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The relationship between tics, OC, ADHD and autism symptoms: A cross-disorder symptom analysis in Gilles de la Tourette syndrome patients and their family members

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Abstract

Gilles de la Tourette's syndrome (GTS) is a disorder in which co-morbid obsessive-compulsive (OC), Attention Deficit Hyperactivity Disorder (ADHD) and autism symptoms occur in up to 60% of patients, suggesting shared etiology. We aimed to explore the phenotypic structure underlying GTS, taking tic, OC, ADHD, and autism symptoms into account as measured by various symptom scales (YGTSS, Y-BOCS, CAARS and AQ) in 225 GTS patients and 371 family members. First, Confirmatory Factor Analyses (CFA) were performed on the symptom structure of each separate symptom scale. Second, the symptom dimensions derived from each scale were combined in one model, and correlations between them were calculated. Using the correlation matrix, Exploratory Factor Analyses (EFA) were performed on the symptom dimensions across the scales. EFA revealed a five factor structure: tic/aggression/symmetry; OC symptoms/compulsive tics/numbers and patterns; ADHD symptoms; autism symptoms; and hoarding/inattention symptoms. The symptom factors found in this study are partly in line with the traditional categorical boundaries of the symptom scales used, and partly reveal a symptom structure that cuts through the diagnostic categories. This phenotypic structure might more closely reflect underlying etiologies than a structure that classically describes GTS patients according to absence or presence of comorbid OCD, ADHD and autism, and might inform both future genetic and treatment studies.

Keywords

ASD; CFA; comorbidity; EFA; etiology; factor analysis; tic-disorder

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1 Introduction

Gilles de la Tourette Syndrome (GTS) is a neurodevelopmental disorder characterized by motor and vocal tics (Cath et al., 2011). The most frequent comorbidities of GTS are Attention Deficit Hyperactivity Disorder (ADHD) (Stewart et al., 2006) and Obsessive Compulsive Disorder (OCD) (Pauls et al., 1986). Several family-based studies have robustly indicated that, within GTS families, OC symptoms and tics are etiologically related, and OC symptoms might even represent alternate expressions of the same overlapping genetic etiologies (Pauls et al., 1991).

ADHD symptoms are also etiologically related to tics, although in a more complex manner (Stewart et al., 2006). Although less well-documented, recent studies suggest that Autism Spectrum Disorders (ASD) are co-morbid with GTS as well (Burd et al., 2009; State, 2010; Cath and Ludolph, 2013).

As already hypothesized in 1997, this comorbidity of tics, OC, ADHD, and autism symptoms might be the result of shared underlying genetic factors that converge at the level of cortico-striatal-thalamocortical circuits (Palumbo et al., 1997). Therefore the notion is growing that, instead of viewing GTS, OCD, ADHD, and autism as separate but co-morbid disorders, these disorders should be seen as part of a spectrum of disorders with overlapping etiologies, converging in dysfunctional cortico-striatal circuitry underlying these disorders.

Several studies have explored the relationship between GTS and comorbid diagnoses of OCD and ADHD (Grados et al., 2001; Stewart et al., 2006; Grados and Mathews, 2009; State et al., 2010). Further, one study has investigated symptom structures underlying tics and other comorbid disorders, including OCD, ADHD, depression and anxiety disorders (Eapen et al., 2004). However, to date no factor analytic studies have explored the overall symptom structure of tics, OC, ADHD, and autism symptoms in Tourette's syndrome patients and their family members. A more refined phenotyping of patients across the boundaries of these comorbid diagnoses might lead to more rational symptom–based classification, informing genetic studies and enabling fine-tuning of treatment studies by distinguishing the distinct symptom profiles.

The variety of symptoms that cover tics, OC, ADHD, and autism symptoms is generally measured using distinct symptom scales for each set of symptoms. On these various symptom scales, several factor (or cluster) analyses have been carried out to determine the underlying symptom dimensions (see Table 1 in the methods section for a selection of studies). Depending on sample size, analytic method used, and definitions of the symptoms/symptom categories under investigation (e.g., broad versus strict), varying numbers of symptom dimensions have been found across studies. In short, with respect to tic symptoms as measured with the widely used Yale Global Tic Severity Scale (YGTSS) (Leckman et al., 1989), between 2 and 5 factors were found (Alsobrook and Pauls, 2002; Mathews et al., 2007; Robertson et al., 2008; de Haan et al., 2015), on the Yale-Brown Obsessive Compulsive Symptom Scale (YBOCS) (Goodman et al, 1989), between 3 and 5 factors were found (Baer et al., 1994; McKay et al., 1995; Leckman et al., 1997; Katerberg et al., 2010), on the Connors Attention Deficit & Hyperactivity Rating Scale (CAARS) (Conners et al.,

1999) 2–3 factors (Conners et al., 1999; Hardy et al., 2007), and finally on the Autism spectrum Quotient (AQ) (Baron-Cohen et al., 2001) 5 factors have been identified, although content of the symptom dimensions somewhat changed with re-analysis and abbreviation of the scale (Baron-Cohen et al., 2001; Hoekstra et al., 2011).

The aim of the current study is to explore the phenotypic structure of tics, OC, ADHD, and autism symptoms across symptom scales in a large sample of GTS patients and their family members. We hypothesized that 1) *within* diagnostic categories (e.g., tics, OCS, ADHD, autism), robust factor structures would be identified, and that 2) across diagnostic categories, a new factor structure, in which some factors contain symptoms from multiple symptom scales and some contain symptoms from only one symptom scale would be identified. More specifically, we hypothesized that we would identify a factor that contained both tic and OC symptoms, a factor that contained both tic and ADHD symptoms (predominatly hyperactivity/impulsivity), a factor that contained OC and autism symptoms (predominantly with respect to attention switch problems, and numbers and patterns).

2 Methods

2.1 Study sample

This study consisted of 225 GTS patients (GTS sample) and 371 of their family members (Family sample) recruited through the Dutch Tourette's patient association and through two specialized Dutch outpatient clinics. The current study samples partially overlap with the study samples described in de Haan et al. (2015). More specifically, the family sample of the de Haan et al. study is similar to the family sample in this study, whereas the patient sample of the de Haan et al. (2015) study has included n=183 Dutch patients that are also included in the current study. The current patient sample included an additional 42 subjects. Moreover, the patient sample in the de Haan et al. study contained two additional patient cohorts of in total n=273 patients, yielding an overlap between the current patient sample and the patient sample in the de Haan et al. study of 40% (n=183/n= 456). Sixty-four percent of the GTS sample were male, with ages ranging from 6 to 72 years (M= 30.15, SD=15.65), of whom 79% were 16 years or older. Forty-seven percent of the family sample were males, with ages ranging from 5 to 88 years (M=41.43, SD=19.20) of whom 85% (n= 315) were 16 years or older. The sample of family members contained 88.7 % first degree relatives, 5.9 % second-degree or more distant relatives (uncle, nephew, cousin, grandfather, etc.), and 5.4% spouses. Since this study did not focus on any genetic aspects of tics, OC, ADHD and Autism factors, and the family sample was added because of the pragmatic reason of having the same questionnaires in both samples, no distinction was made between relatives and spouses included in the study. Of the family sample, 8.1% had a (probable) GTS diagnosis, 27.5% had tic symptoms that did not meet full criteria for GTS, and 53.9% had no tics. Tic data were not available for 10.5% of the family sample, of these participants data concerning OC, ADHD and Autism symptoms were included. IQ was not tested in this study but all patients had attended (or were attending) regular education, and therefore we did not correct symptom scale scores on IQ.

Comorbidity with OCD was measured using the Structured Clinical Interview for DSM-IV axis disorders-I (SCID-I, First et al., 2002). In the GTS sample, 35.9% had a comorbid OCD

diagnosis, in the family sample, 3.3% had OCD. No data on autism diagnosis was available, so autism traits were measured using the Autism-spectrum Quotient (see 2.3 measures). In our study mean AQ scores in the GTS sample were 20.28 (sd=7.43) with 20% of the patients scoring 32 or higher, the official cut off score for an autism spectrum diagnosis. In the family sample mean score were 16.24 (sd=6.24) with 3, 2% of the participants scoring above cut-point of 32. For ADHD the CAARS was used to measure symptom severity, in the GTS sample 26% scored above the cut off for a probable ADHD diagnosis, in the family sample this was 6.2%.

2.2 Procedure

Data were collected between 2004 and 2009 in the Netherlands, as part of a larger study of the genetics of GTS (see Scharf et al., 2013). Respondents were recruited from 1) two mental health outpatient services specialized in treating OC spectrum disorders including tics, and 2) the Dutch Tourette Syndrome Association. Patients with tics were invited for a diagnostic interview and to fill in questionnaires concerning tics, comorbidity, and health issues. In our current study only the questionnaires concerting tics, OC, ADHD and autism symptoms were included. Each patient was asked if there were family members willing to join in the study. Family members willing to participate were invited for the diagnostic interview and questionnaires. In the cases where the participants were younger that 16 years of age, a parent helped filling in the questionnaires. All participants followed or finished regular schools, so IQ was assumed to be sufficient for filling in the self report scales.

The study was approved by the VUmc medical ethical committee and all participants gave written informed consent.

2.3 Measures

Yale Global Tic Severity Scale (YGTSS; Leckman et al., 1989)—The YGTSS is a self report symptom scale, containing 38 items measuring occurrence (and severity) of tic symptoms. The YGTSS has good inter-rater reliability properties with intra class correlations between 0.80 and 0.91, as well as good discriminant and convergent validity properties (Leckman et al., 1989). Response options were coded as yes/no and queried whether tics occurred ‘in the present’ ‘in the past’ or ‘never’. Twenty-six pure motor or vocal tic items were used in this study (Table 1). Because miscellaneous items measure different tics in different participants, all non-specific ‘miscellaneous’ motor, vocal, simple and complex tics were omitted.

2.3.1 Yale-Brown Obsessive Compulsive Symptom Scale (Y-BOCSS; Goodman et al., 1989)—

For the assessment of obsessive compulsive symptoms, 43 items of the 60 item version of the Y-BOCSS were used. The Y-BOCS has excellent inter-rater reliability and good convergent validity properties (Woody, Steketee and Chamlress, 1995). Response options were yes/no for symptoms ‘in the present’ ‘ever’ and ‘never’. Again because miscellaneous items measure different symptoms in different participants, all non-specific ‘miscellaneous’ items were omitted.

2.3.2 Conners Adult ADHD Rating Scale (CAARS; Conners et al., 1999)—For the assessment of inattentive and hyperactive/impulsive symptoms, the short version including 18 items was used that assesses the 18 DSM-IV criteria of ADHD from the 66 item CAARS. The CAARS has excellent internal reliability with alpha scores ranging from 0.86 to 0.92 on the four subscales, as well as good inter-rater reliability and validity properties (Erhardt et al., 1999). The included items are consistent with the DSM-IV criteria of ADHD and are rated on a 0–3 symptom scale, with 0=no symptom; 1= sometimes symptoms; 2= often symptoms and 3= very often symptoms.

2.3.3 Autism-spectrum Quotient (AQ; Baron-Cohen et al., 2001)—For the assessment of autism symptoms all 50 items of the original AQ were used. The AQ is an instrument with good test-retest and inter-rater reliability, with alpha coefficients ranging from 0.63 to 0.77 for the five subscales. Face validity was found to be reasonable (Baron-Cohen et al., 2001). The items contain statements with answer options ‘definitely agree’, ‘slightly agree’, ‘slightly disagree’ and ‘definitely disagree’

2.4 Statistical analyses

To enable item-level factor analysis (FA) across the symptom scales, all items were dichotomized, including those derived from ordinal symptom scales (i.e. CAARS and AQ). We used a conservative approach to dichotomize the CAARS items, since recent reports have indicated that adult self-reports of ADHD symptoms tend to be less reliable to measure ADHD symptoms, partly due to overrating (Franke et al., 2012). Thus, response categories 0–2 (corresponding to: 0=no; 1=sometimes; 2=often) were re-coded as 0; ‘no/mild symptoms’, and response category 3 (corresponding to 3=very often) was re-labelled as 1: ‘moderate/severe’ symptoms. AQ items were recoded and dichotomized according to the rules established by Baron-Cohen et al. (2001). Finally, with respect to tic and YBOCS symptom checklists that measure lifetime tic and OC symptom occurrence, the response categories ‘in the present’ and ‘in the past’ were combined into ‘present’ (coded as 1) versus ‘absent’ (coded as 0).

First the appropriate symptom dimensions of each symptom scale (for tics, OC, ADHD and autism symptoms) were established in our sample by performing confirmatory factor analyses (CFA), testing various models in line with the different symptom factors as reported in the literature (See Table 1 for an overview of the literature on the factors/symptom dimensions of each scale, and the factor models tested). All analyses were first run in the GTS sample and then in the family Sample, to cross-validate the results, and to investigate generalizability of the results from the GTS patient sample to a sample of largely unaffected family members. One of the models we tested was derived from a study of de Haan (2015), who used the same sample as the replication sample used in our study. However because our findings were tested in two different samples this is not a problem for the results of our study.

The symptom dimensions that best fitted the data in the CFAs (see below for details) were included in subsequent analyses, which were performed in two steps.

Step1—The best fitting symptom dimensions of all symptom scales were combined in one model, and correlations between these symptom dimensions were calculated. This step was first performed for each of the samples separately, producing two correlation matrices giving information about the underlying structure of the symptom dimensions in the GTS sample and the family sample. To evaluate the stability of the underlying structure across the samples, we compared the correlation matrices using two multiple group models: 1) A multiple group model where the correlations between the dimensions were freely estimated for each of the two samples, and 2) a multiple group model where the correlations between the dimensions were fixed to be equal across samples. A $\chi 2$ difference test was performed to test the difference between the two models. If the fit of the fixed model is close to the fit of the free model and the two models are not significantly different, we can assume that the factor structure and the correlations between the dimensions are equal across the two groups, providing us with information concerning the stability of the underlying structure. It is then reasonable to combine the two samples in order to evaluate the correlations between the symptom dimensions in one large group with both GTS patients and their family members. This combined correlation matrix is then used for the step 2 analyses.

Step2—In the second step Exploratory Factor Analyses (EFA) were carried out on the correlations between the symptom dimensions. Using both primary factor loadings and cross loadings of the symptom dimensions on the underlying factors, we explored the structure of tic, OC, ADHD, and autism symptoms.

All analyses were performed using M*plus*-6.11 (Muthén and Muthén, 2010). Since the data were dichotomous, the weighted least squares with adjusted means and variances (WLSMV) estimator was used in CFA. Goodness of fit was evaluated using the comparative fit index (CFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA). Conventional fit guidelines were followed: a good fit is indicated by CFI and TLI >0.9 and RMSEA <0.05 (Hu and Bentler, 1999). In the CFA's, Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC) were used for model comparison, where the smallest AIC and BIC values indicated the best fit. AIC and BIC values were obtained using the robust maximum likelihood (MLR) estimator. Then, the best symptom dimensions obtained from each symptom scale were used in subsequent model fitting analyses. EFA was conducted using oblique geomin rotation, and maximum likelihood estimation. Models with different factor solutions were compared using χ^2 difference testing where a χ^2 difference with a p value of <0.001 was chosen to be significant. To evaluate the fits AIC and BIC values were computed as well.

3 Results

3.1 Establishing the most optimal factor structure of each symptom checklist

Table 2 shows results of the CFA's on tics, OCD, ADHD, and autism symptoms. Fit indices are shown for the GTS sample and the family sample. The best fitting solutions are shown in Bold. For tics, a three factor structure (S1: CFI=0.92, TLI=0.92, RMSEA=0.03; S2: CFI=0.99, TLI=0.99, RMSEA=0.02), for OC-symptoms, a four factor structure (S1: CFI=0.92, TLI=0.92, RMSEA=0.03; S2: CFI=0.92, TLI=0.92, RMSEA=0.03), for ADHD

symptoms, a three factor structure (S1: CFI=1.00, TLI=1.00, RMSEA=0.02; S2: CFI=0.99, TLI=0.98, RMSEA=0.02) and for autism symptoms, a five factor structure was found (S1: CFI=0.91, TLI=0.90, RMSEA=0.04; S2: CFI=0.90, TLI=0.89, RMSEA=0.03). In both samples the same models were best represented by the data. For OCD, the AIC value slightly favoured a five-factor solution in the family sample. However, CFI, TLI, and BIC values indicated the best fit for the four factor solution, hence the four factor solution was chosen over the five factor solution.

3.2 Step 1: Testing the stability of the underlying structure across the samples

Results of the multiple group model, where the correlations between the dimensions were fixed to be equal across the two samples, and the model where the correlations between the dimensions were estimated freely across the two samples showed almost identical good fits (CFI=0.90, TLI= 0.90, RMSEA=0.01 in the free model; CFI=0.90, TLI=0.89, RMSEA=0.01 in the fixed model), and were not significantly different (χ^2 difference: 23.8, df difference: 105; p=1.0), meaning that correlations between the symptom dimensions are stable across patients and family members, and therefore samples could be combined. In the combined sample, the model fit estimates were high, CFI and TLI values of 0.97, and a RMSEA value of 0.01. Table 3 shows the various correlation matrices derived from the patient, family and combined sample. The correlations seen in the GTS sample and the family sample seem different from each other in the strength of the correlations. This is due to the fact that the variance in the samples and the height of the scores in the samples are different. However, our results concerning the stability of the structure show that the structure between the samples is the same and that the samples can be combined.

3.3 Step 2: Exploring the factor structure underlying all symptom dimensions

In the next step EFA was performed on the correlation matrix of the combined sample (see Table 4). The results of the EFA suggested that a five factor solution had the best fit to the data, with eigenvalues being equal to or higher than 1 for all factors. AIC values and the χ^2 difference tests also suggested that the 5 factor solution was the best fit for the data. Although the BIC value rose slightly in the fifth factor, most fit indices pointed towards the five factor model, hence this model was chosen over the four factor model, thus including a factor concerning hoarding and inattention. Table 5 shows the factor loadings (including cross-loadings) of the symptom dimensions on the five factors. Factor loadings ≥ 0.40 were chosen to define symptom dimensions that belonged to one factor. The factor loadings of the symptom dimensions yielded a structure in line with the separate diagnostic categories of GTS, OCD ADHD and autism, with the exception of the numbers and patterns dimension. When we included the cross-loadings ≥ 0.40 the following factors emerged: 1) a tic/ hyperactivity/aggressive OC symptom factor, encompassing all three tic dimensions, aggressive obsessions, symmetry behaviour, and ADHD hyperactivity; 2) a “repetitive” OC symptom factor that includes all four OC symptom dimensions plus body tics and the AQ numbers and pattern dimension; 3) an ADHD symptom factor including all three ADHD dimensions, 4) an autism-related symptom factor including routines and attention switching problems, and finally, 5) a hoarding/inattention symptom factor was discerned including hoarding, inattentiveness, and (marginally) attention switching problems.

4 Discussion

This paper is the first to explore the factor structure underlying tics, OC, ADHD, and autism symptoms, using both item level and subscale symptom information in a GTS family sample. We hypothesized to confirm robust factor structures within diagnostic boundaries based on previously reported factor structures, and also that tics, OC, ADHD, and autism symptoms would group together in factors that crossed the traditional diagnostic boundaries.

First, the most optimal factor solution was established for each of the symptom checklists separately. Multiple Group Factor Analyses indicated that the found factor solutions were robust over samples, hence the data of both samples were combined. Then the phenotypic structure of tics and comorbid symptoms was investigated by 1) calculating correlations between symptom dimensions of all checklists, and 2) exploring the underlying factor structure of all these dimensions.

Doing so, the following picture emerged. First, tics, OC, ADHD, and autism symptom dimensions, when analysed in concert, represented distinct and stable symptom factors both within and across the two study samples (GTS patients and family members of GTS patients). When the best-fit EFA model was examined with a focus on the variables that loaded most strongly on each factor, the symptoms fell into classic disorder specific factors. The only two exceptions to this were the numbers and patterns dimension from the AQ, which loaded on the OC factor rather than the autism factor, and the fifth factor including hoarding and inattention. These results are in line with the classic picture that views tic, OC, ADHD and autism symptoms as distinct diagnostic categories reflecting independent but co-morbid GTS, OCD, ADHD and autism spectrum disorders. However, when the factor structure was examined with a focus on all variables loading at ≥0.40, including cross-loading variables, some striking inter-relationships were found across categories.

First, two OC symptom dimensions, aggressive obsessions and symmetry behaviour, also loaded on tic-related symptom dimension. This is in line with previous comparative and factor-analytic studies between GTS and (tic-free) OCD (Miguel et al., 1997; Cath et al., 2001; Diniz et al., 2004; Worbe et al., 2010), indicating that symmetry behaviour is specifically associated with tic related OCD and with GTS. Further, aggressive obsessions, rather than washing and hoarding behaviours, seem to be intrinsically and genetically related to the GTS phenotype. Although we cannot definitively make conclusions with respect to etiological relationships from this descriptive study, this relation might even reflect different phenotypic expressions of the same underlying etiology (Pauls and Leckman, 1986; Pauls et al., 1991; Hebebrand et al., 1997;). The addition of the hyperactivity dimension of the CAARS, although new, seems to perfectly match the tic factor, since tics and hyperactivity both involve increased motor activity.

The second factor, which included body tics, and numbers and patterns from the AQ in addition to the OC symptom dimensions, seems to represent the repetitive behaviour repertoire within the GTS phenotype. It is not clear why body tics load highly on this factor. More study is needed to further investigate this interrelationship. Interestingly, the numbers and patterns dimension within the autism spectrum stood apart from the other autism-related

dimensions, and may represent the phenomenological overlap between tics, OC and autism symptomatology. At present, the various autism related disorders are thought to represent a spectrum of disorders with heterogeneous phenomenology as well as genetic underpinnings. In all, these findings support the view that some symptom dimensions of autism (including repetitive behaviours) are more etiologically related to GTS and OCD than others (i.e. social and communication problems).

The third factor included all ADHD symptom dimensions, i.e. inattention, hyperactivity and impulsivity. Although the cross-loadings of all three tic dimensions are just below the threshold of .40, it is striking that all other symptom dimensions load much lower on the ADHD factor. Hence, within GTS families, the full range of ADHD symptomatology may be related to tics, although our results only slightly suggest this relation (Stewart et al., 2006).

Interestingly, the fourth factor (autism), involving lack of social skills as well as preoccupation with routines, attention switching problems and lack of imagination, was not related to any of the tic or OC symptom factors. This autism dimension might be etiologically distinct from the second factor characterised by repetitive behaviour (including the AQ-related numbers and patterns dimension). It would be of special interest to find out whether these traits run across OCD and autism families as distinguishable symptom dimensions. Only few sufficiently powered family studies have investigated the phenotypic and genetic structure of OC and autism symptoms in families (Bolton et al., 1998; Hollander et al., 2003; Micali et al., 2004;) and no twin studies have been performed to date on this relationship. Also to truly investigate this distinction between autism traits in depth, a clinician-administered autism interview should be used, in stead of a self report autism screener.

Lastly, we identified a fifth factor, which included inattention and hoarding. This inattention/hoarding dimension is in line with recent studies suggesting that hoarding is a symptom dimension separate from the OCD phenotype (Pertusa et al., 2008; Pertusa et al., 2010; Mathews et al., 2014). Moreover, in DSM 5, hoarding is placed as a separate disorder in the group of OCD spectrum disorders (Mataix-Cols and Pertusa, 2012). Furthermore, in line with previous findings on symptom dimensions within OCD patients, hoarding seems to be related to inattention and ADHD symptoms (Anholt et al., 2010; Tolin et al., 2011). The association between hoarding and attentional problems as found in this study might arguably have a broad impact on the treatment of hoarding disorder (with or without co-morbid OCD). In current practice, treating hoarding disorder forms a challenge to clinicians, due to its treatment resistance in comparison with for example the treatment of other symptom dimensions of OCD (Mataix-Cols et al., 1999), and serotonin re-uptake inhibitors are still the pharmacological treatment of choice (Saxena, 2011). However, the treatment effect of SSRIs in hoarding symptoms is limited (Mataix-Cols et al., 1999; Bloch et al., 2010). One recent small case study suggests that the stimulant drug methylphenidate which is regarded as a first choice treatment option of ADHD symptoms (Rabito-Alcon et al., 2014), might be an effective alternative (Rodriguez et al., 2013). Future randomised controlled trials comparing SSRI treatment to psychostimulant treatment in hoarding should be conducted to

explore the potential of an augmentation effect of psychostimulant treatment of ADHD symptoms while treating hoarding disorder.

Although just below the .40 threshold, the inattention/hoarding factor was also associated with the attention switching problem dimension of the AQ, as was found in a previous study in OCD patients (Anholt et al., 2010). Although attention switching problems (hyperfocus) and inattention (easily distracted) intuitively seem to reflect opposite problem behaviours, ADHD patients have repeatedly been found to exhibit both difficulty in attention switching (related to hyperfocusedness) and attention problems (Cepeda et al., 2000; Oades and Christiansen, 2008). Thus this factor may reflect a robust etiological relationship, considering the fact that this association has been found across patient populations of OCD, hoarding and (in this study) GTS. Moreover, the low factor cross-loadings of hoarding on any of the autism symptom dimensions underscore recent notions that hoarding seems unrelated with most of the problems of autism (Pertusa et al., 2012).

4.1 Limitations

This study has several limitations. First, the symptom structure across rating scales has been investigated in a GTS patient sample and their family members, who are (for a large part) genetically related to the patients. No random control groups were studied. Hence, a replication study with independent samples could provide more information on the stability of the found phenotypic structure. Also, replication of these findings in primarily OCD, ADHD, and autism samples is warranted.

Another limitation is that, even with both samples combined, the sample size was still too small to allow a full item-level exploratory factor analysis in which the relation between the symptoms can be explored using the true item scores in stead of the correlations between the symptoms. Thus we needed to rely on existing factor structures within the symptom scales used, which might have -by increasing the within -factor scores somewhat-influenced the final EFA results. However, these results do not only concern the main factor loadings but are informative on the cross factor loadings, which has been the primary interest of this study. Thus, these results are likely to be informative on the structure underlying the tic, OC, ADHD and autism symptoms. These results need replication in future studies with larger sample sizes to permit a full item-level factor analysis.

Another limitation is that there is a large amount of children measured in our study, using the CAARS and the AQ, which are questionnaires for adults. Because it would have been difficult to compare the results of the symptoms if different instruments were used, we decided to use the same instruments in both children and adults, and a parent of the participants younger than 16 helped filling in the questionnaires. There could be reason to aspect differences in symptom structure between children and adults, however it was not in the scope of this study to investigate that, and a larger amount of measurements in children would have been needed to test this hypothesis. In future research this could be tested.

4.2 Implications for future research

This study shows that, although a categorical approach of psychiatric disorders (along the lines of DSM IV and 5) seems logical clinically, a dimensional trans-diagnostic approach

might be more explanatory with respect to the underlying phenotypic structure and might lead to more successful discovery of the shared genetic underpinnings of GTS, OCD, ADHD and autism spectrum disorders, all sharing dysfunctions within frontal striatal circuitries. Family-based studies of the various co-morbid symptom dimensions in concert, as well as longitudinal studies that investigate the development of the tics, OC, ADHD and autism symptom dimensions and possible transitions from one symptom dimension into the other across time are warranted to further understand shared biological and genetic pathways. These findings might inspire the development of more symptom dimension-based behavioural and pharmacological therapies. For example, considering the relationship found between hoarding and inattention, treatment studies using m-phenidate, the drug of first choice in ADHD treatment, seem warranted.

In summary, results have indicated symptom dimensions both within and across the boundaries of current disorders which might better inform future genetic as well as treatment studies, and therefore yield more robust results.

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References

Alsobrook JP, Pauls DL. A factor analysis of tic symptoms in Gilles de la Tourette's syndrome. Amn J Psychiatry. 2002; 159:291–296.

Anholt GE, Cath D, van Oppen P, Eikelenboom M, Smit JH, van Megen HJGM, van Balkom AJ. Autism and ADHD symptoms in patients with OCD: Are they associated with specific OC symptom dimensions or OC symptom severity? J Autism Dev Disord. 2010; 40:580–589. [PubMed: 20039111]

Baer L. Factor analysis of Symptom subtypes of Obsessive Compulsive Disorder and their relation to Personality and Tic Disorders. J Clin Psychiatry (suppl). 1994; 55:18–23.

Baron-Cohen S, Wheelwright S, Skinner R, Martin J, Clubley E. The autism-spectrum quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. J Autism Dev Disord. 2001; 31:5–17. [PubMed: 11439754]

Bloch MH, McGuire J, Landeros-Weisenberger A, Leckman JF, Pittenger C. Meta-analysis of the dose-response relationship of SSRI in OCD. Mol Psychiatry. 2010; 15:850–855. [PubMed: 19468281]

Bolton PF, Pickles A, Murphy M, Rutter M. Autism, affective and other psychiatric disorders: patterns of familial aggregation. Psycholl Med. 1998; 28:385–395.

Burd L, Li Q, Kerbeshian J, Klug MG, Freeman RD. Tourette syndrome and comorbid autism spectrum disorders. J Child Neurol. 2009; 24:170–175. [PubMed: 19182154]

Cath DC, Spinhoven P, van Woerkom TCAM, van de Wetering BJM, Hoogduin CAL, Landman AD, Roos RA, Rooijmans HG. Gilles de la Tourette's Syndrome with and without OCD in comparison to OCD without tics: which symptoms discriminate? J Nerv Ment Dis. 2001; 189:219–228. [PubMed: 11339317]

Cath DC, Hedderly T, Ludolph AC, Stern JS, Murphy TK, Martino D, Munchau A, Rizzo R, ESSTS Guidelines Group. European Clinical guidelines for Tourette syndrome and other tic disorders. Part I: assessment and medical examination. Eur Child Adolesc Psychiatry. 2011; 20:147–172. [PubMed: 21249407]

Cath, DC.; Ludolph, A. Other psychiatric co-morbidities in Tourette Syndrome. In: Martino, D.; Leckman, J., editors. Tourette Syndrome. Oxford University Press; New York: 2013. p. 74-106.

Cepeda NJ, Cepeda ML, Kramer AF. Task switching and attention deficit hyperactivity disorder. J Abnorm Child Psychol. 2000; 28:213–226. [PubMed: 10885680]

Conners, CK.; Erhardt, D.; Sparrow, E. CAARS Adult ADHD Rating Scales; a technical Manual. Multi Health Systems Inc; North Tonawanda, New York: 1999.

Diniz JB, Rosario-Campos MC, Shavitt RG, Curi M, Hounie AG, Brotto SA, Miguel E. Impact of age at onset and duration of illness on the expression of comorbidities in obsessive-compulsive disorder. J Clin Psychiatry. 2004; 65:22–27.

Eapen V, Fox-Hiley P, Banerjee S, Robertson M. Clinical features and associated psychopathology in a Tourette syndrome cohort. Acta Neurol Scand. 2004; 109:255–60. [PubMed: 15016007]

Erhardt D, Epstein JN, Conners CK, Parker JDA, Sitarenios G. Self-ratings of ADHD symptoms in adults: II. Reliability, validity, and diagnostic sensitivity. J Attent Disord. 1999; 3:153–158.

First, MB.; Spitzer, RL.; Gibbon, M.; Williams, JBW. Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Research Version, Patient Edition. (SCID-I/P) Biometrics Research, New York State Psychiatric Institute; New York: 2002.

Franke B, Faraone SV, Asherson P, Buitelaar J, Bau CH, Ramos-Quiroga JA, Mick E, Grevet EH, Johansson S, Haavik J, Lesch KP, Cormand B, Reif A, International Multicentre persistent ADHD Collaboration. The genetics of attention deficit/hyperactivity disorder in adults, a review. Mol Psychiatry. 2012; 17:960–87. [PubMed: 22105624]

Goodman WK, Price LH, Rasmussen SA, Mazure C, Fleischman RL, Hill CL, Heninger GR, Charney DS. The Yale-Brown obsessive-compulsive scale. I. Development, use and reliability. Arch Gen Ppsychiatry. 1989; 46:1006–1011.

Grados MA, Riddle MA, Samuels J, Liang KY, Hoehn Saric R, Bienvenu OJ 3rd, Walkup JT, Song D, Nestadt G. The familial phenotype of Obsessive-Compulsive Disorder in relation to tic disorders: the Hopkins OCD family study. Biol Psychiatry. 2001; 50:559–565. [PubMed: 11690590]

Grados MA, Mathews CA. Clinical phenomenology and phenotype variability in Tourette syndrome. J Psychosom Res. 2009; 67:491–496. [PubMed: 19913653]

De Haan MJ, Delucci K, Mathews CA, Cath DC. Tic symptom dimensions and their heritabilities in Tourette's syndrome. Psychiatr Genet. 2015; 3:112–118.

Hardy KK, Kollins SH, Murray DW, Riddle MA, Greenhill L, Cunningham C, Abikoff HB, McCracken JT, Vitiello B, Davies M, McGough JJ, Posner K, Skrobala AM, Swanson JM, Wigal T, Wigal SB, Ghuman JK, Chuang SZ. Factor Structure of Parent- and Teacher-Rated Attention-Deficit/Hyperactivity Disorder Symptoms in the Preschoolers with Attention-Deficit/Hyperactivity Disorder Treatment Study (PATS). J Child Adolesc Psychopharm. 2007; 17:621–633.

Hebebrand J, Klug B, Fimmers R, Seuchter SA, Wettke-Schafer R, Deget F, Camps A, Lisch S, Hebebrand K, von Gontard A, Lehmkuhl G, Poustka F, Schmidt M, Baur MP, Remschmidt H. Rates for tic disorders and obsessive-compulsive symptomatology in families of children and adolescents with Gilles de la Tourette's syndrome. J Psychiatr Res. 1997; 31:519–530. [PubMed: 9368194]

Hoekstra RA, Vinkhuyzen AA, Wheelwright S, Bartels M, Boomsma DI, Baron-Cohen S, Posthuma D, van der Sluis S. The construction and validation of an abridged version of the autism-spectrum quotient (AQ-Short). J Autism Dev Disord. 2011; 41:589–596. [PubMed: 20697795]

Hollander E, King A, Delaney K, Smith CJ, Silverman JM. Obsessive-compulsive behaviors in parents of multiplex autism families. Psychiatry Res. 2003; 117:11–16. [PubMed: 12581816]

Hu LT, Bentler PM. Cutoff Criteria for Fit Indexes in Covariance Structure Analysis: Conventional Criteria Versus New Alternatives. Struct Equ Modeling. 1999; 6:1–55.

Katerberg H, Delucchi KL, Stewart SE, Lochner C, Denys DA, Stack DE, Andresen JM, Grant JE, Kim SW, Williams KA, den Boer JA, van Balkom AJ, Smit JH, van Oppen P, Polman A, Jenike MA, Stein DJ, Mathews CA, Cath DC. Symptom Dimensions in OCD: Item-Level Factor Analysis and Heritability Estimates. Behav Genet. 2010; 40:505–17. [PubMed: 20361247]

Leckman JF, Grice DE, Boardman J, Zhang H, Vitale A, Bondi C, Alsobrook J, Peterson BS, Cohen DJ, Rasmussen SA, Goodman WK, McDougle CJ, Pauls DL. Symptoms of obsessive-compulsive disorder. Am J Psychiatry. 1997; 154:911–917. [PubMed: 9210740]

Leckman JF, Riddle MA, Hardin MT, Ort SI, Swartz KL, Stevenson JM, Cohen DJ. The Yale Global tic severity scale: Initial testing of a clinician-rated scale of tic severity. J Am Acad Child Adolesc Psychiatry. 1989; 28:566–573. [PubMed: 2768151]

Mataix-Cois D, Rauch SL, Manzo PA, Jenike MA, Baer L. Use of factor-analyzed symptom dimensions to predict outcome with serotonin reuptake inhibitors and placebo in the treatment of Obsessive-Compulsive Disorder. Am J Psychiatry. 1999; 156:1409–1416. [PubMed: 10484953]

Mataix-Cols D, Pertusa A. Annual research review: hoarding disorder: potential benefits and pitfalls of a new mental disorder. J Child Psychol Psychiatry. 2012; 53:608–618. [PubMed: 21895651]

Mathews CA, Jang KL, Herrera LD, Lowe TL, Budman CL, Erenberg G, Naarden A, Bruun RD, Schork NJ, Freimer NB, Reus VI. Tic symptom profiles in subjects with Tourette Syndrome from two genetically isolated populations. Biol Psychiatry. 2007; 61:292–300. [PubMed: 16581034]

Mathews CA, Delucchi K, Cath DC, Willemsen G, Boomsma DI. Partitioning the etiology of hoarding and obsessive-compulsive symptoms. Psychol Med. 2014; 44:2867–76. [PubMed: 25066062]

McKay D, Danyko S, Neziroglu F, Yaryura TJA. Factor structure of the Yale-Brown Obsessive Compulsive Scale: A two dimensional measure. Behav Res Ther. 1995; 33:865–869. [PubMed: 7677726]

Micali N, Chakrabarti S, Fombonne E. The broad autism phenotype: findings from an epidemiological survey. Autism. 2004; 8:21–37. [PubMed: 15070545]

Miguel EC, Baer L, Coffey BJ, Rauch SL, Savage CR, O'Sullivan RL, Phillips K, Moretti C, Leckman JF, Jenike MA. Phenomenological differences appearing with repetitive behaviors in obsessive-compulsive disorder and Gilles de la Tourette's syndrome. Br J Psychiatry. 1997; 170:140–145. [PubMed: 9093502]

Muthén, LK.; Muthén, BO., editors. Mplus users guide. 6th. Muthén & Muthén; Los Angeles, California: 2010.

Oades RD, Christiansen H. Cognitive switching processes in young people with attention-deficit/hyperactivity disorder. Arch Clin Neuropsychol. 2008; 23:21–32. [PubMed: 17976951]

Palumbo D, Maughan A, Kurlan R. Hypothesis III. Tourette syndrome is only one of several causes of a developmental basal ganglia syndrome. Arch Neurol. 1997; 54:475–483. [PubMed: 9109750]

Pauls DL, Towbin KE, Leckman JF, Zahner GEP, Cohen DJ. Gilles de la Tourette's syndrome and obsessive-compulsive disorder. Arch Genl Psychiatry. 1986; 43:1180–1182.

Pauls DL, Leckman JF. The inheritance of Gilles de la Tourette syndrome and associated behaviors. N Engl J Med. 1986; 315:993–7. [PubMed: 3463861]

Pauls DL, Raymond CL, Stevenson JM, Leckman JF. A family study of Gilles de la Tourette syndrome. Am J Hum Genet. 1991; 48:154–163. [PubMed: 1985456]

Pertusa A, Fullana MA, Singh S, Alonso P, Menchon JM, Mataix-Cols D. Compulsive hoarding: OCD symptom, distinct clinical syndrome, or both? Am J Psychiatry. 2008; 165:1289–1298. [PubMed: 18483134]

Pertusa A, Frost RO, Fullana MA, Samuels J, Steketee G, Tolin D, Saxena S, Leckman JF, Mataix-Cols D. Refining the diagnostic boundaries of compulsive hoarding: a critical review. Clinl Psychol Rev. 2010; 30:371–386.

Pertusa A, Fernandez DLC, Alonso P, Menchon JM, Mataix-Cols D. Independent validation of the dimensional Yale-Brown obsessive-compulsive scale (DY-BOCS). Eur Psychiatry. 2012; 27:598–604. [PubMed: 21570815]

Rabito-Alcon MF, Correas-Lauffer J. Treatment guidelines for Attention Deficit and Hyperactivity Disorder: A critical review. Actas Esp Psiquiatr. 2014; 42:315–324. [PubMed: 25388773]

Robertson MM, Althoff RR, Hafez A, Pauls DL. Principal Component Analysis of a large cohort with Tourette Syndrome. Br J Psychiatry. 2008; 193:31–36. [PubMed: 18700215]

Rodriguez CI, Bender J Jr, Morrison S, Mehendru R, Tolin D, Simpson HB. Does extended release methylphenidate help adults with hoarding disorder?: a case series. J Clin Psychopharmacol. 2013; 33:444–447. [PubMed: 23609401]

Saxena S. Pharmacotherapy of compulsive hoarding. J Clin Psychol. 2011; 67:477–484. [PubMed: 21404273]

Scharf JM, Yu D, Mathews CA, Neale BM, Stewart SE, Fagerness JA, Evans P, Gamazon E, Edlund CK, Service SK, Tikhomirov A, Osiecki L, Illmann C, Pluzhnikov A, Konkashbaev A, Davis LK,

Han B, Crane J, Moorjani P, Crenshaw AT, Parkin MA, Reus VI, Lowe TL, Rangel-Lugo M, Chouinard S, Dion Y, Girard S, Cath DC, Smit JH, King RA, Fernandez TV, Leckman JF, Kidd KK, Kidd JR, Pakstis AJ, State MW, Herrera LD, Romero R, Fournier E, Sandor P, Barr CL, Phan N, Gross-Tsur V, Benarroch F, Pollak Y, Budman CL, Bruun RD, Erenberg G, Naarden AL, Lee PC, Weiss N, Kremeyer B, Berrío GB, Campbell DD, CardonaSilgado JC, Ochoa WC, Mesa Restrepo SC, Muller H, Valencia Duarte AV, Lyon GJ, Leppert M, Morgan J, Weiss R, Grados MA, Anderson K, Davarya S, Singer H, Walkup J, Jankovic J, Tischfield JA, Heiman GA, Gilbert DL, Hoekstra PJ, Robertson MM, Kurlan R, Liu C, Gibbs JR, Singleton A, North American Brain Expression Consortium; Hardy J, UK Human Brain Expression Database. Strengman E, Ophoff RA, Wagner M, Moessner R, Mirel DB, Posthuma D, Sabatti C, Eskin E, Conti DV, Knowles JA, Ruiz-Linares A, Rouleau GA, Purcell S, Heutink P, Oostra BA, McMahon WM, Freimer NB, Cox NJ, Pauls DL. Genome-wide association study of Tourette's Syndrome. Mol Psychiatry. 2013; 18:721–8. [PubMed: 22889924]

State MW. The genetics of child psychiatric disorders: focus on autism and Tourette syndrome. Neuron. 2010; 68:254–269. [PubMed: 20955933]

Stewart SE, Illmann C, Geller DA, Leckman JF, King R, Pauls DL. A controlled family study of attention-deficit/hyperactivity disorder and Tourette's disorder. J Am Acad ChildAdolesc Psychiatry. 2006; 45:1354–1362.

Tolin D, Villavicencio A. Inattention, but not OCD, predicts the core features of hoarding disorder. Behav Res Ther. 2011; 49:120–125. [PubMed: 21193171]

Woody SR, Steketee G, Chambless DL. Reliability and validity of the Yale-Brown Obsessive-Compulsive Scale. Behav Res Ther. 1995; 33:597–605. [PubMed: 7598684]

Worbe Y, Mallet L, Golmard JL, Behar C, Durif F, Jalenques I, Damier P, Derkinderen P, Pollak P, Anheim M, Broussolle E, Xie J, Mesnage V, Mondon K, Viallet F, Jedynak P, Ben Djebara M, Schüpbach M, Pelissolo A, Vidailhet M, Agid Y, Houeto JL, Hartmann A. Repetitive behaviours in patients with Gilles de la Tourette syndrome: tics, compulsions, or both? PLoS One. 2010; 5:e12959. [PubMed: 20885982]

Table 1

Selection of models from literature, tested in our study

Model in our study	Numb. of factors	Numb. of items used	Factors (Number of items loading on the factor)	Original Study sample	N in original study	Statistical method in original study	Reference	Year of publication
Tics (YGTSS)								
Model 1	1	26	Tics (26)					
Model 2	2	26	Simple tics (14 items) and complex tics (12 items)	GTS	254	CA, PCA	Mathews et al.	2007
Model 3	3	23	Complex tics (7 items), body tics (6 items) and head tics (10 items)	GTS, family	437	EFA (PCA)	De Haan	2015
Model 4	4	26	Aggressive complex vocal tics (6 items), complex motor tics (5 items), simple head and vocal tics (9 items) and simple motor tics and self-touching (6 items)	GTS	85	CA, PCA	Alsobrook & Pauls	2002
Model 5	5	26	Aggressive complex vocal tics (6 items), complex motor tics (5 items), simple head and vocal tics (9 items), compulsive tics (2 items) and simple motor tics and self-touching (4 items)	GTS	410	CA, PCA	Robertson et al.	2008
OCD (Y-BOCS)								
Model 1	1	43	Obsessive and compulsive symptoms (43)					
Model 2	2	43	Obsessive symptoms (29 items) and compulsive symptoms (14 items)	OCD	83	CFA	McKay et al.	1995
Model 3	3	43	Symmetry and hoarding (11 items), contamination and checking (15 items) and pure obsessions (17 items)	OCD	107	EFA	Baer et al.	1994
Model 4	4	43	Aggressive obsessions and checking (25 items), symmetry (7 items), contamination (9 items) and hoarding (2 items)	OCD	292	EFA	Leckman et al.	1997
Model 5	5	43	Aggressive obsessions and taboo (10 items), contamination and cleaning (8 items), doubts and checking (7 items), superstition/rituals (9 items), and hoarding and symmetry (9 items)	OCD	1224	EFA (PCA)	Katerberg et al.	2010
ADHD (CAARS)								

Model in our study	Numb. of factors	Numb. of items used	Factors (Number of items loading on the factor)	Original Study sample	N in original study	Statistical method in original study	Reference	Year of publication
Model 1	1	18	Hyperactivity/impulsivity and inattention (18)					
Model 2	2	18	Hyperactivity/impulsivity (9 items) inattention (9 items)	ADHD	Unknown	FA	Conners et al.	1999
Model 3	3	18	inattention (9 items), hyperactivity (5 items) and impulsivity (4 items)	ADHD	532	CFA, EFA	Hardy et al.	2007
Autism (AQ)								
Model 1	1	50	Autism symptoms (50)					
Model 2	5	50	Social skills (10 items), attention switching (10 items), attention to detail (10 items) communication (10 items) and imagination (10 items)	Aspergers, control	1088	Unknown	Baron-Cohen	2001
Model 3	5	28	Social skills (7 items), routines (4 items) attention switching (4 items), imagination (8 items) and numbers and patterns (5 items)	ASD	3759	EFA, CFA	Hoekstra	2011

Note: YGTSS=Yale Global Tic Severity Scale, Y-BOCS= Yale-Brown Obsessive Compulsive Scale, CAARS= Conners Adult ADHD Rating Scale, AQ= Autism Questionnaire, CA=Cluster Analysis, FA= Factor Analysis, PCA=Principal Component Anaysis, EFA=Exploratory Factor Analysis, CFA= Confirmatory Factor Analysis

Table 2

Fit statistic CFA test results models in the GTS sample and the family sample for Tics, OCD, ADHD and autism (for a description of the models, see table 1).

	CFI		TLI		RMSEA		AIC		BIC	
Tics (YGTSS)	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**	**S1**	**S2**
Model 1	0.72	0.96	0.69	0.95	0.06	0.03	5232	3065	5404	3263
Model 2	0.78	0.97	0.76	0.97	0.05	0.03	5184	3044	5360	3246
Model 3	**0.92**	**0.99**	**0.91**	**0.99**	**0.03**	**0.02**	**4715**	**2933**	**4877**	**3120**
Model 4	0.87	0.97	0.86	0.97	0.04	0.03	5134	3029	5326	3250
Model 5	0.87	0.98	0.86	0.97	0.04	0.03	5125	3039	5134	3275
OCD (Y-BOCS)										
Model 1	0.86	0.91	0.85	0.90	0.04	0.03	5502	4295	5783	4621
Model 2	0.86	0.91	0.86	0.91	0.04	0.03	5491	4249	5776	4579
Model 3	0.90	0.92	0.89	0.92	0.03	0.03	5416	4215	5708	4553
Model 4	**0.92**	**0.92**	**0.92**	**0.92**	**0.03**	**0.03**	**5351**	**4167**	**5652**	**4516**
Model 5	0.90	0.93	0.89	0.92	0.03	0.03	5407	4151	5722	4518
ADHD (CAARS)										
Model 1	0.99	0.98	0.98	0.98	0.03	0.02	1718	1171	1830	1304
Model 2	0.99	0.98	0.99	0.98	0.02	0.02	1709	1168	1824	1305
Model 3	**1.00**	**0.99**	**1.00**	**0.98**	**0.02**	**0.02**	**1708**	**1164**	**1819**	**1304**
Autism (AQ)										
Model 1	0.62	0.58	0.60	0.56	0.05	0.04	9761	7534	10070	7826
Model 2	0.74	0.63	0.72	0.61	0.04	0.04	9556	7474	9897	7795
Model 3	**0.91**	**0.90**	**0.90**	**0.89**	**0.04**	**0.03**	**5180**	**3936**	**5384**	**4129**

Note. AIC= Akaike information criterion; BIC= Bayesian information criterion; CFI= comparative fit index, RMSEA= root mean square error of approximation; S1=:GTS sample; S2=Family sample ; TLI=Tucker Lewis Index. **Bold**: best fitting model. Best fitting models: Tics: 3 factors, OCD: 4 factors, ADHD: 3 factors and Autism: 5 factors.

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Table 3

Correlation matrix of symptom dimensions of GTS, OCD, ADHD and autism.
Above diagonal: GTS Sample/Family Sample 2, under diagonal: Combined sample

	Tic symptoms (YGTSS)			OCD symptoms (YBOCS)				ADHD symptoms (CAARS)			Autism symptoms (AQ)				
	Complex	**Body**	**Head**	**Agression**	**Symmetry**	**Conta Mination**	**Hoarding**	**Inatten tion**	**Hyper activity**	**Impulsivity**	**Social skills**	**Routines**	**Attention switching**	**Imagination**	**Numbers /patterns**
Complex	–	0.418***/0.955***	0.227*/0.856***	0.518***/0.643***	0.232**/0.328***	0.406***/0.621***	−0.085/0.371**	0.280*/0.594***	0.270**/0.603***	0.421**/0.757***	0.138/0.222	0.270*/0.263	0.394***/0.387*	0.093/0.485*	0.232*/0.719***
Body	0.495***	–	0.625***/0.925***	0.455***/0.453***	0.503***/0.354***	0.359**/0.369***	0.215/0.223*	0.094/0.512***	0.158/0.600***	0.048/0.623***	0.309**/0.283	−0.009/0.373	0.167/0.467*	−0.276**/0.357	0.238*/0.587**
Head	0.437***	0.616***	–	0.267**/0.325***	0.278**/0.310***	0.329*/0.304***	0.038/0.328**	0.086/0.413***	0.295*/0.391***	0.210/0.379***	−0.011/0.236	−0.008/0.232	0.048/0.474***	−0.348**/0.147	0.394***/0.352*
Agression	0.421***	0.460***	0.370***	–	0.649***/0.733***	0.844***/0.964***	0.471***/0.501***	0.333**/0.601***	0.052/0.524***	0.290*/0.645***	0.352***/0.117	0.246*/0.128	0.355**/−0.019	−0.102/0.146	0.567***/0.393***
Symmetry	0.325***	0.458***	0.362***	0.555***	–	0.741***/0.689***	0.383***/0.473***	0.138/0.329***	0.214/0.267**	0.275/0.463***	0.305**/−0.072	0.194/0.075	0.158/0.212	−0.268**/−0.013	0.480***/0.393**
Contamination	0.282***	0.301***	0.280***	0.568***	0.541***	–	0.487***/0.501***	0.459***/0.611***	0.188/0.541***	0.426**/0.663***	0.353**/0.112	0.475**/0.104	0.517***/−0.099	0.039/0.352**	0.526***/0.460***
Hoarding	0.117	0.239***	0.201***	0.427***	0.372***	0.388***	–	0.375*/0.433**	−0.028/0.371	0.371/0.441	0.404**/−0.013	0.027/−0.168	−0.005/0.173	−0.178/−0.310	0.424***/0.352*
Inattention	0.267***	0.265***	0.257***	0.276***	0.217***	0.259***	0.295***	–	0.845***/0.889***	0.867***/0.939***	0.351**/0.592**	0.272/0.474***	0.691***/0.564***	−0.064/0.524***	0.294**/0.406*
Hyperactivity	0.333***	0.406***	0.368***	0.217***	0.286***	0.215***	0.127	0.548***	–	0.855***/0.835***	0.270*/0.090	0.157/0.369**	0.238/0.369**	−0.183/0.635***	0.245/0.269
Impulsivity	0.332**	0.274***	0.264***	0.271***	0.289***	0.251***	0.268**	0.483***	0.601***	–	0.467***/0.312	0.344*/0.292	0.409***/0.494***	−0.146/0.637***	0.433**/0.452
Social skills	0.082*	0.158**	0.098***	0.137***	0.122**	0.129**	0.080	0.146**	0.133**	0.135**	–	0.668***/0.778***	0.524***/0.513***	0.290**/0.476**	0.380***/0.223
Routines	0.207**	0.196**	0.186***	0.223***	0.179**	0.285***	−0.049	0.238***	0.205**	0.237**	0.289***	–	0.673***/0.609***	0.382**/0.768***	0.207/0.386**
Attention Switching	0.220***	0.203***	0.166***	0.213***	0.155**	0.254***	0.046	0.342***	0.213***	0.245***	0.190***	0.366***	–	0.193/0.510***	0.152/0.242*
Imagination	0.082	−0.013	−0.008	−0.012	−0.076	0.063	−0.129	0.099*	0.076	0.104	0.122**	0.263***	0.154**	–	−0.232/0.301
Numbers/patterns	0.191***	0.218***	0.202***	0.337***	0.308***	0.317***	0.252***	0.169**	0.282*	0.249***	0.130**	0.196***	0.120*	0.022	–

Note:

*
=sig <0.05;

**
=sig<0.01;

***
=sig<0.001,

Grey: symptom factors within checklists/symptom domains

Table 4

Factor eigenvalues and χ^2 difference tests between EFA factor solutions

Factors	**1**	**2**	**3**	**4**	**5**	**6**
Eigen value	4.68	1.63	1.30	1.17	1.00	0.86
AIC	21439	21126	20982	20792	**20757**	20776
BIC	21568	21314	21227	**21088**	21101	21132
χ^2	860.48	519.31	349.18	135.19	78.68	47.39
Df	90	76	63	51	40	30

Difference	1−2	2−3	3−4	4−5	5−6
χ^2	341.17	170.14	213.99	56.51	22.17
df	14	13	12	11	10
p	0.000	0.000	0.000	0.000	0.014

Note. AIC= Akaike information criterion; BIC= Bayesian information criterion.

Table 5

Factor loadings of the five factor solution.

		Factor				
	Symptom	**1 Tics**	**2 OCD**	**3 ADHD**	**4 Autism**	**5 Inattention**
Tic symptoms	Complex tics	**0.60**	*0.36*	*0.37*	0.28	0.16
(YTGSS)	Body tics	**0.85**	*0.43*	*0.38*	0.21	0.16
	Head and neck tics	**0.72**	*0.36*	*0.36*	0.19	0.15
OCD symptoms	Aggression	*0.55*	**0.75**	0.24	0.24	0.27
(Y-BOCS)	Symmetry	*0.51*	**0.70**	0.30	0.21	0.12
	Contamination	*0.37*	**0.74**	0.23	0.31	0.26
	Hoarding	*0.25*	**0.59**	0.16	−0.18	*0.44*
ADHD symptoms	Inattention	*0.32*	0.32	0.60	0.27	**0.64**
(CAARS)	Hyperactivity	*0.47*	0.27	**0.89**	0.24	0.23
	Impulsivity	0.34	*0.36*	**0.68**	0.26	*0.36*
Autism symptoms	Social skills	0.14	0.19	0.14	**0.33**	0.18
(AQ)	Routines	0.22	0.28	0.25	**0.72**	0.22
	Attention switching	0.24	0.24	0.25	**0.49**	*0.39*
	Imagination	0.00	0.05	0.12	**0.38**	0.03
	Numbers and patterns	0.26	**0.44**	0.29	0.18	0.11

Note: **bold**: primary factor loadings; *italic*: Cross-loadings ≥ 0.35; Grey: Cross-loadings <0.40