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Categories and Dimensions Advancing Psychological Science Through the Study of Latent Structure

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Abstract

The distinction between categories and dimensions has important consequences for basic and applied science in many areas of psychological research. Decisions as to whether individuals should be assigned to groups or located along one or more continua often are based on personal preferences or discipline-specific measurement traditions, which can lead to the creation, use, or reification of spurious categories or dimensions. Methods for evaluating the latent structure of psychological constructs, using powerful and informative tests between competing models, are available. Rather than choosing on a priori grounds, investigators can perform structural research to evaluate the strength and consistency with which results tease apart categorical and dimensional models. Here, we review why researchers should make this distinction empirically, briefly discuss methods available for doing so, and describe the breadth of areas ripe for exploiting the largely untapped potential of structural research.

Keywords

latent structure; categories; dimensions; taxometric method; mixture models

One of the challenges of any scientific discipline is to determine which of its variables are categorical (i.e., qualitative differences exist between groups of people or objects) and which of its variables are dimensional (i.e., people or objects differ quantitatively along one or more continua). Although a variable may be conceptualized and measured categorically or dimensionally, this need not correspond to its true latent structure. For example, clinical interviews that are used to diagnose mental disorders according to published criteria yield categorical data reflecting the presence or absence of each disorder. In contrast, many self-report or clinician-rated scales yield dimensional data representing the severity of symptoms or disorders. In either case, the dichotomous or dimensional nature of the data may be an artifact of the measurement approach, masking the underlying reality (see Fig. 1).

Fortunately, methodological tools are available to evaluate empirically whether a variable is categorical or dimensional at a latent level, regardless of how it has been conceptualized or measured. In this article, we focus on whether two classes can be distinguished at a latent boundary. We review a number of data-analytic techniques for addressing questions about structure and consider how they can be used to advance basic and applied psychological science.

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WHY DISTINGUISH CATEGORIES AND DIMENSIONS?

Although preferences for categorical versus dimensional representations are explicitly or implicitly endorsed by many researchers, there is considerable value to determining structure empirically rather than relying on untested preferences. First, latent structure constrains plausible causal theories. Consider causal models of psychopathology. Whereas dimensional variation may arise from the sum of many small influences (e.g., additive genetic and environmental factors), categorical variation requires a mechanism such as a dichotomous causal factor (e.g., a single gene or traumatic event necessary and sufficient to produce disorder), cumulative or interactive effects (e.g., neither a genetic predisposition nor a high stress level is necessary to produce disorder, but they are jointly sufficient to do so), or threshold effects (e.g., individuals can cope with stress to a point, but beyond this level stress triggers disorder). For example, Meehl's (1990) etiological theory of schizophrenia posits a genetic liability only among *schizotypes*, who are hypothesized to make up approximately 10% of the general population. Because not all schizotypes develop full-blown schizophrenia, Meehl devised a taxometric method to test for the existence of the hypothesized schizotype category of susceptible individuals. Many taxometric studies have detected such a category (with the predicted base rate), corroborating this aspect of Meehl's causal model.

Second, structural knowledge can inform classification. The basic problem in classification concerns whether cases should be assigned to groups or located along dimensions. Many psychologists, coming from the tradition of psychometric theory, argue that the next edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM) should move toward dimensional classification, at least for the personality disorders (e.g., Widiger & Trull, 2007). In contrast, many psychiatrists, coming from a medical tradition, conceptualize mental disorders as entities that are either present or absent. Rather than presuming a certain latent structure, latent structure should be treated as an empirical question to be resolved for each disorder. A substantial and growing body of structural research has found that some mental disorders and psychopathological constructs are categorically distinct from normality (e.g., eating disorders, endogenous depression), whereas others are not (e.g., borderline personality disorder, pathological worry; for a review, see Ruscio, Haslam, & Ruscio, 2006, pp. 266–267), suggesting that a one-size-fits-all classification may be less appropriate than one informed by structural results.

Third, structural knowledge can help refine the criteria that are used to classify. Locating the threshold between classes with better accuracy can yield improved estimates of prevalence and improved estimates of the sensitivity and specificity of each diagnostic sign or symptom. In a recent study of major depressive disorder (MDD), taxometric analysis was used to identify a categorical boundary and to estimate the validity with which each symptom predicts assignment to the depressed class (Ruscio, Zimmerman, McGlinchey, Chelminski, & Young, 2007). The finding that some symptoms (e.g., fatigue) are more valid predictors than are others (e.g., sleep disturbance) suggests that diagnostic accuracy might be improved by giving greater weight to symptoms that more powerfully distinguish depressed individuals from nondepressed individuals, rather than assigning equal weight to all symptoms, as is the current practice. Even for dimensional variables, pragmatic considerations often necessitate the use of decision thresholds. For such variables, the absence of a latent discontinuity to guide classification requires the use of practically useful thresholds (e.g., an inflection point in the risk function). For example, physicians may prescribe medication to lower blood pressure when it exceeds a threshold indicative of high risk.

Fourth, knowledge of structure can inform assessment. In the absence of such knowledge, a common approach is to develop measures that broadly assess a wide range of trait levels and, if necessary, apply thresholds to classify cases into groups. However, for any set of items, one cannot maximize the efficiency with which individuals are classified into groups *and* the precision with which they are located along dimensions (Ruscio & Ruscio, 2002). Achieving the former goal requires focusing discriminating power near the boundary separating groups, whereas achieving the latter goal requires spreading discriminating power to reliably assess the full range of trait levels. For example, structural studies have found a categorical difference between respondents scoring at high and low levels on the Minnesota Multiphasic Personality Inventory (MMPI) infrequency scale *F* and the MMPI infrequency scale *F*(*p*); these scales are used to detect symptom overreporting (e.g., Strong, Glassmire, Frederick, & Greene, 2006). This finding suggests the utility of developing techniques to assign individuals to groups—those who do and those who do not overreport their symptoms—rather than assessing overreporting as a dimensional construct. The standard practice of dimensional assessment makes structural assumptions that may not be justified and that can sacrifice measurement precision when categorical boundaries do exist.

Fifth, structure has implications for research design and statistical analysis. Group-comparison designs are most appropriate for categorical variables. For dimensional variables, correlational designs enhance the ability to discover nonlinear relationships between dimensional scores and dependent variables of interest. The practice of dichotomizing continuous score distributions is justified when (a) the structure of a variable is categorical and (b) the selected threshold validly classifies cases into groups. If both conditions are not satisfied, the use of dichotomous scores risks discarding important information, reducing the precision of the data and consequently the statistical power of analyses (MacCallum, Zhang, Preacher, & Rucker, 2002). For example, we (Ruscio & Ruscio, 2002) found no evidence that popular thresholds for dichotomizing the Beck Depression Inventory (BDI) correspond to latent categorical boundaries, suggesting that the common research practice of comparing depressed and nondepressed groups formed on the basis of BDI scores be reconsidered.

Sixth and finally, the use of analogue samples (e.g., college students with subclinical symptom levels) is premised on a dimensional structure and may be more acceptable if there are no categorical differences within these samples. If, instead, there is a categorical difference between more and less severe cases, analogue samples containing few members of the category of interest (e.g., a particular mental disorder) may be inadequate for testing substantive hypotheses about that variable.

HOW TO DISTINGUISH CATEGORIES AND DIMENSIONS

Perhaps the most familiar approach to the study of potentially categorical structures is cluster analysis (Everitt, Landau, & Leese, 2001). The prototypical cluster analysis begins by calculating the similarity of all cases in a data set to one another, then fusing cases into clusters one at a time based on their similarities. The difficulty lies in determining when to stop and the number of clusters to retain. To date, no statistical rule recovering the actual number of clusters with sufficient accuracy to recommend its general use has been developed. In particular, existing rules seem to be especially poor at distinguishing a one-cluster solution, in which there are only dimensional (no categorical) divisions between cases, from a two-cluster solution, in which there are two groups separated by a single categorical boundary.

Recently developed approaches to distinguishing categorical and dimensional latent structure include finite mixture models (McLachlan & Peel, 2001), item response theory

(IRT), mixture models (De Boeck et al., 2005), and factor mixture models (Lubke & Neale, 2006). These techniques provide quantitative indices that can be used to select among competing models that vary in their categorical and/or dimensional components. The statistical bases of these models and their accompanying fit indices, as well as the diversity and complexity of models that can be tested, represent advances that hold great potential for the study of latent structure. Computer simulation studies are needed to evaluate the absolute and relative performance of these techniques in distinguishing various latent structures under realistic research conditions (which do not always satisfy strict modeling assumptions) in order to guide researchers in their selection and implementation.

Although there may be intuitive appeal to techniques that compare multiple complex models using all potentially relevant variables in each analysis, this approach may have some drawbacks. Consider, for example, the study of MDD and its putative subtypes (e.g., endogenous vs. reactive). Rather than using all of the available data to test the fit of competing models that vary in their complexity, it may be more effective to test each proposed categorical boundary using a subset of variables appropriate for that boundary (see Ruscio et al., 2006, pp. 51–54). One might begin by testing for a categorical distinction between individuals who do and do not meet diagnostic criteria for MDD using measures of each symptom. If an MDD type exists, subsequent analyses could test for categorical distinctions between endogenous and reactive subtypes using measures of pertinent signs or symptoms.

The taxometric method developed by Meehl (1995) and his colleagues (e.g., Waller & Meehl, 1998) follows a focused analytic approach. It is designed to test for the presence of a single categorical boundary using variables carefully chosen for that purpose. The method includes several nonredundant analytic procedures and emphasizes evaluating the consistency of results to enhance confidence in structural conclusions. Although much remains to be learned about how data conditions influence results—and there are lively debates about how to implement the method most effectively (Cole, 2004; Ruscio & Marcus, 2007)—accumulating evidence suggests that categorical and dimensional structure can be distinguished with impressive validity under a broad range of data conditions when taxometric output is interpreted according to empirically grounded guidelines (Ruscio, 2007; Ruscio et al., 2006; Ruscio, Ruscio, & Meron, 2007). It is unclear whether some or all of the modeling techniques mentioned earlier rival or surpass the utility of taxometric analyses, because research has not yet examined their relative performance.

FUTURE DIRECTIONS

Despite a recent surge of interest in distinguishing categories from dimensions, a vast expanse of psychological science remains to be studied using structural research. Within the realm of psychopathology, many mental disorders await investigation, and the structure of important signs, symptoms, and vulnerability factors has seldom been studied. Perhaps the greatest untapped potential for structural investigation, however, lies outside psychopathology. Although typologies abound in psychological theory and practice, the structure of these variables is rarely tested. For example, Dweck, Hong, and Chiu (1993) distinguished between individuals who view personal traits as fixed (entity theorists) and those who view traits as malleable (incremental theorists) and asserted a categorical structure that has not been evaluated empirically. Likewise, the many typologies of learning styles that have been developed by educational psychologists may or may not correspond to truly different groups of learners. By contrast, some variables that are conceptualized as a matter of degree may not be strictly dimensional at the latent level. For example, one of the paragons of dimensionality—cognitive ability—may possess categorical features, as there are a number of genetic abnormalities that result in low intelligence. Consequently, there may be dimensional variation within the normal and upper ranges, but distinct categories of individuals within the lower range. Investigators in virtually all areas of behavioral science work with constructs that were introduced as typologies or dimensions but whose true structure remains uncertain.

One example that illustrates the diversity of domains that could benefit from structural research is the Myers-Briggs Type Indicator (MBTI), an instrument that is routinely used for such diverse purposes as self-understanding, vocational guidance, and college roommate assignment. The MBTI remains extremely popular despite the poor reliability and validity of its typological classifications (Pittenger, 2005). One ongoing controversy concerns the premise that personality should be divided into 16 types by dichotomizing each of the four dimensional scores calculated from the MBTI (extraversion–introversion, sensing–intuiting, thinking–feeling, judging–perceiving). If structural research suggests that one or more of these scores should not be dichotomized, retaining the dimension(s) could improve the psychometric properties of the instrument.

A second example concerns the management of deceptive responses to noncognitive personnel selection tools, such as biographical inventories. Applicants may distort their responses in order to secure employment. How should firms handle this problem? Should the goal be to identify a group of applicants whose test results can be discarded as invalid? Or should the goal be to statistically adjust each applicant's test results for some degree of distortion? Studying the latent structure of individual differences in response distortion would provide an empirical basis for selecting between these approaches. Similar problems in the realm of clinical assessment have led to taxometric studies (e.g., Strong et al., 2006) that suggest that symptom overreporting may be a categorical phenomenon.

Although structural research usually treats the individual person as the unit of analysis, this treatment is not required by the methodology. In place of the person, one could substitute the family unit, peer group, social network, culture, or any other informative unit of analysis. For example, some have argued that the DSM classification of mental disorders pays insufficient attention to family influences. This omission may stem, in part, from the absence of an empirically based classification of relevant family variables. Structural research using large numbers of families may help to identify systematic ways in which families differ categorically from one another. Alternatively, if research suggests that the key variables are dimensional, attention would shift from superficially categorical variables to those dimensions that hold important consequences for mental health practice.

CONCLUSIONS

Studies of latent structure can address a deceptively simple question with critical implications for psychological science: Which psychological variables are categorical, and which are dimensional? The available data-analytic procedures continue to evolve and are being evaluated, compared, and refined through ongoing investigation. The theoretical and practical importance of studying latent structure suggests that this area of investigation is likely to continue moving into the psychological mainstream. We have attempted to highlight a few of the many avenues that we believe are ripe for investigation. We hope this will encourage future investigators to consider how they might use available methods for studying latent structure to advance their scientific goals.

Recommended Reading

Bauer, D.J., & Curran, P.J. (2004). The integration of continuous and discrete latent variable models: Potential problems and promising opportunities. *Psychological*

Methods, *9*, 3–29. A methodologically rigorous examination of challenges that can arise when using latent-variable models that contain categorical and dimensional elements.

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Meehl, P.E. (1995). (See References). A seminal paper on the use of the taxometric method to improve the classification of psychopathological constructs.

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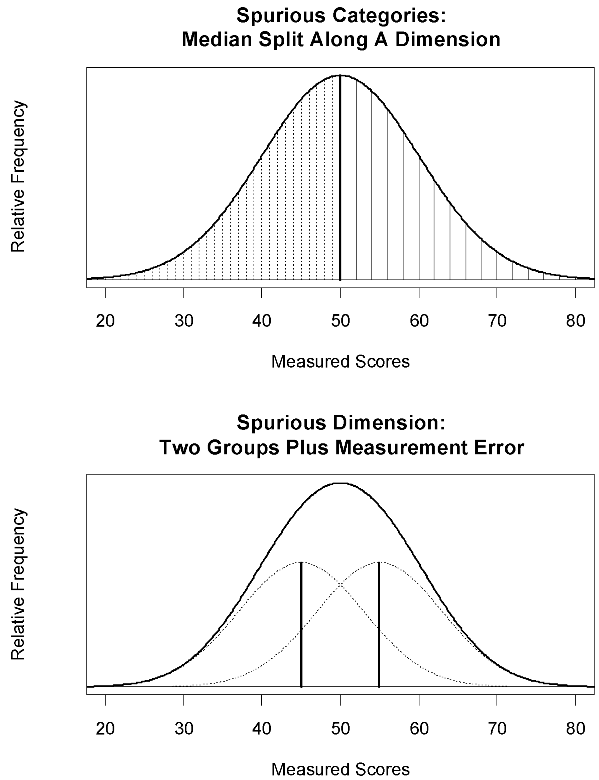

Fig. 1.
Graphs showing spurious categories (top) and a spurious dimension (bottom). In the top panel, a normally distributed dimensional variable is dichotomized at the median to split cases into “high” (solid line fill) and “low” (dotted line fill) groups, which discards variation in true scores along the underlying dimension. In the bottom panel, the overlapping score distributions for members of two groups (dotted curves) are the result of measurement error around the true scores for each group (dark vertical lines); in the full sample, the mixture of groups produces a unimodal distribution of observed scores (solid curve) that could be mistaken for evidence of a dimensional variable.