Exploring the quantitative nature of empathy, systemising and autistic traits using factor mixture modelling

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**Background**
Autism research has previously focused on either identifying a latent dimension or searching for subgroups. Research assessing the concurrently categorical and dimensional nature of autism is needed.

**Aims**
To investigate the latent structure of autism and identify meaningful subgroups in a sample spanning the full spectrum of autism.

**Method**
Factor mixture models were applied to data on empathy, systemising and autistic traits from individuals on the autism spectrum, parents and general population controls.

**Results**
A two-factor three-class model was identified, with two factors measuring empathy and systemising. Class one had high systemising and low empathy scores and primarily consisted of individuals with autism. Mainly comprising controls and parents, class three displayed high empathy scores and lower systemising scores, and class two showed balanced scores on both measures of systemising and empathy.

**Conclusions**
Autism is best understood as a dimensional construct, but meaningful subgroups can be identified based on empathy, systemising and autistic traits.

**Declaration of interest**
None.

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A central debate in the development of DSM-5 has been whether psychopathology is best conceptualised as a continuum of severity or as discrete categories of disorder, including the DSM-5 criteria for autism spectrum disorder. Understanding the latent structure of autism, also referred to as autism spectrum conditions (ASC), is important for guiding future conceptualisations of diagnostic criteria, as well as for informing the development of instruments assessing characteristics of ASC. A number of studies have assessed the latent structure of autism using either dimensional or discrete statistical techniques. In contrast to these methods, factor mixture modelling allows for the presence of a concurrently dimensional and categorical latent structure. Three papers have previously applied mixture modelling to assess the latent structure within children with a clinical ASC diagnosis and non-affected siblings. However, to date none of this work has focused on adult samples. Moreover, there is a large evidence base for the quantitative nature of autistic traits in the general population, with undiagnosed first-degree relatives of individuals with autism displaying intermediate (or subthreshold) levels of autistic traits, also termed the broader autism phenotype (BAP). It is therefore important to assess the latent structure of autism across the full range of genetic vulnerability, from low-risk general population samples to first-degree relatives (medium risk) and individuals with a clinical ASC diagnosis. The Empathising–Systemising (E–S) theory of autism argues that the persistent deficits in communication and social interaction in autism can be accounted for by an impairment in empathy, particularly cognitive empathy (also referred to as ‘theory of mind’), whereas the restricted or repetitive behaviours and unusually narrow interests can be explained by a strong drive to systemise.

Previous research in the same sample as reported here suggested that empathy and systemising are discrete constructs that can reliably be measured in control samples, parents and individuals with ASC. The current study elaborates on these findings using mixture modelling methods. The study aims to assess the dimensional latent structure of empathy, systemising and autistic traits among individuals on the spectrum, first-degree relatives and the general population, while simultaneously examining whether meaningful subgroups can be identified.

**Method**

Participants
Individuals with autism, parents of a child with autism and general population controls were recruited via two volunteer webpages at the University of Cambridge (www.autismresearchcentre.com; www.cambridgepsychology.com). The total sample consisted of 1034 individuals (controls 232, parents 439, ASC group 363). Controls were restricted to individuals with no psychiatric history and consisted of 110 females and 122 males (mean age 33 years, s.d. = 10). The parent group contained 298 females and 141 males (mean age 42 years, s.d. = 8). Parents were included in the study if they had a child with a formal ASC diagnosis, but did not report having a diagnosis of autism themselves. The ASC group comprised 170 females and 193 males (mean age 36 years, s.d. = 11). These individuals had received a formal clinical diagnosis of autism. The individuals in the parent and ASC groups were not part of the same family. IQ was assessed via an online adapted version of the Ravens Progressive Matrices. The control group scored significantly higher on the Ravens than both the parent group (P<0.01) and individuals with ASC (P<0.01). There were no differences in IQ between parents and individuals with autism (P=0.11). As this study relied on self-report, the

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ASC group was restricted to high-functioning individuals, who were able to effectively complete these online questionnaires.

**Measures**

**Autistic traits**

The Autism Spectrum Quotient (AQ)\(^{16}\) is designed to assess quantitative autistic traits including those related to communication, social skills, attention to detail, imagination and attention switching. A total of 50 items are assessed with four response options: ‘definitely agree’, ‘definitely disagree’, ‘slightly agree’ and ‘slightly disagree’. A raw scoring method was used,\(^{17}\) eliciting scores ranging from 50 to 200, higher scores indicating more autistic traits. Previous research suggested the AQ can be split into two reliable subscales relating to social and non-social traits.\(^{17}\) A broad social interaction factor (comprising 40 items assessing communication, social skills, imagination and attention switching) and an attention to detail factor (consisting of the remaining 10 items) were included in all analyses.

**Systemising**

The Systemising Quotient Revised (SQ)\(^{18}\) is a measure designed to assess an individual’s propensity to systemise; to construct and understand rule-based systems for categorisation. This measure includes 75 items scored on a Likert response scale with four response options: ‘strongly agree’, ‘strongly disagree’, ‘slightly agree’ and ‘slightly disagree’. Strong responses score one point, with slightly agree/disagree responses receiving one point. Scores range from 0 to 150, with higher scores indicative of a heightened drive to systemise.

**Empathy**

The Empathy Quotient (EQ)\(^{19}\) is a self-report measure of empathy. This 40-item measure includes equivalent response options and scoring methods to the SQ. Full endorsement of all items gives a score of 80, with higher scores indicative of a better capacity to empathise.

Apart from the AQ, SQ and EQ self-report questionnaires, which were included in the mixture analyses, data were also collected on two performance-based measures of empathy. Due to a large proportion of missing data in the sample of fathers these measures were not included in the factor analyses. The “Reading the Mind in the Eyes’ test revised (Eyes)\(^{18}\) assesses how accurately an individual can read the emotion in another by viewing only the eye region of the face. A total of 36 items are presented with four response options ranging from happy, sad, angry, afraid, disappointed, surprised and neutral, and giving participants the opportunity to view the whole face. This measure consists of 140 items in which accuracy and response time information is recorded. Response times were weighted for accuracy.\(^{22}\) For ease of interpretation, the KDEF was rescored so that higher values indicate higher ability rather than a slower response time.

**Analytic strategy**

Confirmatory factor analyses (CFA) were conducted to assess the dimensional structure of empathy, systemising and autistic traits using the EQ, SQ and the two subscales of the AQ. A one-factor model was implemented to assess whether these traits lie on a continuum of severity (Model 1). Next, a two-factor model representing the distinction between empathy and systemising was fit to the data (Model 2). The EQ and the social interaction factor of the AQ were predicted to load onto a factor representing empathy, with the SQ and the attention to detail factor of the AQ loading onto a second-factor representing systemising.

**Results**

As reported previously,\(^{18,20,32}\) there were a number of differences in the mean scores on the questionnaires for controls, parents and individuals with ASC (Table 1). Individuals with ASC scored significantly lower on the social interaction items of the AQ and...
higher on the attention to detail items compared with controls and parents \((P<0.01)\). Individuals with ASC also obtained significantly higher SQ scores and lower EQ scores compared with all other participants. Parents scored significantly lower on the social interaction factor of the AQ than controls \((P<0.05)\). Control females displayed higher scores on the AQ and on the AQ social interaction factor as well as lower scores on the SQ than control males \((P<0.01)\). This pattern was also observed among parents \((P<0.01)\). Males with ASC displayed higher scores on the social interaction subscale of the AQ than females with ASC \((P<0.01)\), whereas females displayed higher scores on the attention to detail items of the AQ than males with autism \((P<0.05)\). However, there were no gender differences within the ASC group on the other two measures.

Model fit indices for the CFA, LCA and FMM analyses are given in Table 2. Results from the CFA indicated that a two-factor model (Model 2) consisting of empathy and systemising provided the best fit to the data, with lower AIC, BIC and SSABIC values than the one-factor model. There was a moderate negative correlation between the two factors, suggesting that better systemising is associated with lower empathy abilities. LCA models with up to five latent classes were then estimated. The LMR value for the five-class model did not reach significance, indicating that a model with one less class provided a better classification of individuals. The four-class LCA also had the smallest AIC, BIC and SSABIC values of the remaining four models (Model 6) as well as an entropy statistic of 0.81. This model was therefore selected as providing the best fit to the data.

Mixture models consisting of one and two factors and up to five latent classes were then implemented. The smallest BIC values were identified in the two-factor three-class and two-factor four-class models. The three-class model had the smallest BIC value as well as the largest entropy value and provided the most parsimonious explanation for the data. This model, designating three classes with varying levels of empathy, systemising and autistic traits, was therefore selected as the best fitting model.
Individuals with ASC made up the majority of Class S (71%), along with 23% of parents and a very small proportion of controls (6%). Class B consisted of approximately 39% controls, 50% parents and 11% of individuals with ASC. Class E consisted predominantly of parents (67%) and controls (32%) with a very small proportion of those with ASC (1%). Within the parent group, 38% of fathers compared with 18% of mothers fell into Class S. Half of the sample of mothers fell into Class E compared with 20% of fathers.

The proportion of males, females, controls, parents and individuals with ASC falling into each class is given in Fig. 2. Class E primarily comprised females, whereas the gender division was similar in the other two classes. Individuals with ASC made up the majority of Class S (71%), along with 23% of parents and a very small proportion of controls (6%). Class B consisted of approximately 39% controls, 50% parents and 11% of individuals with ASC. Class E consisted predominantly of parents (67%) and controls (32%) with a very small proportion of those with ASC (1%). Within the parent group, 38% of fathers compared with 18% of mothers fell into Class S. Half of the sample of mothers fell into Class E compared with 20% of fathers.

Structural equation modelling including CFA, LCA and FMM analyses in a large sample of individuals with ASC, parents and controls indicated that the characteristics of autism, as measured in a sample spanning the full spectrum of genetic liability, are best described by a two-factor three-class mixture model. The quantitative nature of autistic traits is best captured by two moderately correlated latent factors representing systemising and empathy. In addition, three homogeneous latent classes of individuals could be identified by their mean scores on measures of empathy, systemising and autistic traits. Class one displayed superior performance on systemising, with significantly lower scores on both self-reported and performance-based tests of empathy (Class S). Class three demonstrated the opposite effect, showing increased scores on empathy tasks and lower performance on self-report measures of systemising (Class E). Class two appeared to be more balanced in terms of both empathy and systemising propensity (Class B).

The results provide support for the E–S theory, indicating that empathy and systemising are two separate constructs that together may partly provide a cognitive explanation of the characteristics of autism. The findings also lend indirect support to the current DSM-5 diagnostic criteria, including social and communication impairment (represented in the current study by difficulty with empathy) and repetitive behaviours and narrow interests (represented here by high systemising scores). EQ items map onto empathy) and repetitive behaviours and narrow interests (represented here by high systemising scores). EQ items map onto empathy. In addition, three homogeneous latent classes of individuals could be identified by their mean scores on measures of empathy, systemising and autistic traits. Class one displayed superior performance on systemising, with significantly lower scores on both self-reported and performance-based tests of empathy (Class S). Class three demonstrated the opposite effect, showing increased scores on empathy tasks and lower performance on self-report measures of systemising (Class E). Class two appeared to be more balanced in terms of both empathy and systemising propensity (Class B).

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Fig. 1 Mean scores on self-report and performance tasks across classes.

AQatt, Attention to detail factor of the Autism Spectrum Quotient; AQsoc, Social interaction factor of the Autism Spectrum Quotient; EQ, Empathy quotient; Eyes, Reading the Mind in the Eyes task; KDEF, Karolinska Directed Emotional Faces task; SQ, Systemising Quotient Revised.

Fig. 2 Gender and group membership in each class.

ASC, autism spectrum condition.
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relationships. For example, ‘I can easily tell if someone else wants to enter a conversation’, ‘I am quick to spot when someone in a group is feeling awkward or uncomfortable’ and ‘friendships and relationships are just too difficult, so I tend not to bother with them’. The restricted or repetitive behaviour or interests domain in DSM-5 contains four criteria relating to stereotyped and repetitive movement or use of objects, insistence on sameness, fixedated interests and hyper- or hyporeactivity to sensory stimuli. The first three of these DSM-5 criteria may be (partly) accounted for by a drive to systemise. By engaging in stereotyped and repetitive actions, insisting on sameness and focusing on circumscribed interests, the world becomes more predictable and therefore easier to negotiate. It is as yet less clear how sensory reactivity relates to empathy and systemising. A recent study reported an association between sensory sensitivity and autistic traits, with greater sensitivity associated with more traits on the autism spectrum. However, further research is needed to comprehensively understand the association between sensory reactivity, empathy and systemising.

The two-factor structure found in the current study is consistent with previous factor analytic studies directly assessing autistic characteristics via diagnostic instruments, suggesting that the autism phenotype follows a dyadic structure comprising social communicative difficulties and non-social autistic traits. However, the two factors identified in the present study were moderately correlated \((r = -0.49)\), indicating that empathy and systemising are not entirely independent.

The E–S theory posits that there are five different cognitive profiles that can be identified based on empathy and systemising. Type E \((E > S)\) are individuals with stronger empathy than systemising ability; Type S \((S > E)\) comprises individuals with systemising ability that is stronger than their empathy skills; Type B \((E = S)\) includes individuals with similar empathy and systemising ability; Extreme Type E \((E > S)\) comprises individuals with above average empathy who have difficulty with systemising; and last, Extreme Type S \((S > E)\) includes individuals with above-average systemising who have difficulty with empathy. Individuals with autism are thought to be represented by the Extreme Type S cognitive profile, with varying combinations of the other cognitive profiles in the general population. Using factor mixture modelling techniques, the current study identified classes that map very well onto the Type S, B and E profiles outlined in this theory.

Class S was characterised by low empathy and high systemising scores. It consisted predominantly of individuals with autism (both males and females), with only a very small proportion of the control sample falling into this class. The observation that the majority of individuals with ASC in this study (90%) were identified within Class S follows the predictions of the E–S theory, with autism being characterised by an interest in systemising and difficulties with empathy. However, the finding that a small proportion of individuals with ASC also fell into the other two classes identified highlights the heterogeneity of autism: not every individual with ASC displays the Type S cognitive profile and shows superior systemising and impaired empathy. Approximately 20% of Class S comprised parents of a child with ASC, suggesting that these individuals display the BAP. Propotionally, more fathers than mothers fell into Class S (38% vs. 18% respectively). This is consistent with previous research suggesting that the BAP is more common in male relatives.

The findings of this study should be interpreted in the light of some limitations. Although the gender ratio was balanced for the...
control and ASC groups, there was a larger proportion of mothers (n = 298) than fathers (n = 141) in the parent group. Future research would benefit from the inclusion of more fathers for comparison. Second, this study included similar numbers of males and females, which is different from the documented gender ratio for ASC diagnoses of approximately 4:1. This relative over-representation of female participants with ASC is potentially due to the volunteer bias of online recruitment, with females being more likely to volunteer for research participation than men. However, given that males and females with ASC were equally distributed over the different classes (Class S: males = 170, females = 155; Class B: males = 21, females = 14; Class E: males = 2, females = 1), it is unlikely that this had a significant impact on the analyses and results of the study.

Third, this study only included performance-based measures of empathy abilities; no performance-based measure of systemising was available to compare against the self-report questionnaire data. It should be stressed that as this study included self-rated measures, all individuals with ASC were high functioning. The results from this study can therefore not be generalised to individuals with ASC and intellectual disability. Given that the data were collected online, it was also not possible to verify diagnoses of autism. However, there is evidence to suggest that clinical diagnoses of ASC reported by online volunteers are generally reliable.

In conclusion, this study assessed the quantitative nature of empathy, systemising and autistic traits among individuals on the spectrum, first-degree relatives and general population controls. Results highlighted a two-factor three-class model in which two dimensions based on systemising and empathy were identified. This provides indirect support for the new diagnostic criteria outlined in DSM-5, which follow a dyadic rather than a triadic structure and include a dimensional rather than a categorical approach. Three meaningful classes were defined based on mean scores on empathy, systemising and autistic traits. Taken together, these results support the quantitative approach to autistic traits and confirm that even with the use of quantitative measures, meaningful subgroups can be identified.

References

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BJP published online September 17, 2015 Access the most recent version at DOI: 10.1192/bjp.bp.114.155101

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Published online 2015-09-17T00:05:16-07:00 in advance of the print journal.

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