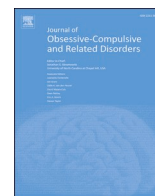




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The latent structure of olfactory reference disorder symptoms: A taxometric analysis

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ABSTRACT

Olfactory reference disorder (ORD), a newly included disorder in the ICD-11, is characterized by 'pathological' concerns about emitting body odor. While research is emerging on the construct, no study has directly examined the boundary between ORD and normal body odor concerns. That is, should ORD be considered as categorical in nature versus a more dimensional construct? As such, the current study explored the extent to which ORD symptoms correspond to a distinct category or dimension in a mixed university student and community sample ($n = 757$). Three indicators, derived from the Yale-Brown Obsessive Compulsive Scale Modified for Olfactory Reference Syndrome, were submitted to three independent taxometric procedures: MAMBAC, MAXEIG, and L-Mode. Two of three procedures showed that the latent structure of ORD is dimensional rather than categorical. The comparison curve fit index profile method yielded dimensional structure. Results suggested that researchers and clinical practitioners would be well-advised to conceptualize, assess, and treat ORD symptoms in a dimensional way.

1. Introduction

Olfactory reference disorder (ORD), a pathological condition characterized by persistent preoccupation that one emits a foul or offensive odor, is now included in the *International Classification of Diseases and Related Health Problems* (ICD-11; World Health Organization, 2018). The most frequently reported odors of concern in ORD originate from the mouth, skin and genitals, though non-bodily smells such as rot and metal are occasionally reported (Feusner, Phillips, & Stein, 2010; Greenberg, Shaw, Reuman, Schwartz, & Wilhelm, 2016). For most people, regardless of ORD status, concern about body odor is a common human experience. Body odor is associated with embarrassment, shame, and even distress in social situations. Affected individuals also worry that their body odor may suggest poor health or hygiene. Thus, a fundamental question is how to distinguish ORD from normal body odor concerns; in other words, does ORD represent a latent category that is distinct from normal experiences, or does it exist along a continuum of body odor concerns.

This kind of boundary question has long been discussed in the mental health field. Major diagnostic classification systems like the *Diagnostic*

and Statistical Manual of Mental Disorders (DSM) and ICD hold a categorical classification of psychopathology for pragmatic reasons, while mounting empirical data indicate a dimensional nature of psychological disorders (Krueger et al., 2018; Krueger & Piasecki, 2002; Wright et al., 2013). On the one hand, ORD could be a discrete disorder. A diagnosis of ORD involves excessive obsessive concerns about having body odor, and maladaptive responses to odor concerns such as rituals to mask or eliminate the perceived smell, resulting in significant distress, and/or impaired social, family or work/school functioning (Stein et al., 2016; World Health Organization, 2018). Only a minority of individuals who have concern about their body smell actually meet criteria for a diagnosis of ORD (Feusner et al., 2010). Accordingly, a cutoff score has been used in the assessment of ORD to differentiate the potential ORD 'patients' from individuals without the 'disorder' (Phillips & Menard, 2011).

On the other hand, ORD may be better conceptualized as the upper extreme of a bodily smell concern continuum. There are several reasons to support this. First, ORD may be influenced by additive effects of multiple influences, including internal factors such as perfectionistic tendencies and attribution of failure or rejection to body odor, and

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external factors such as media and sociocultural pressures about body odor (Begum & McKenna, 2011; Greenberg et al., 2016). Second, higher levels of functional impairment are moderately associated with higher ORD symptom severity (Greenberg et al., 2016; Zhou, Schneider, Cepeda, & Storch, 2018). Third, closely related disorders, such as social anxiety and obsessive-compulsive disorders (Feusner et al., 2010), are conceptualized and assessed as dimensional than categorical in nature (Abramowitz et al., 2014; Haslam, Williams, Kyrios, McKay, & Taylor, 2005; Ruscio, 2010; Shankman et al., 2018).

Although these data support the conceptualization of ORD as dimensional, there remains the possibility that ORD is categorically different from common or less severe body odor concerns. The continuity of scores on a measure does not necessarily imply a continuous latent structure (Ruscio, Haslam, & Ruscio, 2006). One statistical technique especially suited for evaluating the underlying structure of ORD is Meehl's taxometric method (Meehl, 1995, 2004). This approach tests the relative fit of empirical data to categorical and dimensional solutions of latent structure. In recent years, this technique has been increasingly used to assess the underlying latent structure of psychopathology (Haslam, Holland, & Kuppens, 2012; Walters, Duncan, & Mitchell-Perez, 2007; Wright et al., 2013).

Examining the latent structure of ORD has important implications regarding conceptualization, assessment and intervention of ORD (Ruscio et al., 2006). If ORD is dimensional in nature, classification of individuals as 'disordered' or 'normal' should be done with caution, and measurement of ORD should cover the whole spectrum of symptom severity and capture meaningful variability. Individuals with lesser severity could benefit from treatment to prevent symptom escalation and reduce symptoms. Alternatively, if the construct of ORD is categorical in nature, individuals in the 'pathological' taxon may be qualitatively distinguished from 'normal' people who are concerned with body odor. Assessment of ORD should employ items best discriminate the two groups, and optimal cutoff point should be identified to detect the ORD taxon. Accordingly, treatments would be mainly designed for the 'pathological' group.

The current study represents an initial effort to examine the latent structure of ORD in a mixed college student and community mixed sample using taxometric analysis. The study utilized the Yale-Brown Obsessive Compulsive Scale Modified for Olfactory Reference Syndrome (ORS-YBOCS, Greenberg et al., 2016), as it provides an opportunity for latent structure analysis. Specifically, the ORS-YBOCS captures different aspects of ORD as conceptualized by the ICD-11, including obsessions, related compulsive rituals and insight (Stein et al., 2016; World Health Organization, 2018), and the items are scored on a quasi-continuum scale, which meet the requirement of taxometric analysis (Walters & Ruscio, 2009).

2. Method

2.1. Participants and procedure

Participants in the present study were Chinese college students and community adults. Some participants ($n_1 = 403$) were recruited from three universities in Shanghai, China. Participants took about 30 min to complete a paper-and-pencil battery of questionnaires (including ORS-YBOCS) in May 2017. Participants received \$3 USD as remuneration. More detailed information about the recruitment procedure was described by Zhou et al. (2018).

The other participants ($n_2 = 286$ college students, $n_3 = 68$ community adults) were recruited through an online data portal from late May to early June 2020. The online portal provides connections between social science researchers and potential participants. Through this online portal, college students and adults in the community can find and voluntarily participate in social science studies or services based on their interest after reviewing the project title and description. For the current online study, named "mental health survey", participants completed the

ORS-YBOCS and demographic questions about age, sex, ethnicity and student status (college student or not). Participants took between 1 to 4 min to complete the survey and received \$0.5 USD as remuneration.

For all subjects, inclusion criterion were: (1) aged 18 years or above; (2) no missing values on ORS-YBOCS. The study received ethical approval at Shanghai Normal University. All participants provided written or online informed consent. Online and paper data were combined since prior research indicates that the effect of the mode of administration is generally small (Carini, Hayek, Kuh, Kennedy, & Ouimet, 2003). The final sample consisted of 757 participants (44.5% male), with a mean age of 21.2 years (range = 18–52 years, $SD = 1.12$). A majority of subjects were Han (94%); other participants represented eleven minorities, including Tujia, Hmong, among others. The mean ORS-YBOCS score was 9.53 ($SD = 7.29$; range = 0 to 31). Compared with the ORD sample in Greenberg et al. (2016), the mean score of the current sample suggested mild severity of ORD symptoms.

2.2. Measures

ORS-YBOCS (Greenberg et al., 2016). The ORS-YBOCS is a twelve-item self-report measure assessing current (over the past week) severity of ORD symptoms. It is modified from the BDD-YBOCS (Phillips, Hollander, Rasmussen, & Aronowitz, 1997), which is an adaptation of the Y-BOCS (Goodman et al., 1989). The ORS-YBOCS consists of two subscales: obsessions which includes five items rating preoccupation with body odor, compulsions which includes five items assessing the ritual behaviors in response to the body odor concerns. Additionally, one item assesses insight regarding bodily odor, and another rates avoidance of activities due to ORD. Each item is scored using a five-point scale from 0 to 4 with varying scale anchors (e.g. none to extreme). All items are summed to yield a total score (range = 0 to 48), with higher scores indicating more severe ORD symptoms. A total score of 20 or higher was used as the cutoff score to determine the presence of ORD (called taxon and $n = 78$ in the present study); this is based on the threshold of the BDD-YBOCS (Greenberg et al., 2016). The reliability measured by Cronbach's alpha for the ORD obsessions subscale was 0.72, for ORD compulsions subscale was 0.83, and for the total scale was 0.87.

2.3. Taxometric analyses

Indicator selection. Multiple indicators covering distinct aspects of the ORD construct are required for taxometric analysis. In keeping with the features of ORD in the ICD-11, four indicators can be derived from ORS-YBOCS: ORD obsessions, ORD compulsions, insight and avoidance. Among the four indicators, ORD obsessions and compulsions are composite indicators which sum the five items from ORD obsessions subscales and compulsions subscales respectively; insight and avoidance indicators are derived from the individual items. For the consideration of minimizing indicator redundancy and nuisance covariance, the mean indicator correlations should be higher in the full sample than within each of the hypothetical taxon and complement group (Ruscio et al., 2006). In addition, the indicators should separate the putative taxon and complement groups at Cohen's $d \geq 1.25$ (Meehl, 1995).

Taxometric method. A core feature of the taxometric method is the emphasis on consistent findings across different tests to gain confidence in the reliability of results. In the current study, consistency was evaluated across three commonly used, mathematically non-redundant taxometric procedures: MAMBAC (Mean Above Minus Below a Cut; Meehl & Yonce, 1994; Meehl & Yonce, 1996), MAXEIG (MAXimum EIGenvalue; Waller & Meehl, 1998), and L-Mode (Latent Mode; Waller & Meehl, 1998).

MAMBAC aims to search for an optimal cutting score, which maximally separates complement from taxon. If the score can be found, this suggests a categorical structure; if not, it suggests a dimensional structure. The MAMBAC procedure examines mean differences of each indicator (output) in turn above and below sliding cuts on the sum of the

remaining indicators (input). We calculated 50 evenly-spaced cuts sorted along the input variable beginning 25 cases from either extreme. Ten internal replications were calculated to reduce the bias influence of cutting between same score cases. The differences are graphed into curves. A peaked curve suggests taxonic structure, while a relatively flat or dish shaped curve suggests dimensional structure. The MAXEIG procedure is used when there are two or more indicators, using all the indicators simultaneously. Along the input indicator, the full sample is divided into a range of overlapping subsamples (called windows); all of the remaining indicators (called output variables) are factor analyzed and the first eigenvalue is plotted for each window. Each analysis uses 50 windows that overlap 0.9 with adjacent subsamples, and 10 internal replications. Similar to MAMBAC curves, a peaked curve indicates a taxonic solution, while an irregular, flat, or concave curves indicates a dimensional solution. The L-Mode procedure needs multiple indicators. The L-Mode uses factor analysis to calculate scores on the first principal component and plot the distribution of scores. A unimodal curve suggests the dimensional structure, while a bimodal curve suggests the taxonic structure.

In all three independent taxometric procedures, simulated taxonic and dimensional comparison data sets are generated. Each simulated comparison data match the distributional (e.g., sample size, mean, standard deviation, indicator skewness) and correlational (e.g. inter-indicator correlations) parameters of the empirical research data, only differing in latent structure (i.e., taxonic or dimensional). Empirical research data and simulated comparison data sets are submitted to the same analyses. The results are interpreted by visually comparing curves yielded by the research data to that of the simulated taxonic and dimensional data.

Comparison can be aided by a comparison curve fit index (CCFI), which is an objective and accurate measure of relative fit between the research data and the simulated taxonic and dimensional data (Ruscio, Ruscio, & Meron, 2007). The CCFI ranges from 0 (strongest indication of dimensional structure) to 1 (strongest indication of taxonic structure), with 0.50 suggesting equal support of both taxonic and dimensional structure. CCFI values between 0.45 and 0.55 indicated ambiguous results that should be interpreted with caution (Walters & Ruscio, 2013).

Besides the standard methods stated above, the CCFI profile analysis, i.e., rerun the MAMBAC, MAXEIG and L-Mode procedures, with 39 different simulated base rates from 0.025 to 0.975 in increments of 0.025, is also used to help to distinguish taxonic and dimensional structure. The CCFI estimate is a less biased index and helps to reduce the subjectivity in interpreting the results; furthermore, more precise taxon base rate estimation can be obtained when the latent structure is categorical (see Ruscio, Carney, Dever, Pliskin, & Wang, 2018). The CCFI profile yields aggregate CCFI indices, which are the weighted means of all 39 CCFI values from each of the MAMBAC, MAXEIG and L-Mode procedures in the profile. Recent simulation studies on taxometric techniques showed that mean CCFIs (mean CCFI of the standard MAMBAC, MAXEIG and L-Mode procedures, see Ruscio, Walters, Marcus, & Kaczetow, 2010) and CCFI profiles obtained a high accuracy (over 98%) in latent structure classification.

Standard taxometric analysis and the CCFI profile (Ruscio et al., 2018) were conducted in the RTaxometrics package (Ruscio & Wang, 2017), following the default settings in the program. The base rate was set using the prevalence calculating from our sample. Although our base rate of 10.3% is adequate according to the rule of thumb (the generally required base rate is $P = .10$, Ruscio et al., 2006), our adoption of the more accurate techniques, i.e., mean CCFIs and CCFI profiles, which are especially useful for challenging data condition and exploratory taxometric examination (Ruscio et al., 2010, 2018), might offset the potential concerns.

3. Results

3.1. Data check

For taxometric analysis, data should meet several minimal requirements. First, more than 300 participants are needed (Meehl, 1995); the present sample consisted of 757 participants. Second, indicators should have at least 4 ordered categories to reach the quasi-continuum scale level; The two summed indicators have 10-12 ordered categories, and the two individual items have 5 ordered categories. The present data met these requirements.

3.2. Indicator suitability analyses

The indicators of ORD obsessions, ORD compulsions, insight and avoidance were first examined to determine if they were suitable for taxometric analysis. As shown in Table 1, all indicators but avoidance were distributed normally (Tabachnick & Fidell, 2007). The standard differences (Cohen's d s) between the putative taxon (≥ 20 on the ORS-YBOCS, $n = 78$) and complement (< 20 on the ORS-YBOCS, $n = 679$) groups were: 2.15 for ORD obsessions, 2.40 for ORD compulsions, 0.69 for insight, and 1.67 for avoidance. Only the insight indicator failed to meet the Cohen's $d \geq 1.25$ standard. Therefore, the insight item was removed from taxometric analysis.

The mean correlation between the three indicators in the full sample was 0.67, which was considerably higher than that in the taxon group ($r = -0.15$) and complement group ($r = 0.57$). Taken together, the properties of these three indicators (ORD obsessions, ORD compulsions and avoidance) were favorable for taxometric analysis.

3.3. The latent structure of ORD

We first ran the standard taxometric analysis, using the cut-off score of 20 on ORS-YBOCS, that is, base rate of 10.3%. As shown in Fig. 1, the shape of the averaged MAMBAC, MAXEIG curves were flat and had no obvious peak, and the averaged L-Mode curves was unimodal. The research curves appeared more similar to the dimensional curves. Visually, the results of the three procedures consistently supported a dimensional structure of ORD.

The objective CCFI indices of the MAMBAC, MAXEIG and L-Mode procedures, based on the empirical base rate of 10.3%, are presented in Table 2. The mean CCFI was 0.465. Although the CCFI value of MAMBAC and total mean CCFI fell into the ambiguous [0.45, 0.55] interval, the CCFI indices of the MAXEIG and L-Mode procedures were lower than 0.50, providing additional support of the dimensional interpretation (Ruscio et al., 2007).

We then ran CCFI profile analysis. As shown in Fig. 2, for the various base rates, most of the CCFI values were below 0.50, suggesting a dimensional latent structure. The CCFI profile yielded an average base rate of 7.4%, close to the empirical base rate of 10.3% in the present sample. Using a base rate of 7.4% to generate the taxonic comparison data, the average CCFI was 0.42, well below 0.45, indicating a dimensional structure. Besides, the aggregate CCFIs of the three procedures were all below 0.45, based on the average base rate of 7.4%, pointed to a

Table 1
Descriptive statistics of indicators ($n = 757$).

	Mean	SD	Skewness	Kurtosis	d
ORD obsessions	3.61	2.91	0.54	-0.46	2.15
ORD compulsions	3.92	3.82	0.72	-0.58	2.40
Insight	1.02	1.17	0.96	-0.04	0.69
Avoidance	0.99	0.94	1.16	1.44	1.67

Note. SD = standard deviation; d = Cohen's d , the standard differences between the putative taxon group (scored 20 or higher on the ORS-YBOCS) and complement group (scored less than 20 on the ORS-YBOCS).

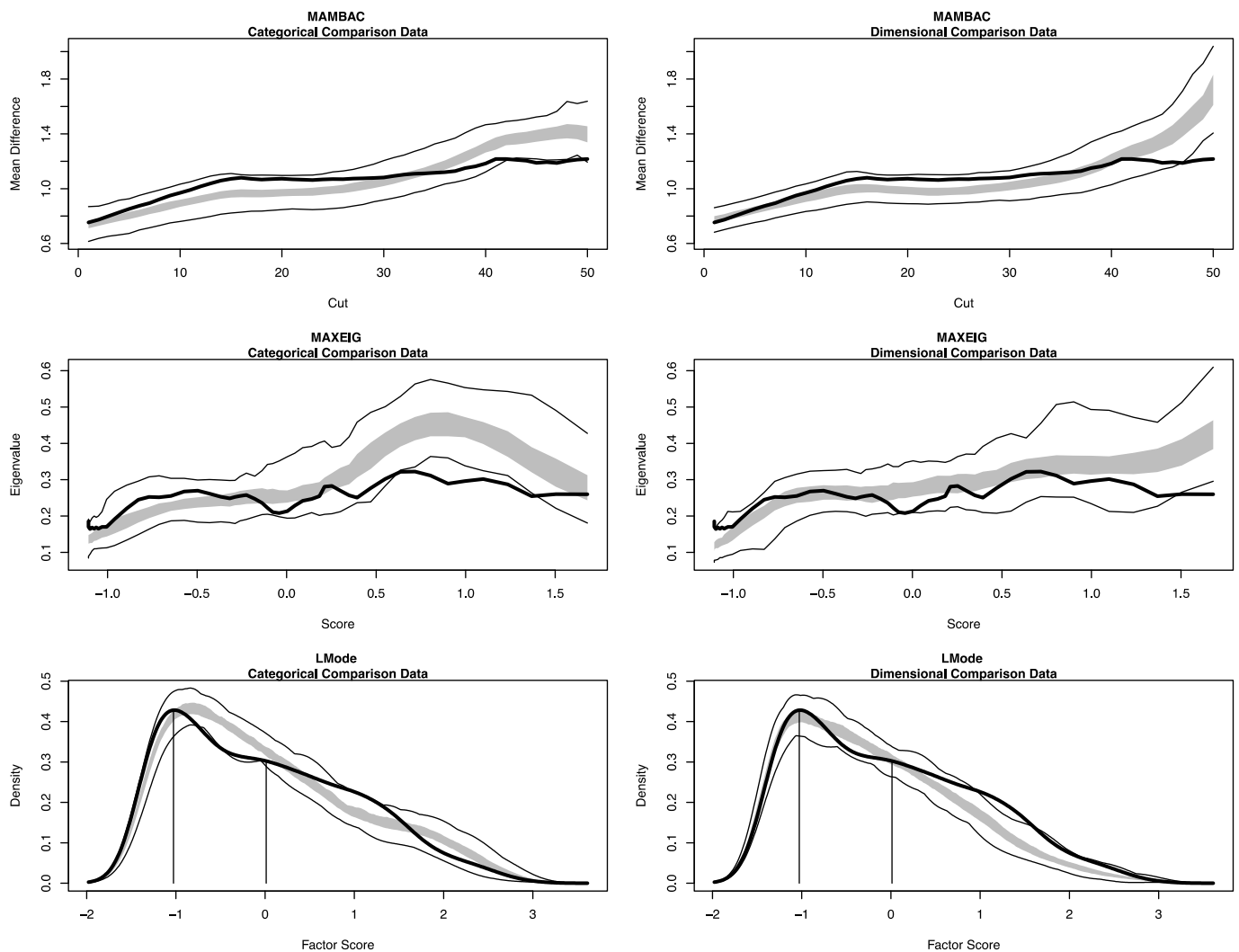


Fig. 1. Average MAMBAC, MAXEIG and L-Mode curves for the present data (the dark line), simulated taxonic data (left) and simulated dimensional data (right) for the four-dimension model of ORS-YBOCS with a base rate based on a cut-off score of 20. In each graph, the two light lines depict the maximum and minimum simulated taxonic or dimensional values. The gray areas indicate the middle 50% of simulated values.

Table 2
CCFI index and base rate.

Procedures	CCFI	Base Rate
MAMBAC	0.543	0.410
MAXEIG	0.427	0.297
L-Mode	0.424	0.488

Note. CCFI = Comparison Curve Fit Index generated by the standard taxometric analysis; Base Rate = taxon ratio generated by each taxometric procedure.

dimensional structure (Ruscio et al., 2010), as shown in Table 3. Therefore, consistent results suggested that the latent structure of ORD is dimensional.

4. Discussion

The current study explored the latent structure of ORD in a large sample of Chinese university students and community adults. Three non-redundant taxometric procedures and aggregate CCFIs converged on a dimensional underlying structure of ORD. In another word, ORD existed on a continuum of body smell concern. The findings of dimensionality related to ORD are strengthened by some methodological features: the indicators covered several defining features of the ICD-11 ORD

diagnosis; the indicators focused on current symptoms to minimize recall bias; the balanced gender distribution of participants; consistent results across different taxometric procedures; the adoption of objective CCFI indices, as well as the CCFI profiles rather than relying only on visual judgment of graphical shape, reduce subjectivity of result interpret.

Dimensional constructs tend to be affected by various additive factors, while taxonic constructs tend to result from dichotomous factors or threshold effects (Ruscio et al., 2006). Our results of dimensionality are in line with prior research that multiple factors account for the varying ORD symptom severity on a continuum (Begum & McKenna, 2011; Greenberg et al., 2016). Future research could further investigate how an array of potential factors interact to lead to the symptom profile of ORD.

Dimensional constructs are characterized by the lack of a clear threshold between full- and sub-syndrome ORD (Ruscio et al., 2006). Our findings, together with previous evidence that increasing ORD symptom severity was associated with increasingly impaired functioning (Greenberg et al., 2016), suggested the value of paying attention to sub-syndrome body odor concerns. Sub-syndrome symptoms may provide additional information about the clinical courses of ORD symptoms (including prodromal and residual stage, and fluctuations of symptoms), causal relationships, preventive interventions, and

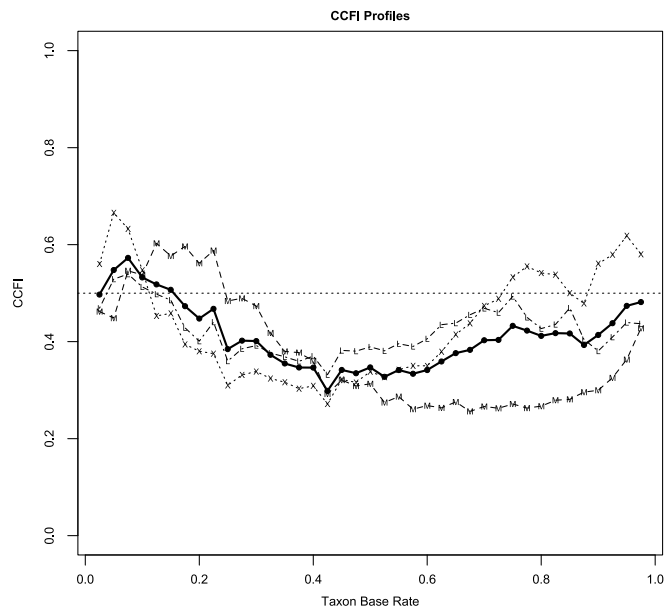


Fig. 2. Comparison Curve Fit Index Profile. CCFI profiles are labeled as M for MAMBAC, X for MAXEIG, L for L-Mode. The solid pint is the mean CCFI profile.

Table 3
Aggregate CCFI and base rate.

Procedures	CCFI	Base Rate
MAMBAC	0.414	0.145
MAXEIG	0.420	0.025
L-Mode	0.427	0.067

Note. CCFI = Comparison Curve Fit Index generated by the CCFI profile analysis; Base Rate = taxon ratio generated by each taxometric procedure.

worthwhile targets of treatment (Jaisoorya et al., 2017; Roberts, Fisher, Blake, & Tang, 2015; Schneider, Mond, Turner, & Hudson, 2017). Artificially reducing the continuum of body odor concern into dichotomies of ‘ORD present’ and ‘ORD absent’ could thus miss individuals who score below the ORD diagnostic threshold but still would benefit from intervention. It is also useful to examine treatment effectiveness across the full range of ORD symptoms. In the assessment of ORD symptoms, compared to the dichotomization of ‘present’ and ‘none/absent’, ratings of continuous symptom severity may be more valuable. Diagnostic decision would be more precise when combined symptom severity with other characteristics, such as severity of avoidance and functioning impairments.

Our findings are also consistent with the substantial evidence supporting the dimensional nature of most forms of psychopathology, including anxiety disorders, eating disorders, and personality disorders among others (Haslam et al., 2012), and the call for shifting to a dimensional classification scheme (Brown & Barlow, 2009; Krueger et al., 2018). Although the ICD-11 acknowledged the dimensional property of insight related to ORD and the broader Obsessive-Compulsive and Related Disorders category, this dimensional model is yet to be integrated consistency into the whole diagnosis. Future studies should compare the clinical utilities of the dimensional ORD diagnosis and the categorical ORD diagnosis in terms of assessment utilities and clinical outcome prediction.

Several limitations to the current study should be noted. First, the samples were limited to college students and community adults. It is worth noting that the college students and community adults recruited through the online portal responded to the study based on the title “mental health survey”. As well, the online data was collected during COVID-19, which may have influenced responses. Replication in other

community samples during other time periods is needed. In particular, enriching future studies with larger samples of individuals with clinical levels of ORD symptoms will help to confirm dimensionality of symptoms at higher levels of symptom severity. Further, the present study relied on only one self-report measure, which may be susceptible to the possibility of the mono-methodological bias (Shadish, Cook, & Campbell, 2002). Future studies could adopt both structured clinical interviews and self-report questionnaires. As a condition with few empirical studies (Greenberg et al., 2016), there are only one self-report questionnaire (i.e., the ORS-YBOCS) and one structured clinical interview (developed by Phillips & Menard, 2011) to assess ORD. Additional dimensional assessment tools are in need for both research and clinical utilities. Finally, some characteristics of our data were less than ideal. For example, the high indicator correlations in complement group may affect the CCFI index of MAMBAC procedure (Ruscio et al., 2006). Some curves for the three procedures are visually ambiguous.

The present study is the first effort, to our knowledge, to examine the latent structure of ORD. Consistent results from different procedures suggested a dimensional nature of ORD symptoms. Future studies should replicate findings with different measures and in clinical samples, as well as other community samples. Researchers and clinical practitioners would be advised to conceptualize, assess and treat ORD symptoms in a dimensional versus categorical manner.

CRediT authorship contribution statement

Fen Ren: Data curation, Formal analysis, Writing - original draft, collected part of the data, did data analysis, and drafted the manuscript. All authors contributed to the article and approved the submitted version. Ruichao Zhou: revised the manuscript. All authors contributed to the article and approved the submitted version. Xiaolu Zhou: Data curation, contributed to the conception and design of the study, provided part of the data, as well as revised the manuscript. All authors contributed to the article and approved the submitted version. Sophie C. Schneider: revised the manuscript. All authors contributed to the article and approved the submitted version. Eric A. Storch: contributed to the conception of the study, and revised the manuscript. All authors contributed to the article and approved the submitted version.

Declaration of competing interest

We report no conflicts of interest.

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