widiger & Samuel, 2005; Wright et al., 2013), but if such entities were to emerge, they could be incorporated easily into a quantitative nosology. Modern statistical tools, such as factor mixture models (Hallquist & Wright, 2014; Y. Kim & Muthén, 2009), permit modeling of dimensions and categories simultaneously.

Applicability to clinical settings. A common concern with dimensional classifications is whether they are applicable to clinical settings, as clinical care often requires categorical decisions. Indeed, actionable ranges of scores will need to be specified on designated dimensions for such a classification to work effectively in clinical practice. Rather than being posited *a priori*, these ranges are straightforward to derive empirically, as is commonly done in medicine (e.g., ranges of blood pressure, fasting glucose, viral load, etc.). For example, more intrusive and costly interventions tend to be indicated for greater illness severity, and this can be accommodated by specifying one range for preventive interventions, a somewhat higher one for

outpatient care, and the highest for inpatient treatment. In contrast, traditional taxonomies tend to offer a single cutoff, the diagnostic threshold, regardless of the clinical question. *DSM-5* has made some progress in changing this practice, supplementing formal diagnosis (in Section II) with cross-cutting and severity measures (in Section III) and allowing severity specifiers (e.g., mild, moderate, and severe) for some disorders.

The diagnosis of intellectual disability may serve as a useful model of how dimensions can be adapted for diagnostics. Intellectual disability is defined by two quantitative dimensions, intelligence and adaptive functioning, that are then categorized for diagnostic purposes into profound, severe, moderate, and mild. Ranges of intelligence scores are specified for each group, and assessors have the flexibility to consider adaptive functioning when assigning the diagnostic descriptor rather than rigidly following predetermined cutoffs. Beyond intellectual and neuropsychological testing, clinicians have made effective use of a variety of dimensional assessment tools, such as the Minnesota Multiphasic Personality Inventory (MMPI; Hathaway & McKinley, 1942), the Personality Assessment Inventory (PAI; Morey, 1991, 2007), and the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach & Rescorla, 2001), for several decades; thus, a substantial precedent for the clinical utility of dimensional systems already exists.

Interface with RDoC. The RDoC (Cuthbert & Insel, 2010, 2013) framework represents a related response to the shortcomings of traditional taxonomies. The National Institute of Mental Health created this framework to encourage the development of a dimensional research classification system of psychological processes with established neural bases and potential relevance to psychiatric symptoms. The emerging system spans eight units of analysis (from genes to behavioral tasks), a diverse range of constructs, and cuts across diagnostic categories.

This dimensional approach has the potential to address many problems of the current system. However, the RDoC framework is concerned with basic biological processes (e.g., neural circuits) as much as with pathological behavior, and seeks to link animal and human research, thus largely focusing on constructs that apply across species (Cuthbert & Kozak, 2013). As such, the RDoC system holds particular promise for advancing the understanding of biological processes relevant to psychopathology, but its coverage of clinical phenomena is neither highly detailed nor comprehensive. A substantial need remains to systematically describe dimensions of psychiatric phenotypes. A quantitative nosology goes well beyond the scope of the RDoC in meeting this need and can inform the RDoC framework with regard to key clinical dimensions that need to be considered. Another limitation of the RDoC is that it seeks to restructure psychiatric nosology at a very basic level, so that the translation of advances it produces to diagnostic practice likely lies well in the future. In contrast, the quantitative nosology is driven by clinical constructs and specifically targets shortcomings of existing diagnoses, while also defining clearer phenotypes for basic research.

At the same time, a quantitative nosology is limited by its focus on clinical manifestations. The resulting dimensions are descriptive, and their nature is not immediately clear. Validation studies, perhaps conducted within the RDoC framework, are needed to elucidate the etiology, pathophysiology, and treatment response of these quantitative dimensions. Moreover, even a comprehensive analysis of signs and symptoms may miss disorders that are etiologically coherent but have multiple clinical manifestations (e.g., manifestations of tertiary syphilis differ dramatically depending on the organs affected). In contrast, the RDoC approach begins with research on biological systems, and may ultimately identify etiologically coherent nosologic entities even if they lack a singular clinical presentation.

Overall, these two efforts approach nosology from different perspectives, but are well positioned to advance toward one another in order to produce a unified system (Patrick & Hajcak, 2016). For example, a quantitative nosology can inform the RDoC initiative with regard to pivotal phenotypic dimensions that can serve as referents for biological and behavioral constructs. Conversely, the RDoC integrates information from various approaches to characterizing psychopathology (e.g., biological, animal models). Consequently, RDoC can clarify the nature of quantitative dimensions and suggest new constructs that should be operationalized phenotypically, thereby shaping a quantitative nosology. Joint analyses of quantitative and RDoC constructs are likely to reveal some points of convergence, dimensions that are clearly measurable with biological markers, behavioral tasks, and self-report (see Patrick, Venables, et al., 2013; Yancey, Venables, & Patrick, 2016). These analyses also would reveal dimensions that are not prominent in some units of analysis, such as a trait with highly complex neural architecture or a physiological process that has only weak connections with phenomenology. Such information is essential for both refinement of RDoC constructs and validation of quantitative dimensions.

The Emerging Classification

Research on a quantitative nosology has produced considerable structural evidence on constructs at each level of the hierarchy and examined the validity of many of the identified dimensions, including common risk factors, biomarkers, illness course, and treatment response. In this section, we propose the HiTOP model based on a review of structural evidence and validity data on spectra (and super-spectra), subfactors, syndromes, and traits/homogeneous components. We consider evidence from clinical disorders and personality disorders (PDs)

separately, because many papers focused on one of these two domains, but also jointly when relevant studies exist.

Spectra

Introduction of the spectra. Factor analytic research has consistently identified two fundamental dimensions of common mental disorders, internalizing and externalizing. The internalizing dimension accounts for the comorbidity among depressive, anxiety, posttraumatic stress, and eating disorders, as well as sexual dysfunctions and obsessive-compulsive disorder (OCD). The traditional externalizing dimension captures comorbidity among substance use disorders, oppositional defiant disorder (ODD), conduct disorder, adult antisocial behavior, intermittent explosive disorder (IED), and attention-deficit/hyperactivity disorder (ADHD). These dimensions (spectra) were first identified in child psychopathology (Achenbach, 1966; Achenbach & Rescorla, 2001; Achenbach et al., 1991; Blanco et al., 2015; Lahey et al., 2004; Lahey et al., 2008) and have since been replicated in adult samples (Achenbach & Rescorla, 2003; Carragher et al., 2014; Forbush & Watson, 2013; Krueger & Markon, 2006; Roysamb et al., 2011; Slade & Watson, 2006). They also have been observed in various cultures (Kessler et al., 2011; Krueger, Chentsova-Dutton, Markon, Goldberg, & Ormel, 2003).

More recently, a thought disorder spectrum was identified, which encompasses psychotic disorders, cluster A PDs, and bipolar I disorder (Kotov, Chang, et al., 2011; Keyes et al., 2013; Kotov, Ruggero, et al., 2011; Markon, 2010a; Wright et al., 2013). This dimension has been well replicated in adults. A similar dimension of thought problems has been documented extensively in youth, and studies have found that it is not subsumed by either the internalizing or externalizing spectra (Achenbach & Rescorla, 2001). The internalizing, externalizing, and thought disorder dimensions have emerged in both community and patient samples (Kotov,

Chang, et al., 2011; Kotov, Ruggero et al., 2011; Miller, Fogler, Wolf, Kaloupek, & Keane, 2008). Extensive data are now available on these spectra with studies including as many as 25 disorders (Røysamb et al., 2011) and 43,093 participants (Eaton et al., 2013). Finally, initial evidence suggests existence of an additional somatoform spectrum (Kotov, Ruggero et al., 2011). The resulting four dimensions are listed in Figure 1.

An important limitation of this work in adults is that nearly all of the aforementioned studies analyzed dichotomous diagnoses. One issue with such analyses is that many diagnoses are defined by symptoms that are only loosely interrelated and sometimes reflect different psychopathology dimensions. Consequently, some diagnoses are prone to cross-loading in factor analyses, complicating the resulting structure. Another limitation is that to analyze dichotomous markers, many studies assume that a continuous, normally distributed variable underlies each disorder. Internally consistent dimensional markers of psychopathology would address the aforementioned limitations. Initially, such markers were derived from rating forms, and analyses of these data replicated the internalizing, externalizing, and thought disorder spectra (Achenbach & Rescorla, 2001, 2003; Kramer, Krueger, & Hicks, 2008; Sellbom, Ben-Porath, & Bagby, 2008). Furthermore, two studies replicated the somatoform spectrum (McNulty & Overstreet, 2014; Sellbom, in press). More recently, development of novel measures allowed for dimensional scoring of homogeneous symptom dimensions from interviews (Markon, 2010a; Kotov et al., 2015; Lahey, 2004; Wright et al., 2013). Factor analyses of these instruments confirmed the existence of the internalizing, externalizing, and thought disorder spectra.

The structure of personality pathology. In parallel, other studies investigated the structure of personality pathology. Five domains emerged from this research: negative affectivity, detachment (i.e., social withdrawal), disinhibition, antagonism, and psychoticism (the personality

counterpart of thought disorder). The first body of evidence comes from factor analyses of PD diagnoses. O'Connor (2005) reanalyzed 33 such studies and found four dimensions, which he coordinated with the prominent five-factor model (FFM) of personality. The first dimension was defined by dependent, avoidant, and borderline PDs, which suggested negative affectivity as a common theme. The second was composed of antisocial, narcissistic, histrionic, borderline and paranoid PDs, and likely reflected antagonism. The third included schizoid, schizotypal, and avoidant PDs, as well as a negative loading from histrionic PD, which indicated detachment. The fourth was defined solely by obsessive-compulsive PD.

Other research examined the structure of maladaptive personality traits using dimensional markers, such as the scales of the Schedule for Nonadaptive and Adaptive Personality-2nd Edition (SNAP-2; Clark, Simms, Wu, & Casillas, 2014) and the Dimensional Assessment of Personality Pathology—Basic Questionnaire (DAPP-BQ; Livesley & Jackson, 2009). These inventories reflect somewhat different structures, but they have four fundamental dimensions in common: negative affectivity, detachment, antagonism, and disinhibition vs. compulsivity (Clark, Livesley, Schroeder, & Irish, 1996). Another model, the Personality Psychopathology—Five (PSY-5; Harkness & McNulty, 1994), includes the same four dimensions plus psychoticism. The most recent efforts to map personality pathology are the Personality Inventory for DSM-5 (PID-5; Krueger et al., 2012) and the Computerized Adaptive Test of Personality Disorder (CAT-PD; Simms et al., 2011). They were developed independently from each other to assess personality pathology comprehensively and explicate its organization using factor analysis. These projects revealed very similar five-dimensional structures that are highly congruent with the PSY-5, consisting of negative affectivity, detachment, disinhibition,

antagonism, and psychoticism (Wright & Simms, 2014; Krueger & Markon, 2014). These dimensions are listed in Figure 1.

Further studies conceptualized pathological personality traits as maladaptive variants of the FFM (Widiger & Trull, 2007). These variants are elaborated in the Five-Factor Model Personality Disorder (FFM-PD; Widiger, Lynam, Miller, & Oltmanns, 2012) scales and the Five Factor Form (FFF; Rojas & Widiger, 2014). For example, the FFF assesses maladaptive variants of 30 traits included within the FFM. Factor analyses of the FFF produced a five-dimensional structure that reflects neuroticism, extraversion, openness, agreeableness, and conscientiousness. With regard to the five domains, negative affectivity was found to map onto neuroticism, detachment on (low) extraversion, disinhibition on (low) conscientiousness, and antagonism on (low) agreeableness, and may be conceptualized as maladaptive versions of these four traits (Krueger & Markon, 2014). Psychoticism is the only domain not clearly represented in the FFM. Nevertheless, the five domains (negative affectivity, detachment, disinhibition, antagonism, and psychoticism) have emerged clearly across different operationalizations of personality pathology.

Joint structure. In previous sections, we discussed studies that focused either on symptoms or on maladaptive traits. Several studies analyzed symptoms and traits together and showed that the internalizing spectrum is connected with negative affectivity, thought disorder with psychoticism, and externalizing with both disinhibition and antagonism. In contrast, somatoform appears to lack a clear personality pathology counterpart, and detachment may be lacking a clear symptom counterpart (Figure 1).

Specifically, three studies evaluated the joint structure of DSM clinical and personality disorders most comprehensively. Røysamb et al. (2011) examined 25 disorders in 2,974 twins from Norway. They observed factors that clearly reflect the internalizing (anxiety and depressive

disorders and borderline PD), traditional externalizing (substance use disorders, antisocial PD, and conduct disorder), antagonism (narcissistic, histrionic, borderline, and paranoid PD but also obsessive-compulsive and schizotypal PD), and pathological introversion/detachment (avoidant, dependent, schizoid, and depressive PD and dysthymia) spectra. Importantly, this investigation did not include psychotic disorders or mania, which likely precluded modeling of the thought disorder dimension.

In contrast, Kotov, Ruggero et al. (2011) included both psychosis and mania. They analyzed 25 disorders in 2,900 outpatients and reported recognizable dimensions of internalizing (anxiety and depressive disorders along with dependent, obsessive-compulsive, borderline and paranoid PD), traditional externalizing (substance use disorders, antisocial behavior, and conduct problems), thought disorder (psychotic disorders, bipolar I disorder, schizotypal, paranoid, and schizoid PD), and antagonism (histrionic, narcissistic, borderline, and paranoid PD as well as antisocial behavior and conduct problems) spectra; they also reported a somatoform factor (undifferentiated somatoform disorder, hypochondriasis, and pain disorder). However, Kotov, Ruggero et al. (2011) were unable to delineate a detachment factor because their analyses excluded avoidant PD due to its high correlation with social phobia. They also attempted to model Axis II negative affectivity separately from Axis I internalizing, but found the two factors to correlate .96.

Finally, Wright and Simms (2015) conducted joint structural analyses of common mental disorders, personality disorders, and maladaptive personality traits in a sample of 628 current and recent outpatients; importantly, all disorders were scored dimensionally (i.e., as symptom counts). They found evidence of five dimensions: internalizing (anxiety and depressive disorders, along with borderline, avoidant, dependent, and paranoid PDs), disinhibition

(substance use disorders, antisocial PD), antagonism (narcissistic and histrionic PDs), detachment (defined by schizoid, avoidant, and dependent PD at the high end and by histrionic PD at the low end), and thought disorder (psychotic symptoms and schizotypal PD).

Several other studies operationalized psychopathology using homogeneous symptom and trait dimensions rather than DSM disorders. Two analyses of self-ratings found six dimensions that clearly reflected the aforementioned spectra: negative affectivity (internalizing), psychoticism (thought disorder), disconstraint (externalizing), aggressiveness (antagonism), introversion (detachment), and somatization (somatoform) (McNulty & Overstreet, 2014; Sellbom, in press). The most comprehensive investigation of interview-based data reported four spectra: internalizing, thought disorder, traditional externalizing, and pathological introversion/detachment, which was defined by unassertiveness, dependence, and social anxiety (Markon, 2010a). This study did not recover antagonism and somatoform dimensions likely because few relevant markers were included (e.g., only one variable for the latter).

The six spectra in the HiTOP model. Altogether, six spectra were included in the HiTOP model: internalizing (or negative affectivity), thought disorder (or psychoticism), disinhibited externalizing, antagonistic externalizing, detachment, and somatoform (see Figure 2). Given direct correspondence between internalizing and negative affectivity as well as between thought disorder and psychoticism, each of these pairs is represented by one dimension. Externalizing behavior has two personality counterparts: disinhibition and antagonism. Disinhibition is particularly prominent in substance-related disorders. Antagonism is especially significant in narcissistic, histrionic, paranoid, and borderline PDs. Both disinhibition and antagonism contribute to antisocial behavior, aggression, ODD, ADHD, and IED (Gomez & Corr, 2014; Herzhoff & Tackett, 2016; Jones, Miller, & Lynam, 2011; Kotov et al., 2011; Wright & Simms,

2015). Importantly, all of these conditions comprise a broader super-spectrum, and recent research has elevated the "externalizing" label to denote this general dimension (Krueger & Markon, 2014). Consequently, the two spectra may be best named disinhibited externalizing (what traditionally was called externalizing) and antagonistic externalizing (traditional antagonism).

As noted earlier, detachment appears to be limited to personality pathology. Detachment is well documented in personality pathology, but it is less clear whether it fully accounts for the pathological introversion factor reported by Markon (2010a) and Røysamb et al. (2011); thus, social phobia and dysthymic disorder were retained within the internalizing spectrum rather than assigned to detachment. Finally, somatoform is a novel dimension that emerged clearly only in three studies (Kotov et al., 2011; McNulty & Overstreet, 2014; Sellbom, in press), whereas three other studies placed somatoform conditions on the internalizing spectrum. However, of the latter studies, one had too few markers to model the somatoform factor (Markon, 2010a), another found a somatoform factor but was not designed to test whether it was a subfactor of internalizing or a separate spectrum (Simms, Prisciandaro, Krueger, & Goldberg, 2012), and the third produced mixed results (Krueger et al., 2003). Thus, the somatoform spectrum has been included in the HiTOP model on a provisional basis.

Of note, the disorder/syndrome level of Figure 2 is described in terms of *DSM-5* diagnoses. This is done simply for convenience of communication. The objective of the HiTOP consortium is to construct the nosology from empirically derived building blocks such as homogeneous components, maladaptive traits, and dimensional syndromes, not by merely rearranging *DSM-5* disorders. Fortunately, studies of empirical homogeneous dimensions have supported these spectra (Achenbach & Rescorla, 2001, 2003; Kotov et al., 2015; Kramer et al.,

2008; Lahey, 2004; Markon, 2010a; McNulty & Overstreet, 2014; Sellbom, in press; Sellbom, Ben-Porath, & Bagby, 2008).

Validation of spectra

Although structural evidence can help to identify new diagnostic entities, such constructs require further validation against criteria important for clinical practice and research. The APA Diagnostic Spectra Study Group reviewed evidence for five potential psychopathology spectra with regard to 11 validators that may be shared by, or at least be similar across, disorders within a spectrum: genetic risk factors, familial risk factors, environmental risk factors, neural substrates, biomarkers, temperamental antecedents, cognitive or emotional processing abnormalities, illness course, treatment response, symptoms, and high comorbidity within the spectrum (Andrews, Goldberg et al., 2009). This meta-structure project examined internalizing/emotional (consisting of *DSM-IV* anxiety, depressive and somatoform disorders, and neurasthenia), disinhibited externalizing (conduct, antisocial personality, and substance-related disorders), thought disorder/psychotic (schizophrenia spectrum disorders, schizotypal PD, and bipolar I disorder), neurocognitive (delirium, dementias, amnestic and other cognitive disorders), and neurodevelopmental (learning, motor skills and communication disorders, pervasive developmental disorders, and mental retardation) spectra. Overall, data for validators included in the reviews generally supported the coherence of these five spectra (Andrews, Pine et al., 2009; Carpenter et al., 2009; Goldberg, Krueger, Andrews, & Hobbs, 2009; Krueger & South, 2009; Sachdev et al., 2009), and more recent reviews have continued to support these conclusions (Beauchaine & McNulty, 2013; Eaton, Rodriguez-Seijas, Carragher, & Krueger, 2015; Nelson et al., 2013).

However, this evidence has some caveats. In particular, bipolar disorder showed clear differences as well as similarities with both schizophrenia and emotional disorders (Goldberg, Andrews, & Hobbs, 2009). Also, validation data were relatively sparse for somatoform disorders and neurasthenia, and thus it was difficult to validate their distinctness from—or similarity to—the internalizing spectrum. Conversely, neurocognitive and neurodevelopmental clusters have not been examined in structural studies, but validity evidence was considered sufficient for inclusion of these entities as classes in the *DSM-5*. Overall, the HiTOP model covers the majority of psychopathology, even though it is not yet comprehensive.

Hierarchy above Spectra

The HiTOP spectra are positively correlated (Achenbach & Rescorla, 2003; Kotov et al., 2011; Krueger & Markon, 2006; Markon, 2010a; Røysamb et al., 2011), and these associations are consistent with the existence of a general psychopathology factor or *p* factor (Caspi et al., 2014; Lahey et al., 2011, 2012). This possibility has been supported by studies that evaluated a bifactor model, which is composed of a general dimension defined by all forms of psychopathology and specific dimensions defined by smaller groups of disorders (Caspi et al., 2014; Lahey et al., 2011, 2012, 2015; Laceulle, Vollebergh, & Ormel, 2015; Olino et al., 2014).

Another approach recognizes that a range of factors can be deliniated to represent different levels of the hierarchy, and most, if not all, levels are meaningful (Goldberg, 2006; Markon et al., 2005). All levels can be mapped jointly using Goldberg's (2006) method, which consists of a series of factor analyses with progressively greater numbers of dimensions, thus describing each level of the hierarchy. This approach has been applied to PDs (Morey, Krueger, & Skodol, 2013; Wright et al., 2012; Wright & Simms, 2014) and clinical disorders (Farmer et

al., 2013; H. Kim & Eaton, 2015). It supported the presence of a *p* factor but also suggested that multiple meaningful structures of different generality exist between the six spectra and a *p* factor.

These higher levels of the structure are particularly useful for describing the most salient general features of patients and for studying common pathological processes. The six spectra provide a more detailed and specific picture of psychopathology and the following discussion focuses on them. Importantly, the hierarchy can be refined further by extension downward to smaller groups of disorders and ultimately groups of symptoms (Figure 2). We discuss this extension next.

Subfactors

More focused factor analyses have identified narrower dimensions within the spectra. Two subfactors have been found frequently within the internalizing spectrum: a distress cluster (consisting of MDD, dysthymic disorder, generalized anxiety disorder [GAD], and posttraumatic stress disorder [PTSD]) and a fear cluster (panic disorder, phobic disorders, OCD, and separation anxiety disorder [SAD]) (Beesdo-baum et al., 2009; Eaton et al., 2013; Keyes et al., 2013; Krueger & Markon, 2006; Lahey et al., 2008; Miller et al., 2008, 2012; Vollebergh et al., 2001). There is accumulating support for a third subfactor, eating pathology, defined by bulimia nervosa, anorexia nervosa, and binge-eating disorder (Forbush et al., 2010; Forbush & Watson, 2013). Evidence also has emerged for a fourth subfactor, sexual problems, defined by symptoms of sexual dysfunctions, such as difficulties with sexual desire, arousal, orgasm, and pain (Forbes, Baillie, & Schniering, 2016a, 2016b; Figure 2). One caveat to this organization is that panic disorder appears to have features of both fear and distress, and has been found to load on both subfactors (Greene & Eaton, 2016; H. Kim & Eaton, 2015; Kotov et al., 2015; Nelson et al., 2015; Watson et al., 2012; Wright et al., 2013). Also, OCD is a relatively weak member of the

fear cluster and shows some overlap with the thought disorder dimension (Caspi et al., 2014; Chmielewski & Watson, 2008; Kotov et al., 2015; Watson, Wu, & Cutshall, 2004). Finally, the fear and distress dimensions tend to be highly correlated and some studies were unable to model them separately (Kessler et al., 2011; Kotov et al., 2011; Markon, 2010; Røysamb et al., 2011; Wright & Simms, 2015).

The disinhibited and antagonistic externalizing spectra encompass at least two subfactors: an antisocial behavior dimension defined by ODD, ADHD, and sometimes conduct disorder, and a substance abuse dimension defined by alcohol and drug use problems (Blanco et al., 2015; Castellanos-Ryan et al., 2014; Farmer, Seeley, Kosty, & Lewinsohn, 2009; Verona, Javdani, & Sprague, 2011; Figure 2). Similar factors also have been observed in analyses of dimensional markers of the disinhibited externalizing spectrum: one resembles antisocial behavior (defined by aggression, lack of empathy, excitement seeking, rebelliousness, dishonesty, etc.) and the other resembles substance abuse (problematic substance use, theft, irresponsibility, and impulsivity) (Krueger, Markon, Patrick, Benning, & Kramer, 2007; Patrick, Kramer et al., 2013). The antisocial dimension blends elements of disinhibition and antagonism, and thus has been linked to both spectra. The substance abuse dimension is more purely disinhibited. It currently is unclear whether the unique content of antagonism (narcissistic, histrionic, paranoid, and borderline personality pathology) defines a coherent subfactor or only indicates, along with antisocial behavior, the broader antagonistic externalizing spectrum.

The other spectra have received less attention, and it is unknown whether they also include subdimensions. It is likely that additional subfactors will be identified with time, explicating the intermediate level of the structure between individual disorders and spectra.

There is accumulating evidence that mania, and bipolar disorders generally, are related to the internalizing spectrum (Blanco et al., 2015; Forbush & Watson, 2013; Keyes et al., 2013; Kotov et al., 2015; Watson, 2005; Watson et al., 2012). However, mania also has been linked with the thought disorder spectrum (Caspi et al., 2014; Keyes et al., 2013; Kotov, Ruggero, et al., 2011). At present, it is unclear whether the mania subfactor belongs to the internalizing or thought disorder spectrum or blends features of both (Figure 2).

Importantly, such interstitial constructs (i.e., dimensions associated with multiple spectra) are allowed, indeed expected, within the HiTOP model. Even when operationalized by empirically derived homogeneous measures, some dimensions show prominent cross-loadings in factor analyses (e.g., Markon, 2010a; Kotov et al., 2015; Wright & Simms, 2014).

Symptom structure

Lower levels of the hierarchy, namely, dimensional syndromes and the components within them, are much less studied in adult populations than the spectra. The primary reason for this is that complete symptom-level data are rarely available. The vast majority of studies of adults analyzed diagnostic interviews, which typically have used skip logic. Skip logic enables the efficient assessment of dichotomous diagnoses but results in incomplete symptom data for respondents who do not endorse the stem question. Several studies have sought to address this limitation by analyzing symptom ratings not affected by skip-outs (Markon, 2010a; Simms et al., 2012; Wright et al., 2013). However, pools of analyzable symptoms were limited as these measures were not designed for structural research. Hence, nosologists have begun developing new instruments that provide comprehensive symptom coverage of various psychopathology domains and do not use skip logic. Structural analyses of the resulting measures have elucidated symptom components and maladaptive traits within a variety of disorders (Figure 3). This is

described in the following section. Because we have greater confidence in the placement of components/traits on spectra than syndromes, Figure 3 is organized around spectra.

Measurement of HiTOP Dimensions

Although an omnibus measure of the HiTOP model has not yet been created, a number of existing instruments can assess component/trait, syndrome, subfactor, and spectrum levels of the model. Examples of such measures are described in this section and summarized in Table 1 (further details are given in eTable 1). We selected instruments that provide maximal coverage of the model. We required them to cover either (a) at least two levels of the hierarchy in multiple spectra or (b) at least three levels of the hierarchy in a single spectrum. The only exception was the thought disorder spectrum, for which two companion measures were needed to describe three levels of the hierarchy.

The Achenbach System of Empirically Based Assessment (ASEBA; Achenbach & Rescorla, 2001) was initially constructed to assess a wide range of symptoms in youth using self-, parent-, and teacher-ratings. Factor analyses consistently identified eight dimensional syndromes, along with the internalizing and disinhibited externalizing spectra. ASEBA also includes a total problems index that mirrors the *p* factor. Subsequently, self- and informant-report versions of the instrument were developed both for adults (Achenbach & Rescorla, 2003) and the elderly (Achenbach, Newhouse, & Rescorla, 2004). Similarly, the Child and Adolescent Psychopathology Scale (CAPS; Lahey et al. 2004) is an interview—conducted with the youth or caretaker—that assesses without skip-outs *DSM-IV* and *ICD-10* symptoms common in children. Factor analyses of the CAPS found the internalizing and disinhibited externalizing spectra as well as nine syndromes. Five of these syndromes mapped clearly onto conduct disorder, ODD, social anxiety disorder, OCD, and SAD; specific phobia and agoraphobia together formed a sixth

dimension, MDD and GAD together formed a seventh, and inattention and hyperactivity-impulsivity emerged as separate syndromes (Lahey et al., 2004, 2008).

The Externalizing Spectrum Inventory (ESI; Krueger et al., 2007) is a self-report measure designed for adults. The ESI assesses the disinhibited externalizing spectrum including substance abuse and antisocial behavior subfactors. Structural analyses (Krueger et al., 2007; Patrick, Kramer et al., 2013) revealed 23 specific dimensions (symptom components and traits). Although the ESI does not explicitly measure syndromes, it includes two scales each for alcohol, marijuana, and other drug use/abuse, allowing modeling of these three syndromes. The ESI also includes multiple scales relevant to externalizing disorders as conceptualized in the *DSM* (e.g., Antisocial PD). Sunderland et al. (in press) recently developed a computerized adaptive version of the ESI.

The Inventory of Depression and Anxiety Symptoms (IDAS; Watson et al., 2007, 2012) is a self-report instrument designed to assess symptom components within internalizing. This measure was designed for adults but also has shown satisfactory psychometric properties in adolescents. Structural analyses of the IDAS item pool found six symptom dimensions within MDD, three within OCD, two within both PTSD and mania, and single factors related to social phobia, panic disorder, and claustrophobia (Watson et al., 2007, 2012). The Interview for Mood and Anxiety Symptoms (IMAS; Kotov et al., 2015) targets the same domain as the IDAS using an interview format. Structural analyses of the IMAS identified syndromes that mirror GAD, PTSD, panic disorder, social phobia, agoraphobia, specific phobia, OCD, major depressive episode, and manic episode (Kotov et al., 2015). Moreover, multiple dimensions were found within nearly all syndromes, amounting to 31 homogeneous components in total (Weinberg, Kotov, & Proudfit, 2015). Parallel IMAS and IDAS scales show strong covergence (Ruggero et

al., 2014; Watson et al., 2007, 2012). At the higher-order level, both instruments can operationalize distress, fear, and mania subfactors.

No comprehensive dimensional measure exists for the full thought disorder spectrum, but there is a long history of such measures for psychosis. Most notably, the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984) and the Scale for the Assessment of Negative Symptoms (SANS; Andreasen, 1983) jointly provide a detailed and thorough evaluation of schizophrenia symptoms. Factor analyses of these measures have identified three symptom dimensions: reality distortion, disorganization, and negative (Andreasen et al., 1995; Blanchard & Cohen, 2006; Grube et al., 1998). New research indicates that it is informative to subdivide negative symptoms into inexpressivity and avolition-apathy (Kotov et al., 2016; Kring et al., 2013; Strauss et al., 2012, 2013), resulting in four homogenous components overall. Novel measures, such as the Clinical Assessment Interview for Negative Symptoms (CAINS; Kring et al., 2013) and the Brief Negative Symptom Scale (BNSS; Kirkpatrick et al., 2011), have been developed to provide reliable assessment of the two dimensions of negative symptoms, but are more narrow in scope than the SANS. Other studies have subdivided schizophrenia symptoms even further (Peralta, Moreno-Izco, Calvo-Barrena, & Cuesta, 2013), but the four-dimensional structure currently is best established. Together, the SAPS and SANS can be used to model these four components, two syndromes (positive and negative), and the overarching thought disorder spectrum. Other models have gone beyond symptoms, including such characteristics as interpersonal functioning, insight, and cognitive performance (Keefe & Fenton, 2007; Strauss, Carpenter, & Bartko, 1974), which led to a dimensional rating system for psychosis included in Section III of *DSM-5* (Barch et al., 2013). Not all of these characteristics have been considered in studies of the thought disorder spectrum, but psychotic symptoms, negative symptoms, and

social withdrawal as well as their personality counterparts have all been found to fall within this spectrum (Kotov, Chang, et al., 2011; Keyes et al., 2013; Kotov, Ruggero, et al., 2011; Markon, 2010a; Wright et al., 2013).

Several dimensional instruments have been developed to assess personality pathology. Seminal measures include the PSY-5 scales of the MMPI-2/MMPI-2-RF (Harkness et al., 2014; Harkness & McNulty, 1994; tapping the five higher-order dimensions), the SNAP-2 (Calabrese, Rudick, Simms, & Clark, 2012; Clark et al., 2014; four higher-order and 15 lower-order traits), and the DAPP-BQ (Livesley & Jackson, 2009; four higher-order and 18 lower-order traits). The PID-5 (Krueger et al., 2012) was designed to cover traits included in these models and in other models of personality pathology. Factor analyses of the PID-5's 25 lower-order traits identified 5 higher-order dimensions, which became the trait structure for the alternative PD model included in Section III of the *DSM-5*. The CAT-PD (Simms et al., 2011) was developed independently of the PID-5 with the same goal. It models virtually all PID-5 dimensions and includes 9 additional lower-order traits. Consistency between the PID-5 and CAT-PD is remarkable (Crego & Widiger, 2016; Wright & Simms, 2014), which highlights the feasibility of creating a consensus regarding lower-order psychopathology dimensions. Furthermore, the FFF (Rojas & Widiger, 2014) is a brief measure that assesses maladaptive variants of the traits included in the five-factor model of personality; namely 5 higher-order domains and 30 specific facets. The FFM-PD (Widiger et al., 2012) provides assessment of the same 5 domains but coordinates assessment of maladaptive facets with the *DSM-IV-TR* personality disorders, resulting in 99 scales. Overall, these measures can be used both to assess personality features of the five established spectra and to model specific maladaptive traits.

A truly omnibus measure would include both traits and symptom components. The Personality Assessment Inventory (PAI; Morey, 1991, 2007) was developed with this goal in mind for a set of clinical problems. Overall, the PAI measures 15 broader syndromes and 30 more specific components/traits: Eight clinical syndromes (somatic complaints, anxiety, anxiety-related disorders, depression, mania, paranoia, schizophrenia, and aggression) containing three components each, three clinical syndromes without specified components (suicidality, alcohol problems, and drug problems), two personality syndromes (borderline features and antisocial features) containing three subtraits each, and two personality syndromes without subtraits (dominance/submission and warmth/coldness modeled after the interpersonal circumplex; Leary, 1996). Structural analyses revealed that the PAI captures the five spectra assessed by the PID-5 (Hopwood et al., 2013). Moreover, the somatic complaints scale may be an acceptable measure of the somatoform spectrum, thus potentially providing full coverage of the HiTOP; however, this possibility has not been formally tested.

The Minnesota Multiphasic Personality Inventory-2 Restructured Form (MMPI-2-RF; Ben-Porath & Tellegen, 2008) also encompasses both traits and symptoms. Structural analyses of the MMPI-2 item pool (Butcher, Dahlstrom, Graham, Tellegen, & Kaemmer, 1989) produced scales tapping three higher-order dimensions (emotional, behavioral, and thought dysfunction), the aforementioned five personality pathology dimensions (PSY-5), nine syndromes (demoralization, somatic complaints, low positive emotions, cynicism, antisocial behavior, ideas of persecution, dysfunctional negative emotions, aberrant experiences, and hypomanic activation), and 23 components/traits. A comparison with the PID-5 suggests that emotional dysfunction combines internalizing and detachment spectra, behavioral dysfunction reflects general externalizing (i.e., it combines disinhibited and antagonistic elements), and thought

dysfunction maps onto thought disorder (Anderson et al., 2015). It appears that these MMPI-2-RF scales measure more general dimensions than the PID-5, whereas the PSY-5 parallels the five PID-5 domains (Anderson et al., 2013). Moreover, there are many similarities between lower-order dimensions of the MMPI-2-RF and PID-5 (Anderson et al., 2015). The MMPI-2-RF Somatic Complaints scale appears to tap the somatoform spectrum (e.g., McNulty & Overstreet, 2014; Sellbom, in press).

Our review has focused on broader measures that assess major sections of HiTOP. We also note that many reliable and valid instruments have been developed to assess narrower aspects of the nosology. These include measures assessing multiple symptom or trait dimensions within PTSD (Gootzeit, Markon, & Watson, 2015; Weathers, Litz, Herman, Huska, & Keane, 1993), OCD (Foa et al., 2002; Watson & Wu, 2005), specific phobia (Cutshall & Watson, 2004), eating pathology (Forbush et al., 2013), sleep disorders (Koffel, 2011), somatoform disorders (Longley, Watson, & Noyes, 2005), and schizophrenia (PANSS; Kay, Flszbein, & Opfer, 1987).

Further studies are needed to evaluate fully how the dimensions of these instruments relate to each other. Ongoing research is working to explicate all four levels of the quantiative classification from symptoms to syndromes to subfactors to spectra. This effort has produced both a replicated core structure (Figure 2) and new measures to operationalize it (Table 1).

Several of these measures have informant-report versions. Further development and routine use of informant instruments remains a high priority for future research. Of note, measures listed in Table 1 have been normed in various populations and can be implemented in clinical practice to describe the HiTOP profile of a given patient. However, an integrated assessment of HiTOP dimensions does not yet exist, and its development (along with a comprehensive normative database for main demographic strata) is a major goal of our group. In

the interim, batteries composed of several measures found in Table 1 can provide a comprehensive assessment. Finally, further research will be needed to identify ranges of scores to inform specific clinical decisions (e.g., initiation of pharmacotherapy, hospital admission).

Measures of HiTOP's lower-order dimensions are not perfectly aligned, and multiple alternative sets of maladaptive traits and homogeneous components exist. We chose lower-order dimensions based on an instrument that provides the most comprehensive coverage of a given spectrum, augmenting it with additional dimensions that are clearly missing (Figure 3). Specifically, internalizing dimensions were drawn from non-redundant scales of the IMAS, IDAS, PID-5, PAI, and FFM-PD (Crego & Widiger, 2016; Hopwood et al., 2013; Watson et al., 2012). Mania dimensions were drawn from the IMAS. Thought disorder dimensions were drawn from the SANS, SAPS, PID-5, and CAT-PD (Kotov et al., 2016; Wright & Simms, 2014). Disinhibited externalizing dimensions were drawn from the ESI and supplemented from the FFM-PD (Crego & Widiger, 2016). Antagonistic externalizing dimensions were drawn from the ESI and supplemented from the PID-5, CAT-PD, PAI, and FFM-PD (Crego & Widiger, 2016; Hopwood et al., 2013). Detachment dimensions were drawn from non-redundant scales of the PID-5 and MMPI-2-RF (Anderson et al., 2015). Somatoform dimensions were drawn from non-redundant scales of the PAI and MMPI-2-RF.

Research and Clinical Applications of a Quantitative Classification

An emerging quantitative classification ultimately may provide a more useful guide for researchers and clinicians than traditional categorical taxonomies. In this section, we review evidence that the HiTOP can effectively summarize information on shared genetic vulnerabilities, environmental risk factors, neurobiological abnormalities, illness course, functional impairment, and treatment efficacy for many forms of psychopathology.

First, the factor analytically derived spectra appear to reflect common genetic vulnerabilities. Twin studies have found that shared genetic factors underlie each of the six spectra (Arcos-Burgos, Velez, Solomon, & Muenke, 2012; Cosgrove et al., 2011; Hicks, Foster, Iacono, & McGue, 2013; Hicks, Krueger, Iacono, McGue, & Patrick, 2004; Kato et al., 2009; Kendler et al., 2011; Kendler et al., 2006; Kendler et al., 2003; Lichtenstein et al., 2009; Thornton, Welch, Munn-Chernoff, Lichtenstein, & Bulik, in press; Torgensen et al., 2008). Moreover, studies that span multiple spectra observed genetic dimensions that mirror the HiTOP spectra (Hink et al., 2013; Kendler et al., 2011; Kendler, Prescott, Myers, & Neale, 2003; Wolf et al., 2010). Additionally, intergenerational transmission of internalizing and externalizing disorders were found to be almost completely mediated by these spectra rather than being disorder-specific (Hicks, Foster, Iacono, & McGue, 2013; Kendler, Davis, & Kessler, 1997; Starr, Conway, Hammen, & Brennan, 2014). Thus, an explicit focus on these spectra can aid research on genetic etiologies of psychopathology. In fact, some molecular genetic studies have begun targeting these spectra to identify genetic contributions to psychopathology (Cardno & Owen, 2014; Dick et al., 2008; Hettema et al., 2008).

Second, common environmental risk factors were found to shape the spectra. Twin studies revealed that common environmental influences underpin many of the spectra alongside shared genetic influences discussed earlier (Bornovalova, Hicks, Iacono, & McGue, 2010; Kato et al., 2009; Krueger et al., 2002; Mosing et al., 2009; Torgensen et al., 2008). Moreover, research is beginning to identify specific environmental factors that contribute to the spectra (Caspi et al., 2014; Lahey et al., 2012). For instance, discrimination and childhood maltreatment are linked much more closely to spectra than to unique aspects of disorders (Eaton, 2014; Keyes et al., 2012; Rodriguez-Seijas, Stohl, Hasin, & Eaton, 2015; Vachon, Krueger, Rogosch, &

Cicchetti, 2015). The HiTOP model may be able to clarify and simplify voluminous literatures on risk factors for individual disorders, thus advancing etiologic models for a broad range of psychopathology.

Third, neurobiological abnormalities may show clearer and stronger links to the HiTOP dimensions than to traditional diagnostic categories (Hyman, 2010), because empirically derived dimensions offer greater informational value and specificity. For example, Nelson, Perlman, Hajcak, Klein, and Kotov (2015) related neural measures of emotional reactivity to the distress and fear subfactors, and found that the former was associated with blunted neural reactivity to all stimuli, whereas the latter was associated with enhanced reactivity to negative stimuli specifically. Weinberg et al. (2015) evaluated links between neural markers of error-processing and symptom components of the internalizing domain, and found that enhanced neural reactivity to errors was specifically associated with the checking component across various disorders. Such studies promise to align the phenotypic and neural architectures of psychopathology more closely.

Fourth, quantitative dimensions can effectively capture illness course. Categorical outcomes such as remission and recovery are controversial as they lack natural benchmarks. In contrast, dimensions can characterize the outcome at every level of psychopathology from severe impairment to subthreshold symptoms to full recovery. Also, categorical descriptions of outcome may either over- or underestimate the degree of change due to their qualitative nature, whereas the dimensional approach can represent change with greater precision. Indeed, the spectra have shown impressive temporal stability over long retest intervals spanning as much as 9 years (Eaton et al., 2013; Eaton, Krueger, & Oltmanns, 2011; Fergusson, Horwood, & Boden, 2006; Krueger et al., 2003; Vollebergh et al., 2001), with the dimensional approach revealing stability

of psychopathology that was partially obscured by categorical descriptions in many previous studies.

Fifth, HiTOP dimensions may account for functional impairment associated with psychopathology with greater parsimony and precision than traditional taxonomies, providing better targets for interventions to improve quality of life in psychiatric populations. Indeed, initial studies found that the spectra, rather than variance specific to individual diagnoses, account for dysfunction: (a) the internalizing dimension fully explained impairment associated with depressive and anxiety symptoms (Markon, 2010b), (b) the internalizing spectrum captured the majority of suicidality, treatment seeking, and disability present in emotional disorders (Sunderland & Slade, 2015), (c) the thought disorder dimension fully accounted for impairment associated with psychosis (Jonas & Markon, 2013; Kotov, Chang et al., 2011), and (d) the internalizing and disinhibited externalizing spectra jointly fully explained related marital distress (South, Krueger, & Iacono, 2011). Other studies did not compare spectra to diagnoses, but they documented robust associations of the internalizing, disinhibited externalizing, and thought disorder spectra with a wide range of criteria, including academic difficulties in kindergarten through high school, unemployment, relationship problems (e.g., divorce or never marrying), use of public assistance, suicide attempts, violence convictions, hospitalizations, and a range of systemic medical conditions (Caspi et al., 2014; Eaton et al., 2013; Lahey et al., 2012, 2015; Slade, 2007).

Sixth, a quantitative organization may explain and predict the efficacy of treatments, including limited diagnostic specificity of treatment response observed for many interventions. For example, selective serotonin reuptake inhibitors originally were regarded as antidepressants but subsequently were found to be efficacious in treating anxiety disorders and are increasingly

used in eating disorders (Martinez, Marangell, & Martinez, 2008). Transdiagnostic cognitive behavioral therapy and even disorder-specific psychotherapies have been found to reduce symptoms of various internalizing conditions (Farchione et al., 2012; Newby et al., 2013; Rodriguez-Seijas, Eaton, & Krueger, 2015). Thus, response to selective serotonin reuptake inhibitors and cognitive behavioral therapy appears to be a shared feature of internalizing disorders. This supports the contention that a quantitative organization can inform intervention research better than traditional taxonomies, which scatter these disorders across several classes and do not provide clear guidance regarding commonalities and differences in treatment response among them. Furthermore, psychiatrists frequently prescribe medication for presenting symptoms, irrespective of diagnosis (Bostic & Rho, 2006; Hermes, Sernyak, & Rosenheck, 2013; Mohamed & Rosenheck, 2008). A quantitative nosology fits naturally with this practice by identifying transdiagnostic and psychometrically sound symptom dimensions comprehensively, and by providing a systematic list of symptom targets for pharmacotherapy.

Overall, the new classification is consistent with patterns of similarities and differences among disorders observed on various diagnostic validators, as discussed earlier. Literature reviews suggest that the internalizing (emotional), disinhibited externalizing, and thought disorder (psychosis) spectra can effectively summarize and convey information on risk factors, etiology, pathophysiology, phenomenology, illness course, and treatment response, thus greatly improving the utility of diagnosis in psychiatry (Andrews et al., 2009).

It is important to highlight that although a quantitative classification is preliminary in many respects, it is nevertheless sufficiently ready for initial implementation. It can be assessed economically with questionnaires completed by either patients or informants, and interview measures are also available. Patients and/or informants can complete questionnaires in a waiting

room or from home, so that the clinician has basic diagnostic information even before seeing them. These instruments can improve standardization of the intake process, especially compared to unstructured interviews. Brief measures sensitive to current status are also available and can be used to track patients' progress between visits. This is particularly true of inventories, such as the IDAS, that assess current (past 2 weeks) symptoms. Indeed, the MMPI-2-RF, PAI, and especially the ASEBA provide good working models for implementing the HiTOP system in clinical settings.

Conclusions

Existing research on the HiTOP classification is still limited in several ways. Relatively few studies have analyzed more than two spectra at a time. Consequently, some uncertainties about the overall structure remain. Data are particularly limited for the somatoform and detachment dimensions. Subfactors have been explicated only for the internalizing and disinhibited externalizing spectra. Evidence is fairly preliminary for the component/trait level of the HiTOP, as it is uncertain whether the proposed sets of dimensions are comprehensive and free from redundancies. Syndromes are the least understood level, as only a few omnibus measures have been analyzed starting with symptoms up to syndromes (Achenbach, Newhouse, & Rescorla, 2004; Achenbach & Rescorla, 2001, 2003; Kotov et al., 2015; Lahey et al., 2004, 2008). The majority of research has relied on *DSM/ICD* diagnoses as proxies for syndromes. Moreover, categorical diagnoses may distort findings, a limitation that applies to many existing studies. Fortunately, various conclusions of these studies have been confirmed with homogeneous dimensional measures (traits and symptom components). However, not all findings have been examined using such dimensions, and some may need to be revised. Future studies should administer various component-level instruments along with a comprehensive

traditional diagnostic assessment to large patient samples, thereby elucidating the structure that spans all levels of the hierarchy and all known spectra.

Also, additional research is needed to incorporate psychopathology not currently included in the HiTOP and to confirm the placement of disorders/syndromes that have received limited attention in structural studies. Moreover, structural studies mostly focused on snapshots of symptoms and syndromes without modeling illness course. Future studies should consider additional markers such as age of onset, illness duration, and chronicity, and incorporate them in the HiTOP explicitly. Furthermore, some structural investigations examined lifetime disorders, whereas others analyzed past-year incidence, and still others considered only current psychopathology. Findings appear to be robust across timeframes, but this issue can be investigated even more systematically. Cross-cultural generalizability is well established for the internalizing and disinhibited externalizing spectra (Kessler et al., 2011; Krueger et al., 2003) and several empirical syndromes within them (Ivanova et al., 2007a, 2007b, 2015a, 2015b), but other HiTOP dimensions need to be similarly studied.

Much of existing research has focused on adults, and generalizability of identified dimensions to youth and older adults is not assured. Studies of children and adolescents also have documented the internalizing and disinhibited externalizing spectra, with some evidence suggesting a separate thought disorder dimension (Achenbach, 1966; Achenbach & Rescorla, 2001, 2003; Achenbach et al., 1991; Laceulle et al., 2015; Lahey et al., 2004, 2008, 2011, 2015; Olino et al., 2014; Tackett et al., 2013). Also, some evidence suggests that certain psychopathology dimensions are already present during preschool and do not change appreciably in subsequent years (Sterba et al., 2007, 2011). Nevertheless, we can expect that some elements of the structure will vary with age (Waszczuk, Zavos, Gregory, & Eley, 2014), and the HiTOP

model needs to be tested across age groups. Another limitation is that existing studies focused on main effects of psychopathology dimensions on validators, although interactions between these dimensions can affect validators (Kotov et al., 2013). Future research needs to consider both the main effects of the HiTOP dimensions and the interactions among them. Also, the vast majority of studies relied on participants' report, although informant reports are crucial for accurate assessment, especially in evaluating the thought disorder and externalizing domains (Achenbach, Krukowski, Dumenci, & Ivanoca, 2005). Integration of informant data is an important consideration for the design of future studies. Finally, structural evidence is essentially descriptive, and validation studies are necessary to understand the nature and utility of the identified phenotypes. Systematic efforts to organize validity data have been largely limited to spectra, and such research is needed at other levels of the hierarchy.

Despite these limitations, many aspects of the model have been investigated extensively and consistence evidence has emerged. For instance, the internalizing, disinhibited externalizing, and thought disorder spectra are now firmly established. Objectives of the present paper are to describe major known elements of a quantitative nosology rather than provide a complete system. Our consortium will continue to review evidence and address gaps in the HiTOP as more data become available.

Overall, a quantitative nosology has made impressive strides in recent years. On the level of spectra, it provides broad, although not yet complete, coverage of psychopathology that includes nearly all common conditions. Homogenous components of disorders have been proposed and corresponding measures have been developed for nearly all domains (e.g., scales of ASEBA, PID5, ESI, IDAS, IMAS and other instruments). These psychometrically sound dimensional markers now can be used to investigate higher levels of the classification and extend

findings that were based on dichotomous diagnoses. The last few years have seen a tremendous growth and maturation of this field. If this trajectory continues, we can expect the HiTOP system to provide a viable alternative to the *DSM* and *ICD* in the near future. A quantitative classification is no longer a distant goal. Clinicians and researchers can apply many aspects of the HiTOP model even now, using concepts and measures already available. These early adopters would benefit from a diagnostic formulation that is more flexible, informative, and accurate than traditional diagnoses. In fact, child psychiatry has been using many elements of a quantitative model for over three decades with considerable success. For example, this model has demonstrated cross-cultural robustness unmatched by traditional nosologies (Ivanova et al., 2007a; Rescorla et al., 2013). A quantitative nosology will substantially improve current research and clinical practice, as it will largely ameliorate problems of heterogeneity, comorbidity, arbitrary boundaries, and diagnostic instability.

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Author Note

Ideas presented in this manuscript have been disseminated previously via conference presentations made by members of the consortium and postings on consortium's website: http://medicine.stonybrookmedicine.edu/HITOP

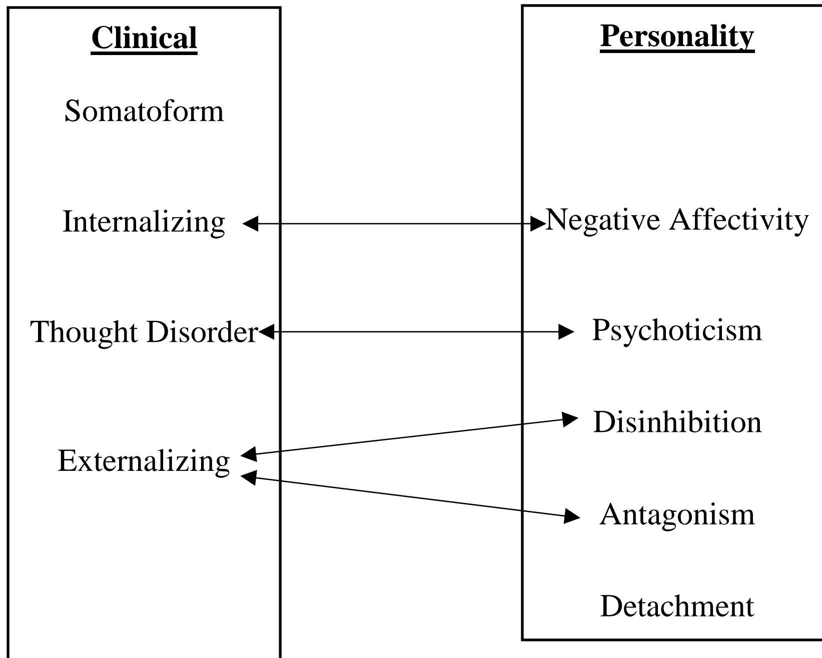
Table 1. Examples of broad-based dimensional measures of the Hierarchical Taxonomy of Psychopathology

Instrument	Reference	Format	Coverage
Achenbach System of Empirically Based Assessment (ASEBA) for youth	Achenbach & Rescorla (2001)	Parent-report, teacher-report, self-report	Internalizing & Disinhibited Externalizing spectra, 8 syndromes
Achenbach System of Empirically Based Assessment (ASEBA) for adults and elderly	Achenbach & Rescorla (2003) Achenbach, Newhouse, & Rescorla (2004)	Informant-report, self-report	Internalizing & Disinhibited Externalizing spectra, 8 syndromes
Child and Adolescent Psychopathology Scale (CAPS)	Lahey et al. (2008)	Interview	Internalizing & Disinhibited Externalizing spectra, 6 syndromes
Externalizing Spectrum Inventory (ESI)	Krueger et al. (2007)	Self-report	Disinhibited Externalizing spectrum, 2 subfactors, 23 traits/components
Inventory for Depression and Anxiety Symptoms (IDAS)	Watson et al. (2012)	Self-report	Internalizing spectrum, 3 subfactors, 18 components
Interview for Mood and Anxiety Symptoms (IMAS)	Kotov et al. (2015)	Interview	Internalizing spectrum, 3 subfactors, 10 syndromes, 32 components
Scale for the Assessment of Negative Symptoms (SANS) and Scale for the Assessment of Positive Symptoms (SAPS)	Andreasen (1983, 1984)	Interview	Thought Disorder spectrum, 2 syndromes, 4 components
Schedule for Nonadaptive and Adaptive Personality, 2nd edition (SNAP-2)	Clark et al. (2014)	Self- and informant report	4 domains, 15 traits
Personality Inventory for DSM-5 (PID-5)	Krueger et al. (2012)	Self and informant-report	5 domains, 25 traits
Five Factor Form (FFF)	Rojas & Widiger (2014)	Self- and therapist report	5 domains, 30 traits

Five-Factor Model Personality Disorder Scales	Widiger, Lynam, Miller, & Oltmanns (2012)	Self-report	5 domains, 99 traits
Computerized Adaptive Test of Personality Disorder (CAT-PD)	Simms et al. (2011)	Self-report	5 domains, 33 traits
Dimensional assessment of personality pathology—Basic Questionnaire (BQ)	Livesley & Jackson (2009)	Self-report	4 domains, 18 traits
Personality Assessment Inventory (PAI)	Morey (2007)	Self-report	5 spectra, 15 syndromes, 30 components/traits
Minnesota Multiphasic Personality Inventory-2 Restructured Form (MMPI-2-RF)/ Personality Psychopathology—Five (PSY–5)	Ben-Porath & Tellegen (2008), Harkness et al. (2014)	Self-report	3 higher-order dimensions, 5 personality domains, 9 syndromes, 23 components/traits

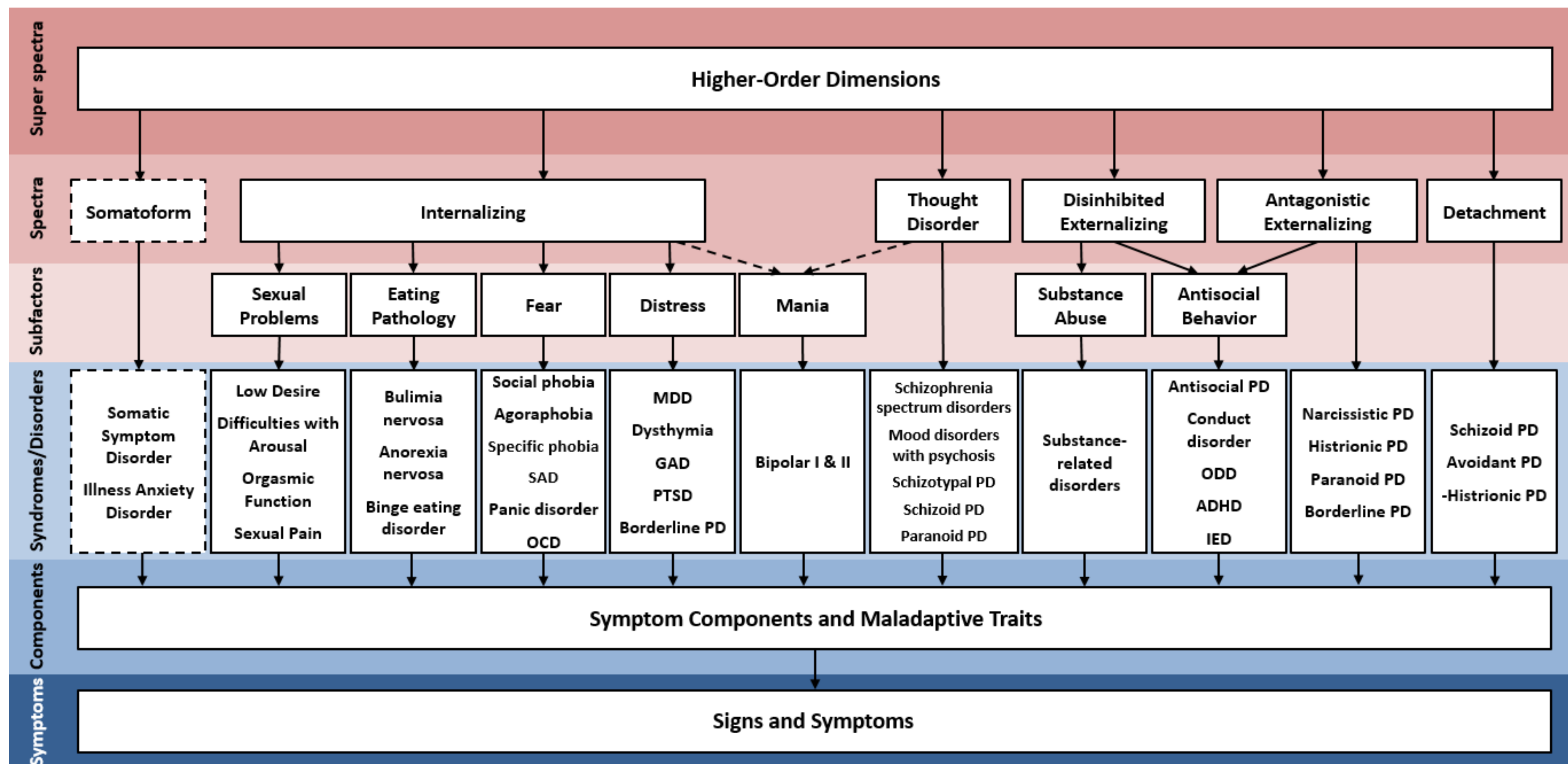
Note: Measures were included if they either assessed (a) at least two levels of the hierarchy in multiple spectra or (b) at least three levels of the hierarchy in a single spectrum. The SANS and SAPS are companion measures, and both are needed to describe three levels of the hierarchy.

Figure 1. Cross-walk between major dimensions of clinical and personality disorders



Note: The diagram is derived from studies discussed in the "Spectra" section. Solid arrows indicate paired dimensions that cut across clinical and personality domains.

Figure 2. Spectra of the Hierarchical Taxonomy of Psychopathology



Note: Dashed lines indicate elements of the model that were included on provisional basis and require more study. Disorders with most prominent cross-loadings are listed in multiple places. Minus sign indicates negative association between histrionic personality and detachment spectrum.

Figure 3. Proposed symptom components and maladaptive traits organized by spectrum

INTERNALIZING

Distress components
Dysphoria
Lassitude
Anhedonia
Insomnia
Suicidality
Agitation
Retardation
Appetite loss
Appetite gain
(low) Well-being
GAD Symptoms
Re-experiencing
Avoidance
Hyperarousal
Numbing
Dissociation
Irritability
Pure obsessions

Fear components
Interactive anxiety
Performance anxiety
Public places
Enclosed spaces
Animal phobia
Situational phobia
Blood-injection-injury
Physiological panic
Psychological panic
Cleaning
Rituals
Checking

Traits
Anxiousness
Emotional lability
Hostility
Perseveration
(low) Restricted affectivity
Separation insecurity
Submissiveness
Identity problems
Negative relationships
Fragility
Ineptitude
(low) Invulnerability

THOUGHT DISORDER

Components
Psychotic
Disorganized
Inexpressivity
Avolition

Traits
Eccentricity
Cognitive/perceptual dysregulation
Unusual beliefs and experiences
Fantasy proneness

Mania components
Euphoric activation
Hyperactive cognition
Reckless overconfidence

DISINHIBITED EXTERNALIZING

Components
Alcohol use
Alcohol problems
Marijuana use
Marijuana problems
Drug use
Drug problems

Traits
Problematic impulsivity
Irresponsibility
Theft
Distractibility
Risk taking
(low) Rigid perfectionism
(low) Ruminative deliberation
(low) Workaholism

ANTAGONISTIC EXTERNALIZING

Traits
Attention seeking
Callousness
Deceitfulness
Grandiosity
Manipulativeness
Rudeness
Egocentricity
Dominance
Flirtatiousness
(low) Timorousness

Antisocial behavior

Components
Physical aggression
Destructive aggression
Relational aggression
Fraud

Traits
Impatient urgency
(low) Planful control
(low) Dependability
Alienation
Boredom proneness
Blame externalization
(low) Honesty
Rebelliousness
(low) Empathy
Excitement seeking

DETACHMENT

Traits
Anhedonia
Depressivity
Intimacy avoidance
Suspiciousness
Withdrawal
Interpersonal passivity
Disaffiliativeness
(low)Attention seeking

SOMATOFORM

Components
Conversion
Somatization
Malaise
Head Pain
Gastrointestinal
Cognitive

Note: Selection of these dimensions is described in the "Measurement of HiTOP Dimensions" section. Mania components are listed in a separate box because they cross-load between internalizing and thought disorder spectra; likewise antisocial behavior dimensions are listed separately because they cross-load between disinhibited externalizing and antagonistic externalizing spectra.