Psychometric properties of the Chinese version of the children's empathy quotient and systemizing quotient

Psychometric Properties of the Chinese Version of the Children's Empathy Quotient and Systemizing Quotient: 4-12 years

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Authors' contributions

XW, MD, LL, SL and JC contributed to the data collection. XW, MD designed the current study. XW and MD performed the statistical analysis and drafted the manuscript. AM, BA guided the statistical analysis. LL, JJ supervised the analysis and revised the manuscript. All authors read and revised the manuscript, and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Data availability statement

The generated datasets available by request to the corresponding author.

Abstract

We aimed to validate the Children's Empathy Quotient (EQ-C) and Systemizing Quotient (SQ-C) in Mainland China, which can reflect the profiles of empathizing and systemizing, and describing specific characteristics of autism spectrum disorder (ASD) and gender-typical behaviors in general population. A total of 800 typically developing (TD) children, aged 4-12 years was recruited initially with whose parents/guardians complete the measurements, and 782 TD children who met inclusion criteria were finally included. A 23-item three-factor EQ-C and a 22-item four-factor SQ-C was developed with good internal consistency (Omega total values of 0.87 and 0.86) and test-retest reliability (Pearson correlation coefficients of 0.82 and 0.69). In TD children, girls scored significantly higher on EQ-C (31.4±7.8 vs. 28.2±7.7) but there were no gender differences in SQ-C scores. TD children showed different cognitive styles (empathizing-dominant for girls with 42.6% identified as Type E; systemizing-dominant for boys with 40.7% identified as Type S). A further sample of 222 children with ASD indicated that they scored lower on EQ/SQ-C compared to TD children (13.2±5.1 vs. 29.7±7.9, 12.4±5.8 vs. 23.5±8.3) and were generally systemizing-dominant (Type S: 50.8% for boys and 64.0% for girls). Autistic children scored higher on the SQ-C in those without intellectual disability and with higher paternal education level and family income (14.2±6.1 vs. 10.9±5.0, 13.3±6.2 vs. 11.5±5.1,13.7±5.6 vs. 11.9±5.8), while there were no differences in the EQ-C. This study indicated good reliability and validity of the Chinese version of EQ/SQ-C, which can be used in Chinese children with and without ASD.

Lay Summary: We developed the Chinese version of the Children's Empathy Quotient (EQ-C) and Systemizing Quotient (SQ-C) in 782 typical developing (TD) children aged 4-12 years in Mainland

China, yielding a 23-item, 3-factor EQ-C and a 22-item, 4-factor SQ-C with good psychometric properties. In TD children, we found gender difference only in scores of EQ-C. Further analyses of 222 autistic children indicated that differences were found in scores of SQ-C when considering their gender, intelligence and socio-economic status.

Keywords: empathy quotient, systemizing quotient, autism spectrum disorder, gender differences, children

Introduction

There is a drive to understand different features or dimensions that might contribute to the experiences of autistic individuals beyond the core deficits in autism spectrum disorder (ASD), namely in social communication and the presence of repetitive behaviors and/or restricted interests(Baron-Cohen, 2002, 2009). The profiles of empathizing and systemizing can be used to reflect specific characteristics of ASD related to these two deficits, and describe gender-typical behaviors in general population(Goldenfeld, 2005; Greenberg, Warrier, Allison, & Baron-Cohen, 2018; Lawson, Baron-Cohen, & Wheelwright, 2004). 'Empathizing' is the drive to identify another person's emotions and thoughts, and to respond to these with an appropriate emotion; while 'Systemizing' is the drive to analyze the variables in a system, to derive the underlying rules that govern the behavior of a system(Baron-Cohen, 2002). These two components allow individuals to predict the behaviors of a person or system thereby achieving socialization and adaptation(Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Golan & Baron-Cohen, 2006).Accordingly, two parent-reported questionnaires have been developed for children to measure the extent to which children possess empathizing and systemizing; the children's empathy quotient (EQ-C) and systemizing quotient (SQ-C) (Auyeung et al., 2009).

Previous studies suggested good cross-cultural stability of the EQ-C and SQ-C among different countries, but with some differences(Auyeung et al., 2009; Chaidir, Nathania, Mahdiyyah, Phallavi, & Wiguna, 2020; Escovar, Rosenberg-Lee, Uddin, & Menon, 2016; Huang, 2015; Nasr Esfahani et al., 2018; Park et al., 2012; Sonié et al., 2011; Wakabayashi, 2013) (**Table S1 and S2 in Appendix A**). Specifically, these previous studies focused on gender difference when characterizing the profiles of EQ-C and SQ-C. For example, studies of general population in UK(Auyeung et al., 2009)

and Japan(Wakabayashi, 2013) found significant gender difference on both empathizing and systemizing. However, research from Korea(Park et al., 2012) revealed a gender difference only in systemizing while other studies of Taiwan, China and Indonesia(Chaidir et al., 2020) indicated a gender difference only in empathizing. Meanwhile, there were small or no gender differences in children with ASD when examining scoring patterns on the EQ/SQ-C (Auyeung et al., 2009; Nasr Esfahani et al., 2018; Park et al., 2012) in previous cross-culture studies. In addition, the cognitive 'brain types' constructed by empathizing and systemizing were also reported showing that TD girls were mostly identified as empathizing-dominant type, while TD boys were mostly identified as systemizing-dominant type (Auyeung et al., 2009; Wakabayashi, 2013). The vast majority of children with ASD were found to exhibit 'hyper-masculinization' type(Auyeung et al., 2009).

In China, to our knowledge, no psychometric properties of a Chinese variant of these questionnaires are available yet. Specifically, since about 30%-70% of autistic children were identified as having an intellectual disability (ID) in previous prevalence studies (Maenner et al., 2020; Matson & Shoemaker, 2009; Mefford, Batshaw, & Hoffman, 2012), and earlier work has seldom investigated empathizing and systemizing in this subpopulation. Meanwhile, socioeconomic status (SES), defined as the social and material resources an individual possesses(Kraus, Cote, & Keltner, 2010), has been identified as a potential influence on the development of empathy and systemizing(Takeuchi et al., 2018). Therefore, this study aims to address these two challenges through the development of a Chinese version of the EQ/SQ-C.

Here we aim to validate the Chinese version of the EQ/SQ-C in children aged 4-12 years from both clinical and general population. Through this sample, we aim to: (1) examine the psychometric properties of a new Chinese translation of the EQ/SQ-C for use in mainland China; (2) investigate

gender differences and cognitive brain types based on the EQ/SQ-C in Chinese children with and without ASD; and (3) understand the differences of EQ/SQ-C scores in autistic children by considering their intelligence and socio-economic status.

Methods

Participants

The current study included a group of typically developing children (n=800, 436 boys, 364 girls) aged 4-12 years from two samples: 1) 300 children from mainstream kindergartens in the Luohu District, Shenzhen City and 2) 500 children from a mainstream primary school in the Huangpu District, Guangzhou City. Questionnaires were distributed to parents of children from these two samples.

We also recruited children with a diagnosis of ASD for further analyses from two samples. In ASD sample 1, 144 autistic children (128 boys, 16 girl) were recruited between 2017 and 2020 from the Research Center of Children and Adolescent Psychological and Behavioral Development in the Department of Public Health, Sun Yat-sen University. In ASD sample 2, 78 autistic children (69 boys, 9 girls) were recruited from three therapeutic centers in Guangzhou City located in Southern China, which offered therapeutic services for children with ASD and other developmental disorders. All the participants had a historical diagnosis of ASD confirmed by the Childhood Autism Rating Scale (CARS) and an expert clinician in the hospitals. Diagnoses were further confirmed by two expert child psychiatrists (Jin Jing and XiuHong Li) using Diagnostic and Statistical Manual of Mental Disorders, Fifth Revision (DSM-5) criteria.

All the participants were recruited during 2017-2020. The inclusion criteria for TD children and

children with ASD were as follows: (1) chronological age between 4 years 0 months and 12 years 12 months; (2) voluntarily participation of the children's parents; (3) absence of head trauma, cerebral palsy, or other movement disorders that would interfere with study assessments; and (4) absence of known genetic or chromosomal abnormalities or severe visual or hearing impairment. The exclusion criteria were as follow: (1) missing data of the questionnaire was more than five items; (2) there were parent-reported neuropsychiatric conditions, such as ASD (only in TD children), attention deficit/ hyperactivity disorder, dyslexia, tic disorder, mood disorder and other disorders those would interfere with social ability. The demographic characteristics of TD children and children with ASD were shown in **Table S3 in Appendix A**.

All the parents of the participants provided written consent. The study received approval from the Ethical Review Committee for Biomedical Research, Sun Yat-sen University (2015-No.29, 2020-No.133).

Instruments

A Chinese translation of the children's Empathy Quotient (EQ-C) and Systemizing Quotient (SQ-C) was used. The measure includes items rated on a 3-point scale: 2 = definitely agree, 1 = slightly agree, 0 = disagree/strongly disagree (Auyeung et al., 2009). Items 2, 4, 7, 9, 13, 17, 20, 23, 33, 36, 40, 53 and 55 for the EQ-C and item 3, 11, 15, 16, 22, 27, 32, 47, 51 and 54 for the SQ-C are reverse scored, where 'slightly disagree' scores one point, 'definitely disagree' scores two points, and 'slightly agree' or 'definitely agree' scores zero points. The maximum attainable score for the EQ-C is 54, and for the SQ-C is 56.

Five cognitive 'brain types' can be defined by comparing an individual's performance on the EQ-

C and SQ-C using standardized scores which were calculated according to the formulae suggested by Bonnie Auyeung et al(Auyeung et al., 2009). The five types include Extreme Type E (Empathizer), Type E, Type B (Balanced), Type S (Systemizer), and Extreme Type S, and the detail information was described in the supplemental file (**Appendix B**).

The translation of the EQ-C and SQ-C followed the forward and backward procedure(Hall et al., 2018). First, two of the authors (Lizi Lin and Meixia Dai) translated the items from English into Chinese independently, discussed and resolved any differences that arose during the translation. Then, an English-Chinese bilingual developmental and behavioral specialist (Jin Jing) checked whether the translated items corresponded with the original English items and also took into account any cultural adjustments. For example, we avoided using "Meccano model" in item 12 because this kind of item is not popular among Chinese children. Other cultural adjustments were listed in **Table S4** in **Appendix A**. An English-Chinese bilingual translator then back-translated Chinese items into English and checked whether the items corresponded with the original English items. Finally, the Chinese version of EQ-C and SQ-C was modified via discussion with the original author (Bonnie Auyeung), and the final version was agreed.

Cognitive measures for children with ASD

All children with ASD underwent face-to-face cognitive measures, and we assessed developmental quotient (DQ) using the Chinese version of Gesell Development Scale (GDS) (Xiuling, 1994) (≤6 years) and intelligence quotient (IQ) using the Chinese version of Wechsler Intelligence Scale for children, Fourth vision (WISC-IV) (>6 years)(Houshen, 2009), which has been validated in mainland China with relatively good reliability and validity(Houshen, 2009; Xiuling, 1994). These measures were performed by trained psychometrists, graduate students, or

research assistants, who were trained by certified professionals of two authors (Xin Wang and Meixia Dai). All of them have practiced within the research group and they were allowed to perform measurements only when they passed the qualifying examination. The GDS provides DQ calculated by five domains: adaptive behavior, gross motor, fine motor, language behavior and personal-social behavior(Xiuling, 1994). WISC-IV provides a full-scale intelligence quotient (FSIQ) based on the sum of scores from the 10 core subtests, as well as four index scores: Verbal Comprehension Index, Perceptual Reasoning Index, Working Memory Index, and Processing Speed Index(Houshen, 2009). DQ scores ≤ 75 or FSIQ < 70 was classified as intellectual disability (ID) group.

Demographic information

We obtained children's age, gender, maternal and paternal age, maternal and paternal education level, and per capita monthly household income via questionnaires. We defined low education levels as parents who completed their highest education in primary, secondary and high school. We defined low and high per capita monthly household income based on the statistics from the Guangzhou Statistical Yearbook 2021 (i.e., mean of ¥7123 per month for upper middle-income households)(Guangzhou Statistic Bureau Survey Office of the National Bureau of Statistics in Guanghzou, 2021).

Statistical analyses

We calculated the means and standard deviations for continuous variables and percentages for categorical variables. We compared the basic information between TD children and children with ASD using chi-square tests and t-tests. We evaluated the gender difference by reporting effect size of Cohen's *d*(Cohen, 1988).

We carried out multivariate analyses on the EQ/SQ-C to confirm their factorial consistency. Given the ordinal nature of the three-ordered item categories (i.e., definitely agree, slightly agree and disagree/strongly disagree), we perform the confirmatory factor analysis (CFA) with diagonally weighted least squares (DWLS) method(Rhemtulla, Brosseau-Liard, & Savalei, 2012) to examine the original one-factor structure of EQ/SQ-C. A variety of fit indices (listed in **Appendix B**) to determine if the model fit is acceptable, and the original structure of EQ/SQ-C fitted adequately. We also tested the best fitting model by removing items with low item-total correlations ($\leq$ 0.30)(Ferketich, 1991) .

In addition, we hypothesized that the cross-cultural adaptions of the two instruments might change their internal structure, and we therefore followed a standard procedure by conducting both exploratory factor analysis (EFA) and CFA to understand their current structures. We randomly split the original sample into a calibration and validation sample with the EFA on one half and the CFA on the other. We confirmed that the polychoric correlation matrix of EQ/SQ-C was factorable(Lee, Zhang, & Edwards, 2012), and then used Bartlett's test of sphericity to ensure that the polychoric correlation matrix was not random and the overall Kaiser-Meyer-Olkin (KMO) statistic was above a minimum of 0.50. Common factor analysis was selected because the intent was to identify a latent factor structure. Very Simple Structure (VSS)(Cattell, 1966), parallel analysis(Horn, 1965) and the visual scree test(Velicer, 2000) were used to determine the appropriate number of factors to retain. Parallel analysis with polychoric correlations, using principal component analysis (PCA) method of extraction and the mean eigenvalue criterion(Garrido, Abad, & Ponsoda, 2013). After determining the number of factors to retain, ordinary least squares (OLS) estimation of parameters in EFA with polychoric correlations was used(Lee et al., 2012) and an oblique (Promax) rotation was employed

to rotate the factors (Watkins, 2018). The CFA was performed based on the results of EFA with items assigned to a factor having a loading >|.3| was estimated, using the DWLS method (Detail listed in **Appendix B**).

For testing the reliability of the instrument, we applied a set of analyses including internal consistency (Cronbach's alpha coefficients, Omega Hierarchical coefficients and Omega Total coefficients [α, ωh and ωt]) and test-retest reliability (Pearson correlation coefficient).

We examined the known-groups validity by comparing the gender difference in both TD children and children with ASD separately. In children with ASD, we also compared the difference of EQ-C score and SQ-C score in children with different intelligence levels and SES.

We conducted all statistical analyses in the statistical software R 4.0.3 (R Core Team 2019) and its psych package (Version 2.0.12). We considered a two-sided *P* value <0.05 as statistically significant.

Results

Four questionnaires were discarded due to missing data on more than five items, and another fourteen questionnaires were discarded because parents reported that the TD children were diagnosed with neuropsychiatric conditions (three with ASD, four with attention deficit/hyperactivity disorder, three with dyslexia, two children with tic disorder, one with mood disorder and one with seizure). A total of 782 TD children (mean age:7.9±2.3 years, 423 boys, 359 girls) and a total of 222 children with ASD (mean age 7.2±1.8 years, 197 boys and 25 girls) were included in the final analyses.

Factorial validity

Three CFA models were tested. Model 1 tested the original one-factor solution as proposed by the original study. Model 2 tested a one-factor solution by excluding the items with item-total correlations less than or equal to 0.30. We removed several items in EQ-C (item 7, 17, 40 and 43) and SQ-C (item 12, 15, 21, 51 and 54) according to the item-total correlations (**Table S5** and **Table S6** in **Appendix A**). Model 3 tested a three-factor 23-item solution for EQ-C and a four-factor 22-item solution for SQ-C based on the results of EFA. During the EFA procedure, we examined the factorability of the EQ-C and SQ-C after testing the significance of Bartlett's test of sphericity (χ^2=2138.32 and 1972.25, all df=253, all P< 0.001) and obtaining the overall Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy (0.84 and 0.82). We chose Model 3 based on the best fit indices which were shown in **Table 1** (The standard factor loading of CFA for EQ-C and SQ-C was in **Table S7** and **Table S8** in **Appendix A**).

In the EQ-C, according the result of VSS, parallel analysis and scree plot **(Figure S1** in **Appendix A**), three factors were identified (the different number of factor solutions were listed in **Table S9** in **Appendix A**). The factor loadings of the included items varied from 0.314 to 0.798, accounting for 39.0% of the total variance (**Table S10 in Appendix A**). The three factors were labeled as "cognitive empathy" with nine items (1, 2, 6, 13, 18, 26, 28, 30 and 42), "social skills" with eight items (4,9, 20, 23, 33, 36, 53, 55) and "affective empathy" with six items (14, 31, 37, 45, 48, 52).

In the SQ-C, a four-factor model should be retained according to the VSS and parallel analysis (the scree plot was showed in **Figure S2** and the different number of factor solutions were listed in **Table S11** in **Appendix A**). We extracted four factors with 22 items (item 38 was removed because the factor loading <0.3) and factor loads varied from 0.306 to 0.830, accounting for 41.4% of the total variance (**Table S12 in Appendix A**). The four factors were labeled as "technical systems"

with eight items (24, 34, 35, 41, 44, 46, 49, 50), “abstract systems” with six items (25, 27, 29, 32, 39, 47), “organizable systems” with five items (3, 5, 11, 16, 22) and “collectible systems” with three items (8, 10, 19).

Internal consistency and test-retest reliability

The internal consistency was acceptable in both the EQ-C and SQ-C (Omega total value: 0.87 and 0.86; Omega Hierarchical value: 0.67 and 0.53; Cronbach’s alpha value: 0.85 and 0.85).

A total of 64 parents returned the second report two weeks after initial contact. There was a moderate correlation between the EQ-C scores or SQ-C scores obtained on the first and second visits for the overall scores (0.82, 95% CI: 0.72-0.89; 0.69, 95%CI: 0.53-0.80).

Known-groups validity of the EQ-C and SQ-C in Chinese children

According to the 23-item EQ-C and 22-item SQ-C, we calculated the total score and subscale scores based on the 23-item EQ-C and 22-tem SQ-C (see **Table 2**). With regards to the EQ-C, TD girls scored higher than TD boys in the total scores (31.4±7.8 vs. 28.2±7.7) and the three subscale scores (cognitive empathy: 12.2±3.5 vs. 11.3±3.5; social skill: 11.0 ± 3.3 vs. 9.6±3.6; affective empathy: 8.2±2.7 vs. 7.2±2.7). However, there were no gender differences in the SQ-C total scores and its subscale scores except collectible systems (4.1±1.5 vs. 3.4±1.6). In children with ASD, there were no gender differences in EQ-C total score and its subscale scores, except that the subscale score of social skill was higher in autistic boys than those in girls (7.7±3.1 vs. 6.4±2.6). We found significant gender differences in the SQ-C total scores (12.7±5.9 vs. 10.5±4.0) and subscale score of abstract, organizable and collectible systems (5.1±2.9 vs. 4.4±2.8; 2.6±1.9 vs. 1.6±1.5; 1.9±1.4 vs. 1.6±1.5). We also compared EQ-C and SQ-C scores on different demographic status in TD children (**Table S13** in **Appendix A**) and the distribution of EQ-C and SQ-C scores in different

gender of TD children and children with ASD (**Figure S3** in **Appendix A).**

As shown in **Figure 1,** most of the TD boys were identified as Type S (40.7%) and TD girls as Type E (42.6%). Most of the autistic children were identified as Type S, and there were no gender differences in autistic children.

As shown in **Table 3**, autistic children without ID scored higher in SQ-C total score compared with their counterparts (14.2±6.1 vs.10.9±5.0), while no group difference were found in EQ-C total score. Meanwhile, although children with or without ID exhibited Type S, children without ID exhibited Extreme S type (10.6%) more when compared with autistic children with ID (1.7%) and TD children (3.5% in boys and 1.4% in girls). In **Table 4**, autistic children with high paternal education level and high household income scored higher in SQ-C total score when compared with their counterparts (13.3±6.2 vs. 11.5±5.1, 13.7±5.6 vs. 11.9±5.8). However, there was no difference on the EQ-C on different socioeconomic status.

Discussion

After an iterative process of translation and revision of the scale, the Chinese version of EQ/SQ-C showed good psychometric properties including internal consistency, test-retest reliability, factorial validity and known-groups validity, which can be used to provide profiles of empathizing and systemizing in both TD children and autistic children aged 4-12 years. Based on our cross-cultural adaptation, we developed a three-factor structure for EQ-C (cognitive empathy, social skills and affective empathy) and a four-factor structure of SQ-C (technical systems, abstract systems, organizable systems and collectible systems).

This is the first study to translate and employ the EQ/SQ-C for use in Mainland China. Although

the original structures of EQ/SQ-C did not fit this Chinese sample adequately, the revised version demonstrated that the reliability and validity were adequate to measure individual difference of empathy and systemizing in Chinese children. Although studies of Japan(Wakabayashi, 2013) and Korea(Park et al., 2012) retained the 27-item one-factor model for EQ-C and 28-item one-factor model for SQ-C as original structures(Auyeung, Allison, Wheelwright, & Baron-Cohen, 2012), other studies conducted in Taiwan, China (Huang, 2015) and Indonesia(Chaidir et al., 2020) suggested a different structure by removing several inappropriate items. The Taiwan version provided a 20-item 3-factor model for EQ-C and 12-item 3-factor model for SQ-C, and the Indonesian version provided a 20-item one-factor model for EQ-C and 18-item one-factor model for SQ-C. We found similar structure when comparing the Taiwan version, indicating that different child rearing culture in China might result in some inappropriate items in the original version. For instance, item 17 “My child can be blunt giving their opinions, even when these may upset someone” and item 43 “My child is good at negotiating for what they want” indicated a more Western style of self-expression, and Chinese parents tended to teach children to express their feeling in a conservative, subtle and restrained way(Sharp, 2020). These items might be less meaningful when considering the Chinese culture. We also found different items between the traditional Chinese version developed in Taiwan, China(Huang, 2015), and the current simplified Chinese version due to the difference in vocabulary, syntax and semantics when translating from English to simplified Chinese or traditional Chinese (Zhou & Zhou, 2019). Therefore, it is necessary for Chinese population to select appropriate version according to their language preference.

The factor analysis indicated that EQ/SQ-C showed good internal consistency despite moderately low Omega Hierarchical Coefficients, which is the ratio of the variance of the general factor

compared to the total test variance. This value should be higher if we aim to make final, high-stakes decisions rather than for screening decisions in a measurement (Green & Yang, 2015; Trizano-Hermosilla, Gálvez-Nieto, Alvarado, Saiz, & Salvo-Garrido, 2021). Since EQ/SQ-C were validated to quantify autistic trait instead of diagnostic measurements, we believed that the values were acceptable.

The Chinese version of three-factor 23-item EQ-C and four-factor 22-item SQ-C mapped onto the traditional approaches of empathizing(Lawrence, Shaw, Baker, Baron-Cohen, & David, 2004) and systemizing(Baron-Cohen et al., 2003), and the final model accounted for a moderate amount of the total variance. The three-factor model of EQ-C was in line with the original EQ developed for adults(Lawrence et al., 2004). Specifically, the first factor of cognitive empathy covered several items that measured the attribution of others' mental state (item 6, 30 and 42), which was in line with the broader definition of theory of mind [ToM, the ability to attribute mental states and predict behavior accordingly(Frith, 1999)]. One items in another factor of affective empathy had high loadings in the cognitive empathy factor (item 31), indicating that affective empathy might rely on a certain amount of cognitive empathy(Lawrence et al., 2004). Regarding the SQ-C, we developed a four-factor model to describe the profile of systemizing with acceptable model fit. Systemizing allows us to predict the behavior of a system and to control it. According to Baron Cohen's description, there are at least six kinds of systems: Technical, Abstract, Organizable, Collectible, Natural, Social and Motoric systems(Baron-Cohen et al., 2003). We only extracted four systems (Technical, Abstract, Organizable and Collectible) in this version of SQ, but all kinds of systems shared the same underlying process which is monitored closely during systemizing(Baron-Cohen, 2002).

Consistent with other studies, we confirmed the gender difference of empathy in TD children. In both Western (the UK(Auyeung et al., 2009; Baron-Cohen, 2002) and the USA(Escovar et al., 2016)) and Eastern (Japan(Wakabayashi, 2013) and Indonesia(Chaidir et al., 2020)) countries, TD girls scored higher on EQ than TD boys, suggesting that the gender difference in empathy might be stable in general population across different countries(Hoffman, 1977). We found no gender difference in empathy scores in children with ASD, indicating the general empathy impairment of ASD, which were also in line with most of the previous studies(Auyeung et al., 2009; Lawrence et al., 2004; Park et al., 2012). However, we did not find similar gender differences in systemizing scores in TD children, which was inconsistent with the results of UK(Auyeung et al., 2009), Japan(Wakabayashi, 2013) and Korea(Park et al., 2012), but similar to results of Taiwan, China(Huang, 2015). Meanwhile, we also found that children with ASD did not reveal a systemizing-dominant profile compared with TD children although we found gender differences in total score and the subscale of organizable system. One potential explanation was that the ability of systemizing might be influenced by educational environment in China(Groen, Fuermaier, Tucha, Koerts, & Tucha, 2018) since the Chinese overall education strategy focuses on teaching in accordance with procedures and standards, and more emphasis on repeated practice and effort to obtain certain results(Fang & Gopinathan, 2009), which might improve systemizing ability in children and reduce the gender gap. More studies are needed to explore the systemizing profile in Chinese children.

When using empathizing or systemizing to describe the brain types, the distribution of the brain types in TD children were consistent with previous studies(Auyeung et al., 2009; Greenberg et al., 2018), indicating that TD girls on average were more likely to be Type E and TD boys on average were more likely to be Type S. Children with ASD were “masculinized” with S type and Extreme S

type in both genders, but the proportion of Extreme S type in children with ASD was lower than the result of the UK(Auyeung et al., 2009). The difference might be attributable to the difference in intelligence level of the included autistic children. In our study, half of the autistic children were identified with ID indicating a more representative ID-ASD co-occurrence rate since about 3/4 of the individuals in the UK sample were Asperger Syndrome and high-functioning ASD(Auyeung et al., 2009). When we further considering the intelligence level, we found that autistic children without ID scored higher in SQ-C with higher proportion of Extreme S type compared with autistic children with ID, while there were no differences in EQ-C and related brain types (E and extreme E). Larson et.al indicated that the bias for empathizing over systemizing was modulated by intelligence and autistic adults presented a stronger drive to empathize than to systemize with decreasing in intelligence(Larson, Lai, Wagner, Baron-Cohen, & Holland, 2015). Therefore, more studies are needed to consider the intelligence in autistic children to understand the differences in the profiles of empathizing and systemizing.

In addition, we found that children with ASD were more systemizing-dominant in those with high paternal education level and high family income, which was in line consistent with the previous findings in the general population(Baron-Cohen, Knickmeyer, & Belmonte, 2005). Fathers with higher education level might promote their involvement in the education of children with ASD, contributing to a better development of children with ASD(Sharabi & Marom-Golan, 2018). In addition, children with ASD could obtain better ASD-related services (e.g., intervention, parenting consultation) and more support for the exploration of interests in higher-income families(Rosenbrock, Mire, Kim, & Aguirre-Munoz, 2021), strengthening the development of their systemizing ability. SES is an important factor that affects an individual's neural and cognitive

development. Higher family SES is associated with increased intelligence, academic performance, and sense of well-being and other cognitive and social behaviors in young individuals(Takeuchi et al., 2018). However, we did not observe the role of family SES in EQ-C of children with ASD, and more studies are needed to understand the associations between socio-economic factors and the development of ASD in China.

Strengths and Limitations

To our knowledge, this is the first study using a large sample of clinical and general population to validate the Chinese version of the EQ/SQ-C using a comprehensive process of validation in Mainland China. However, the present study has some limitations. First, the ratio of boys to girls in the ASD sample was not balanced with a small sample of girls, which might have biased the results when discussing their gender gap. Future studies should be conducted by considering oversample of girls with ASD. Second, empathizing and systemizing profiles involves the internal state of children, and the evaluation of EQ/SQ-C were derived from parent reports, which might not fully address the real situation of children and be affected by the parents' personal perspective and expectations. More studies are needed to measure children's empathizing and systemizing by laboratory experiment and compare the differences with parent-reports. Third, the neuropsychiatric conditions of TD children were obtained via parent-reported questionnaires rather than confirmed diagnosis, but this might be the most cost-effective method in studies with large sample size. Fourth, although the EQ/SQ-C covered the 4-12 years age span, similar measurements should be developed and validated for younger toddlers and older adolescents in Mainland China. Fifth, this validation study was conducted in more developed areas with high-SES households in China, which might not

be representative for the general situation in China. We should and will replicate these findings in a nationwide sample and to develop Chinese specific norms in the future.

Conclusions

This study indicated good reliability and validity of the Chinese 23-item EQ-C and 22-item SQ-C, which can therefore be used to reliably assess Chinese children's empathizing and systemizing cognitive style according to their parents' report, especially in Southern China.

Table.1 The comparisons of confirmatory factor analysis model in the Chinese version of EQ-C and SQ-C

Instrument	Model structure	# Items	Internal consistency (Cronbach's *a*)	Fit indices in confirmatory factor analysis				
				χ^2/df	CFI	TLI	SRMR	RMSEA
EQ-C	Model1: original one-factor	27	Total (0.84)	2143.298/324	0.885	0.876	0.112	0.085
	Model2: one-factor (items with item-total correlations ≤ 0.30 removed)	23	Total (0.85)	1310.973/230	0.925	0.918	0.099	0.078
	Model3: three-factor (items with item-total correlations ≤ 0.30 and factor loadings ≤0.3 removed based on EFA)	23	Total (0.85) Cognitive empathy (0.74) social skill (0.70) Affective empathy (0.75)	465.728/227	0.968	0.964	0.084	0.052
SQ-C	Model1: original one-factor	28	Total (0.83)	1410.549/350	0.918	0.912	0.082	0.062
	Model2: one-factor (items with item-total correlations ≤ 0.30 removed)	23	Total (0.85)	994.520/230	0.937	0.931	0.065	0.081
	Model3: three-factor (items with item-total correlations ≤ 0.30 and factor loadings ≤ 0.3 removed based on EFA)	22	Total (0.85) technical systems (0.75) Abstract systems (0.68) Organizable systems (0.68) collectible systems (0.52)	413.828/206	0.964	0.959	0.052	0.076

Abbreviation: EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient; CFI, Comparative Fit Index; TFI, Tucker-Lewis Index; RMSEA, the root mean square error of approximation; SRMR, the standardized root mean square residual.

Table. 2 Gender difference of Chinese version of EQ-C, SQ-C and the subscales

	TD children				Children with ASD			
	Total (N=782)	Boy (N=423)	Girl (N=359)	Cohen's *d*	Total(N=222)	Boy (N=197)	Girl (N=25)	Cohen's *d*
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)	
EQ-C								
Total score	29.7 (7.9)	28.2 (7.7)	31.4 (7.8)	**-0.41**	13.2(5.1)	13.3(5.1)	12.4(4.9)	0.18
Cognitive empathy	11.7 (3.5)	11.3 (3.5)	12.2 (3.5)	**-0.26**	3.1(2.5)	3.1(2.5)	3.1(2.6)	0.00
Social skill	10.3 (3.5)	9.6 (3.6)	11.0 (3.3)	**-0.41**	7.5(3.0)	7.7(3.1)	6.4(2.6)	**0.45**
Affective empathy	7.7 (2.8)	7.2 (2.7)	8.2 (2.7)	**-0.37**	2.5(2.3)	2.4(2.3)	2.8(2.2)	-0.18
SQ-C								
Total score	23.5 (8.3)	23.8 (8.2)	23.2 (8.5)	0.07	12.4(5.8)	12.7(5.9)	10.5(4.0)	**0.44**
Technical systems	7.5 (3.8)	7.4 (3.8)	7.6 (3.8)	-0.05	3.0(2.7)	3.0(2.7)	2.9(2.1)	0.04
Abstract systems	8.3 (2.8)	8.5 (2.6)	8.1 (2.9)	0.15	5.0(2.9)	5.1(2.9)	4.4(2.8)	**0.25**
Organize systems	3.9 (2.7)	3.8 (2.8)	4.1 (2.7)	-0.11	2.5(1.9)	2.6(1.9)	1.6(1.5)	**0.58**
Collectible systems	3.8(1.6)	4.1(1.5)	3.4(1.6)	**0.45**	1.9(1.4)	1.9(1.4)	1.6(1.5)	**0.21**

Abbreviation: TD, typically developing; ASD, autism spectrum disorder; SD, standard deviation; EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient.

Table. 3 The comparison of EQ-C scores, SQ-C scores and 'brain type' in autistic children with and without ID

	ASD with ID (N=118) N (%) /Mean (SD)	**ASD without ID (N=104) N (%) /Mean (SD)**	***p* value**
EQ-C scores	12.8 (5.1)	13.6 (5.1)	0.25
SQ-C scores	10.9 (5.0)	14.2 (6.1)	**< 0.01****
Brain type			**0.02***†
Extreme E	0 (0.0)	0 (0.0)	
Type E	15 (12.7)	13 (12.5)	
Type B	41 (34.7)	24 (23.1)	
Type S	60 (50.8)	56 (53.8)	
Extreme S	2 (1.7)	11 (10.6)	

Abbreviation: ASD, autism spectrum disorder; ID, intellectual disability; SD, standard deviation; EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient.

† We combined the groups of Extreme E and Type E together when we performed the chi-square test due to the null cells in the group of Extreme E.

**P* <0.05, ** *P* <0.01.

Table. 4 The comparison of EQ-C and SQ-C scores on different socioeconomic status in children with ASD

Socioeconomic characteristics	N	EQ-C Mean (SD)	SQ-C Mean (SD)
Maternal education level‡			
Low	130	12.8 (4.9)	11.9(5.6)
High	92	13.6 (5.4)	13.2 (5.9)
P value†		0.26	0.10
Paternal education level‡			
Low	109	13.3(4.9)	11.5 (5.1)
High	113	13.0 (5.3)	13.3 (6.2)
P value†		0.72	**0.02***
Per capita monthly household income‡			
Low	153	13.0 (5.0)	11.9 (5.8)
High	69	13.6 (5.3)	13.7 (5.6)
P value†		0.45	**0.03***

Abbreviation: SD, Standard deviation; EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient.

†All the comparisons were adjusted for child's age, childe's gender, with ID (IQ<70) or without ID (IQ≥70), maternal age, paternal age.

‡ Maternal and paternal education level: low level including primary, secondary, high school; high level including university and above. Per capita monthly household income: low refers to the income < ¥8000; high refers to the income ≥ ¥8000.

**P* <0.05

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix A and **Appendix B**: Supplemental files.

Appendix. A

Table.S1 Overview of reliability and validity in different version of EQ-C and SQ-C

Author	Country	Age of participants	No. of Items and factors	Internal consistency (Cronbach's α)	Test-retest reliability (Pearson r)
Auyeung, B., et al. (2009)	UK	4-11 years	55 items, 2factors	EQ-C, 0.93	EQ-C,0.86
				SQ-C, 0.78	SQ-C, 0.84
Akio Wakabayashi, et al. (2013)	Japan	6-15 years	55items, 2 factors	EQ-C, 0.85	
				SQ-C, 0.74	
HuiYi Huang (2015)	Taiwan	6.5-13.5 years	32item, 6 factors	EQ-C, 0.84	EQ-C, 0.77
				SQ-C, 0.80	SQ-C, 0.64
				Combined, 0.87	
Kamila Ratu Chaidir, et al. (2020)	Indonesia	4-14years	38 items ,2 components	EQ-C, 0.957	
				SQ-C, 0.962	

Table.S2 Overview of gender difference on the EQ-C and SQ-C in different countries

Author	Country	Age of participants	children with ASD			TD children			Cognitive style				
			N (males)	EQ-C	SQ-C	N (males)	EQ-C	SQ-C	Extreme E	E	B	S	Extreme S
Auyeung, B., et al (2009)	UK	4-11 years	265 (219)	Boy:13.66±6.90	27.71±9.22	1256 (581)	20.16±8.89	25.81±7.79	0.5	20.3	29.5	45.6	4.1
				Girl:15.43±6.27	26.11±9.11		Girl,34.84±10.07	22.64±7.94	4.0	41.9	31.7	21.2	1.2
				Cohen's *d*=0.27	Cohen's *d*=0.17		**Cohen's *d*=0.56**	**Cohen's *d*=0.4**					
Subin Park, et al (2012)	Korea	4-15 years	111 (91)	Boy:15.55±6.06	25.37 ±6.00	51 (26)	32.04 ±10.49)	24.46±7.27					
				Girl:17.13±11.61	23.94 ±6.40		37.06±8.38	19.11±6.12					
				t=-0.53, *P*=0.605	*t*=0.87, *P*=0.388		*t*=-1.67, *P*=0.104	***t*=2.52, *P*=0.016**					
Akio Wakabayashi, et al (2013)	Japan	6-15 years				626 (313)	Boy: 31.2±8.58	19.3±7.15	2.2	9.3	56.5	21.4	10.5
							Girl: 35.1±8.27	16.7±6.7	9.3	23.3	55.9	11.5	0
							***t* = 5.748,**	***t*= 4.755,**					
							***P* < 0.01**	***P* < 0.01**					
HuiYi Huang (2015)	China (Taiwan)	6.5-13.5 years	105 (90)	Boy: 13.02±5.50	8.85±4.15	1205 (600)	20.21±7.05	11.04±4.12	0.6	19.6	29.5	45.3	5.1
									ASD0.0	10.6	26.6	45.7	17.0
				Girl:11.91±6.16	7.45±2.50		23.08±6.77	8.64±4.06	3.5	49.7	28.1	18.6	0.2
									ASD0.0	18.2	18.2	54.6	9.1
Emily Escovar, et al (2016)	USA	7-12 years				112 (55)	Boy:33.95±7.26	23.73±7.69					
							Girl:38.79±7.59	20.91±7.87					
							***t*=3.45, *P*<0.01**	*t*=-1.91, *P*=0.06					
Kamila Ratu Chaidir, et al. (2020)	Indonesia	4-14years				620 (267)	Boy:16.68±4.20	14.42±4.23	0.5	9	13.3	17.7	2.6
							Girl:17.5±4.38	14.08±4.41	1.9	15.8	16.9	21.5	0.8
							***P*<0.05**	*P*>0.05					

Table.S3 Demographic characteristics of TD children and children with ASD

	TD (N=782) N (%)/Mean (SD)	ASD (N=222) N (%)/Mean (SD)	*p* value
Age	7.9 (2.3)	7.2 (1.8)	**< 0.01****
Gender			**< 0.01****
Boy	423 (54.1%)	197 (88.7%)	
Girl	359 (45.9%)	25 (11.3%)	
Whether only child in family			**0.02***
Only child	316 (40.4%)	109 (49.1%)	
Child with siblings	466 (59.6%)	113 (50.9%)	
Maternal age (N of missing in TD =3)	28.6 (3.8)	29.7 (4.0)	**< 0.01****
Paternal age (N of missing in TD =6)	30.8 (4.3)	32.4 (5.2)	**< 0.01****
Maternal education level†			0.56
(N of missing in TD =7)			
Low	437 (56.4%)	130 (58.6%)	
High	338 (43.6%)	92 (41.4%)	
Paternal education level†			0.21
(N of missing in TD =6)			
Low	344 (44.3%)	109 (49.1%)	
High	432 (55.7%)	113 (50.9%)	
Per capita monthly household income†			**< 0.01****
(N of missing in TD =296)			
Low	197 (40.5%)	153 (68.9%)	
High	289 (59.5%)	69 (31.1%)	

Abbreviation: TD, typically developing; ASD, Autism spectrum disorder; SD, Standard deviation;

†Maternal and father's education level: low level including primary, secondary, high school; high level including university and above. Per capita monthly household income: low level refers to the income < ¥8000; high level refers to the income ≥ ¥8000.

*P <0.05, ** P <0.01.

Table. S4 The list of cross-cultural adaptations on the simplified Chinese version of the children's empathy quotient and systemizing quotient

No. of item	Original version	Simplified Chinese version with back-translated	Explanation of cross-cultural adaptation
9	My child has stolen something they wanted from their sibling or friend.	My child takes things that belong to his/her sibling or friends without permission.	Here we use the word "permission" because in China stealing is such a sensitive topic that parents will immediately tell you that their children will never ever steal things from others. In fact, in Chinese this sentence express the same meaning of English version but it will be easier for parents to tell us the truth.
12	If they had to build a Lego or Meccano model, my child would follow an instruction sheet rather than "ploughing straight in".	My child prefers to follow instructions while building toy blocks or assembling toys rather than stack things straight.	In China, Meccano model was not familiar with this kind of toy, while Lego is popular among young adults and/or adolescents. Lego was one type of toy blocks or assembling toys when speaking in Chinese. Therefore, we use toy blocks and assembling toys to make it more clear for parents to understand the meaning of this item.
15	My child prefers to read or listen to fiction rather than non-fiction.	Compared to non-fiction books (such as science books), my child prefers to read fiction books or listen to stories (such as fairy tales).	In China, there are many kinds of non-fiction books, so we add a example to help the respondent to understand the meaning well.
25	My child can easily figure out the controls of the video or DVD player.	My child can easily learn to control the electronic products (such as TV, computer, DVD player, etc).	We believe we don't use the video or DVD player that often in China now. So we add TV and computer as another examples because these electronic products may be more common for children.
38	My child knows the differences between the latest models of games-consoles (e.g.X-box, Playstation, Playstation 2, etc) or other gadgets.	My child knows the differences between all the latest consoles (such as X-box, Playstation2, etc) and other small gadgets (such as iPhone, iPad, electronic watches, etc).	Most Chinese children don't know the games-consoles, so we emphasize the small gadgets in this item.
46	My child likes to spend time mastering particular aspects of their favorite activities (e.g. skate-board	My child likes to spend time on learning some particular skills of their favorite activities (such as	In China, children learn folk dance more than ballet in their childhood, so we use dance moves instead of ballet moves in case that they will

	or yo-yo tricks, football or ballet moves).	skateboarding, yo-yo, soccer moves or dance moves)	misunderstand that only ballet moves are involved in the item.
50	My child enjoys events with organized routines (e.g. brownies, cubs, beavers, etc).	My child likes activities that have fixed schedule (such as summer camps, national customs activities, etc.)	In China, it's not familiar for children to join the brownies, cubs or other activities that are more common abroad, so we change the examples.

Table.S5 Item analysis of EQ-C

Item	Mean	SD	Item-total correlation *r*	*skewness*	*kurtosis*
1	1.38	0.68	0.53	-0.63	-0.71
2	0.66	0.78	0.34	0.67	-1.06
4	0.97	0.88	0.31	0.05	-1.70
6	1.15	0.72	0.43	-0.23	-1.07
7†	1.84	0.48	0.19	-2.97	7.81
9	1.19	0.85	0.35	-0.36	-1.51
13	1.57	0.69	0.53	-1.28	0.23
14	1.46	0.63	0.56	-0.71	-0.49
17†	0.41	0.64	0.26	1.30	0.47
18	1.14	0.78	0.36	-0.24	-1.34
20	1.17	0.84	0.54	-0.33	-1.51
23	1.66	0.65	0.31	-1.71	1.48
26	1.52	0.62	0.49	-0.91	-0.21
28	1.79	0.46	0.32	-2.07	3.58
30	1.28	0.66	0.61	-0.39	-0.78
31	1.49	0.67	0.66	-0.97	-0.27
33	0.95	0.83	0.45	0.10	-1.53
36	1.13	0.82	0.46	-0.24	-1.47
37	1.32	0.72	0.46	-0.57	-0.91
40†	0.97	0.87	0.28	-0.06	-1.68
42	1.19	0.74	0.53	-0.32	-1.12
43†	0.99	0.76	0.06	-0.02	-1.27
45	0.88	0.72	0.38	0.18	-1.09
48	1.25	0.71	0.43	-0.40	-0.97
52	1.29	0.72	0.55	-0.49	-0.95
53	1.57	0.68	0.31	-1.26	0.24
55	1.68	0.61	0.40	-1.75	1.79

†The item-total correlation $r \leq 0.30$

Table.S6 Item analysis of SQ-C

Item	Mean	SD	Item-total correlation *r*	*skewness*	*kurtosis*
3	0.52	0.75	0.49	1.05	-0.44
5	0.98	0.81	0.54	0.03	-1.50
8	0.96	0.81	0.31	0.06	-1.46
10	1.38	0.77	0.44	-0.76	-0.93
11	0.68	0.82	0.32	0.65	-1.22
12†	1.16	0.79	0.11	-0.29	-1.35
15†	0.29	0.60	-0.08	1.87	2.26
16	0.61	0.81	0.38	0.82	-1.01
19	1.41	0.72	0.46	-0.80	-0.68
21†	1.30	0.72	0.14	-0.51	-0.95
22	1.06	0.85	0.48	-0.11	-1.60
24	0.91	0.83	0.43	0.16	-1.55
25	1.71	0.57	0.45	-1.85	2.33
27	1.04	0.88	0.40	-0.07	-1.70
29	1.41	0.68	0.45	-0.73	-0.64
32	1.21	0.83	0.47	-0.40	-1.43
34	0.86	0.78	0.34	0.24	-1.33
35	0.86	0.75	0.41	0.23	-1.21
38	0.80	0.84	0.42	0.38	-1.49
39	1.41	0.77	0.65	-0.84	-0.82
41	0.91	0.79	0.51	0.16	-1.38
44	0.86	0.82	0.51	0.26	-1.46
46	1.30	0.74	0.58	-0.54	-1.03
47	1.45	0.70	0.36	-0.88	-0.51
49	0.91	0.81	0.43	0.16	-1.46
50	0.75	0.77	0.48	0.46	-1.18
51†	0.51	0.72	0.21	1.03	-0.35
54†	1.31	0.76	0.26	-0.59	-1.04

†The item-total correlation $r \leq 0.30$

Table. S7 Standard Factor loading and item-total correlations of confirmatory factor analysis for EQ-C

Item	Correlation between item and total score	Std. Factor loading				
		Model 1†	Model 2†	Model 3†		
		Factor I	Factor I	Factor I	Factor II	Factor III
1	0.53	0.660	0.669	0.701		
2	0.34	0.363	0.352	0.376		
4	0.31	0.330	0.322		0.297	
6	0.43	0.513	0.520	0.546		
7	0.19	0.282	-	-	-	-
9	0.35	0.382	0.370			
13	0.53	0.654	0.653	0.632		
14	0.56	0.665	0.662			0.669
17	0.26	0.300	-	-	-	-
18	0.36	0.431	0.443	0.436		
20	0.54	0.604	0.585		0.851	
23	0.31	0.399	0.360		0.483	
26	0.49	0.599	0.609	0.667		
28	0.32	0.479	0.483	0.444		
30	0.61	0.706	0.712	0.729		
31	0.66	0.808	0.814			0.842
33	0.45	0.492	0.474		0.555	
36	0.46	0.496	0.474		0.644	
37	0.46	0.538	0.544			0.558
40	0.28	0.302	-	-	-	-
42	0.53	0.635	0.647	0.689		
43	0.06	0.106	-	-	-	-
45	0.38	0.479	0.489			0.534
48	0.43	0.517	0.526			0.608
52	0.55	0.686	0.696			0.768
53	0.31	0.354	0.329		0.452	
55	0.40	0.517	0.496		0.731	

†Model 1 was the original model;

Model 2 was the model with item of item-total correlation ≤ 0.3 removed;

Model 3 was the model based on the EFA.

Table. S8 Standard Factor loading and item-total correlations of confirmatory factor analysis for SQ-C

Item	Correlation between item and total score	Std. Factor loading					
		Model 1†	Model 2†	Model3†			
		Factor I	Factor I	Factor I	Factor II	Factor III	Factor IV
3	0.49	0.593	0.590			0.698	
5	0.54	0.632	0.634			0.828	
8	0.31	0.334	0.339				0.468
10	0.44	0.523	0.533				0.588
11	0.32	0.339	0.334			0.532	
12	0.11	0.118	-	-	-	-	-
15	-0.08	-0.169	-	-	-	-	-
16	0.38	0.468	0.464				
19	0.46	0.586	0.591				0.713
21	0.14	0.154	-				
22	0.48	0.533	0.521			0.612	
24	0.43	0.509	0.508	0.522			
25	0.45	0.594	0.585		0.568		
27	0.40	0.457	0.447		0.481		
29	0.45	0.509	0.504		0.502		
32	0.47	0.525	0.516		0.590		
34	0.34	0.385	0.387	0.443			
35	0.41	0.488	0.492	0.597			
38‡	0.42	0.502	0.510	-	-	-	-
39	0.65	0.768	0.770		0.862		
41	0.51	0.567	0.570	0.592			
44	0.51	0.594	0.595	0.665			
46	0.58	0.681	0.684	0.716			
47	0.36	0.433	0.426		0.445		
49	0.43	0.539	0.546	0.595			
50	0.48	0.569	0.575	0.677			
51	0.21	0.223	-	-	-	-	-
54	0.26	0.284	-	-	-	-	-

†Model 1 was the original model;

Model 2 was the model with item of item-total correlation ≤ 0.3 removed;

Model 3 was the model based on the EFA.

‡The standard factor loading ≤|0.3| on Model 3

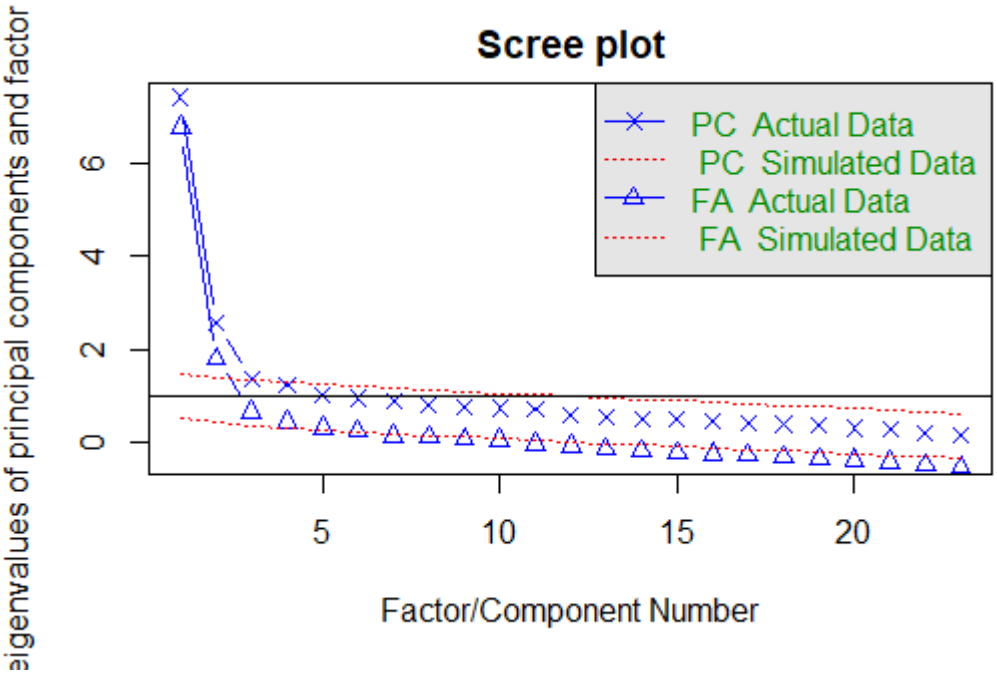

Figure.S1 The scree plot of EQ-C

Table. S9 The comparison of different number of factors of EQ-C

Item	Factor loading										
	Two-factor		Four-factor				Five-factor				
	Factor I	Factor II	Factor I	Factor II	Factor III	Factor IV	Factor I	Factor II	Factor III	Factor IV	Factor V
1	0.780		0.726				0.728				
2		0.316				0.642				0.639	
4		0.346				0.306				0.301	
6	0.558		0.72				0.677				
9		0.577		0.446				0.44			
13	0.479	0.313	0.621				0.551				
14	0.459	0.303	0.324	0.353			0.362	0.366			
18	0.482							0.592			
20		0.607		0.586				0.816			
23		0.801		0.822			0.567		0.357		
26	0.612		0.571			0.35	0.306				0.865
28	0.442		0.457				0.681				
30	0.608		0.698				0.614				
31	0.818		0.576		0.339						
33		0.492		0.427				0.462			
36		0.602		0.594				0.615			
37	0.485				0.729				0.758		
42	0.748		0.629				0.668				
45	0.651		0.317		0.406		0.364		0.365		
48	0.481				0.723				0.65		
52	0.731		0.425		0.423		0.487		0.363		
53		0.715		0.576				0.582			
55		0.719		0.762				0.753			
Cumulative Var	38.60%		42.30%				45.40%				

Table.S10 The factor loadings of each item of EQ-C

Item		Factor I	Factor II	Factor III
1	My child likes to look after other people.	0.505		0.349
2	My child often doesn't understand why some things upset other people so much.	0.381		
6	My child is quick to notice when people are joking.	0.650		
13	My child has trouble forming friendships.	0.690		
18	My child would enjoy looking after a pet.	0.342		
26	At school, when my child understands something, they can easily explain it clearly to others.	0.720		
28	My child has one or two close friends, as well as several other friends.	0.454		
30	My child listens to others' opinions, even when different from their own.	0.719		
42	My child can easily tell when another person wants to enter into conversation with them.	0.643		
4	My child would not cry or get upset if a character in a film died.		0.337	
9	My child has stolen something they wanted from their sibling or friend.		0.555	
20	My child is often rude or impolite without realizing it.		0.581	
23	My child has been in trouble for physical bullying.		0.798	
33	My child can seem so preoccupied with their own thoughts that they don't notice others getting bored.		0.446	
36	My child blames other children for things that they themselves have done.		0.571	
53	My child has been in trouble for name-calling or teasing.		0.691	
55	My child tends to resort to physical aggression to get what they want.		0.694	
14	When playing with other children, my child spontaneously takes turns and shares toys		0.314	0.347
31	My child shows concern when others are upset.	0.454		0.460
37	My child gets very upset if they see an animal in pain.			0.610
45	My child would worry about how another child would feel if they weren't invited to a party.			0.448
48	My child gets upset at seeing others crying or in pain.			0.766
52	My child likes to help new children integrate in class.			0.519

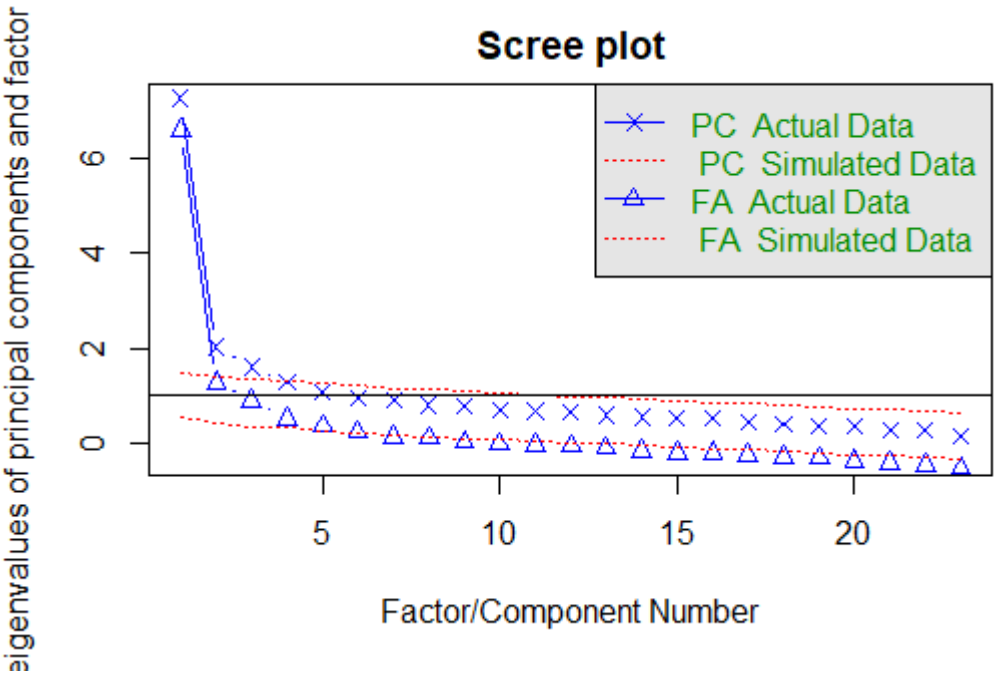

Figure.S2 The scree plot of SQ-C

Table. S11 The comparison of different number of factors of SQ-C

Item	Factor loading							
	Three-factor			Five-factor				
	Factor I	Factor II	Factor III	Factor I	Factor II	Factor III	Factor IV	Factor V
3			0.68			0.603		
5	0.46	-0.391	0.621	0.411		0.648		
8	0.399						0.622	
10	0.484						0.712	
11			0.472			0.493		
16			0.83			0.855		
19	0.433			0.336				
22			0.397		0.351			
24	0.517			0.569				
25		0.699			0.75			
27		0.483	0.356		0.514			
29		0.539			0.647			0.306
32		0.658			0.675			
34	0.432			0.309				0.368
35	0.515			0.582				
38†	0.399			-	-	-	-	-
39	0.406	0.442		0.446	0.455			
41	0.531			0.423				0.396
44	0.446			0.617				
46	0.499	0.314		0.558	0.306			
47		0.737			0.862			
49	0.716			0.731				
50	0.752			0.825				
Cumulative Var	37.70%					46.30%		

† The factor loading ≤|0.3| on the Five-factor model

Table.S12 The factor loadings of each item of SQ-C

Item		Factor I	Factor II	Factor III	Factor IV
24	My child enjoys physical activities with set rules (e.g., martial arts, gymnastics, ballet, etc.).	0.606			
34	My child enjoys games that have strict rules (e.g., chess, dominos, etc.).	0.455			
35	My child gets annoyed when things aren't done on time.	0.534			
41	My child is interested in following the route on a map on a journey.	0.562			
44	My child likes to create lists of things (e.g., favorite toys, TV programs, etc.).	0.457			
46	My child likes to spend time mastering particular aspects of their favorite activities (e.g., skate-board or yo-yo tricks, football or ballet moves).	0.408	0.318		
49	If they had a sticker album, my child would not be satisfied until it was completed.	0.648			
50	My child enjoys events with organized routines (e.g., brownies, cubs, beavers, etc.).	0.830			
25	My child can easily figure out the controls of the video or DVD player.		0.695		
27	My child would find it difficult to list their top 5 songs or films in order.		0.505	0.341	
29	My child quickly grasps patterns in numbers in math.		0.560		
32	My child is not interested in understanding the workings of machines (e.g., cameras, traffic lights, the TV, etc.).		0.642		
39	My child remembers large amounts of information about a topic that interests them (e.g., flags of the world, football teams, pop groups, etc.).	0.337	0.450		
47	My child finds using computers difficult.		0.788		
3	My child doesn’t mind if things in the house are not in their proper place.			0.700	
5	My child enjoys arranging things precisely (e.g. flowers, books, music collections).	0.463		0.598	
11	My child does not spend large amounts of time lining things up in a particular order (e.g., toy soldiers, animals, cars).			0.513	
16	My child’s bedroom is usually messy rather than organized.			0.802	
22	My child would not notice if something in the house had been moved or changed.		0.342	0.363	
8	My child is interested in the different members of a specific animal category (e.g., dinosaurs, insects, etc.).				0.591
10	My child is interested in different types of vehicles (e.g., types of trains, cars, planes, etc.).				0.776
19	My child likes to collect things (e.g. stickers, trading cards, etc).				0.306

Table.S13 The comparison of EQ-C and SQ-C scores on different demographic status in TD children

Demographic characteristics	N	EQ-C Mean (SD)	SQ-C Mean (SD)
Age stage			
Kindergarten	298	33.5 (6.2)	31.3(4.0)
Grade1-3	336	26.9 (7.7)	19.0(6.5)
Grade 4-6	148	28.1 (8.2)	18.0(6.3)
p value		**<0.001*** **	**<0.001*** **
Whether only child in family			
Only child	316	30.8 (7.3)	25.2 (7.8)
Child with siblings	466	28.9 (8.2)	22.3 (8.5)
p value		**<0.01** **	**<0.001*** **
Maternal age (N of missing =3)			
<35 years	721	29.4 (7.9)	23.3 (8.3)
≥35 years	58	32.1 (7.2)	26.2 (7.8)
p value		**0.01***	**< 0.01** **
Paternal age (N of missing =6)			
<35 years	649	29.4 (7.9)	23.2 (8.3)
≥35 years	127	31.1 (7.7)	24.9 (8.3)
p value		**0.02***	**0.03***
Maternal education level† **(N of missing =7)**			
Low	437	30.0 (7.6)	23.3 (8.4)
High	338	29.1 (8.3)	23.6 (8.3)
p value		0.09	0.64
Paternal education level† **(N of missing =6)**			
Low	344	30.3 (7.6)	23.7 (8.4)
High	432	29.1 (8.1)	23.2 (8.3)
p value		0.03	0.40
Per capita monthly household income† **(n of missing = 296)**			
Low level	197	26.1 (7.8)	18.0 (6.2)
High level	289	28.1 (7.8)	19.1 (6.6)
p value		**<0.01** **	0.06

Abbreviation: SD, Standard deviation; EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient.

†Maternal and father's education level: low level including primary, secondary, high school; high level including university and above. Per capita monthly household income: low level refers to the income < ¥8000; high level refers to the income ≥ ¥8000.

*P <0.05; ** P <0.01; ***P <0.001

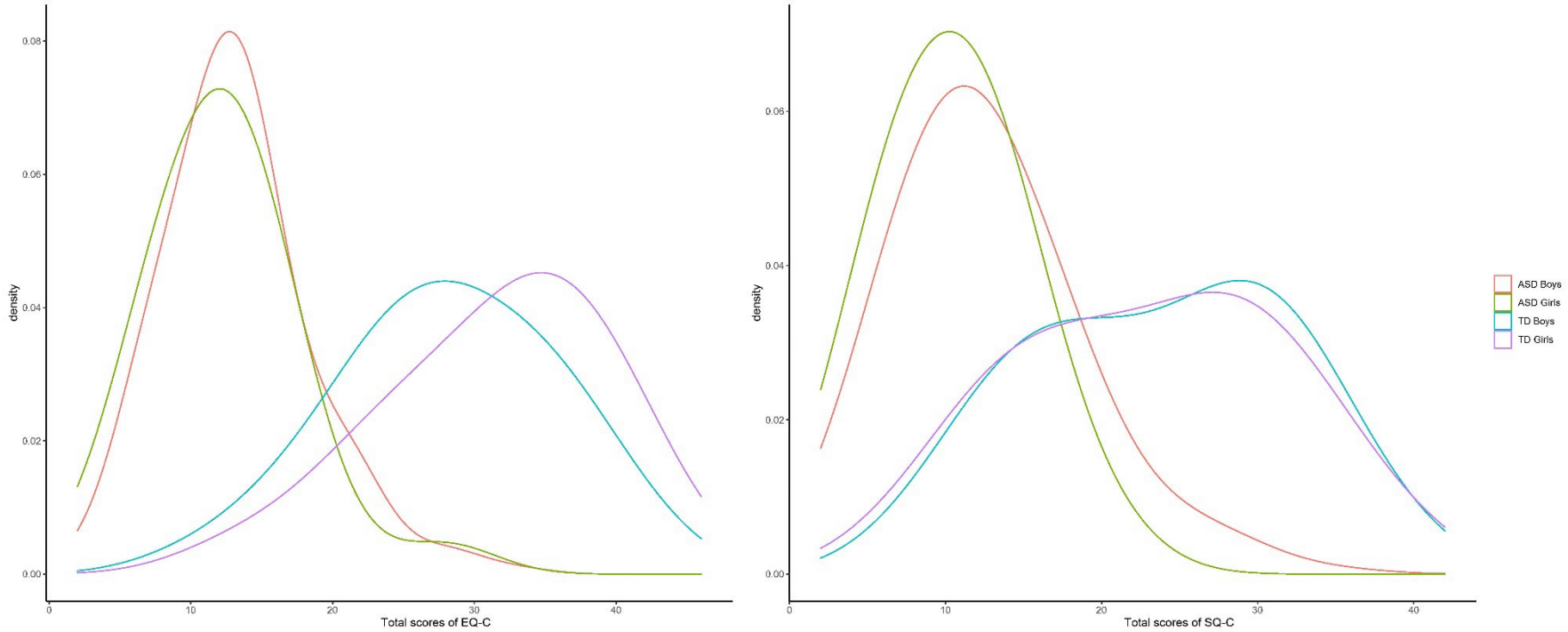

Figure.S3 The distribution of EQ-C and SQ-C total scores in different gender of TD children and children with ASD

Abbreviation: EQ-C, children's version of empathizing quotient; SQ-C, children's version of systemizing quotient. ASD, autism spectrum disorder; TD, typically developing

Appendix B

The calculation of Brain Types

Standardized scores were calculated for both EQ-C and SQ-C according to the formulae suggested by Auyeung Bonnie, et al(Auyeung et al., 2009).

E (standardized) = [(EQ-C observed - EQ-C mean for typical population)/maximum possible score for EQ-C]

S (standardized) = [(SQ-C observed - SQ-C mean for typical population)/maximum possible score for SQ-C]

D (difference between the normalized SQ-C and EQ-C scores) = (S-E) /2

The 'brain types' were numerically assigned according to the percentiles of TD children on the 'D' score where:

- The lowest scoring 2.5% are classified as Extreme Type E (Empathizer).
- Participants scoring between the 2.5th and 35th percentiles are classified as Type E.
- Participants scoring between the 35th and 65th percentile were classified as Type B (Balanced).
- Participants scoring between the 65th and 97.5th percentile are classified as Type S (Systemizer).
- The top 2.5% are classified as Extreme Type S.
- The 'brain types' boundary according to the percentiles of TD children on the 'D' score in Chinese version was: Extreme E, $D < -0.166$; Type E, $-0.166 \leq D < -0.029$; Type B, $-0.029 \leq D < 0.034$; Type S, $0.034 \leq D < 0.172$; Extreme S, $D \geq 0.172$.

The fit indices of exploratory factor analysis (CFA)

The fit indices to evaluate CAF measure included the model χ^2 and its *p* value(Kidwell, Tomaso, Lundahl, & Nelson, 2020), the Comparative Fit Index (CFI) and Tucker-Lewis Index (TFI, values ranging from 0.90 to 0.95 indicate an adequate fit and values greater than or equal to 0.95 indicate a good fit), the root mean square error of approximation (RMSEA; values ranging from 0.05 to 0.08 represent adequate fit and values less than 0.05 indicate good fit), the standardized root mean square residual (SRMR; values less than or equal to 0.08 indicate good fit).

The procedure of explore factor analysis (EFA)

Given the ordinal nature of the three-ordered item categories (i.e., definitely agree, slightly agree and disagree/strongly disagree), polychoric correlation coefficients were used for the matrix of inter-item relationships. After confirming that the polychoric correlation matrix (i.e., the 27*27 for EQ-C and 28*28 for SQ-C) was factorable, it was submitted for EFA. Common factor analysis was selected over PCA because the intent was to identify a latent factor structure(Fabrigar, 1999). In the extraction phase, A maximum likelihood extraction method was employed because that sample size is large, multivariate normality is attained(Watkins, 2018).

Following the advice of Velicer et al.(Velicer, 2000), parallel analysis(Horn, 1965), MAP(Velicer, 2000), and the visual scree test(Cattell, 1966) were used to determine the appropriate number of factors to retain. Parallel analysis with polychoric correlations, using principal component analysis (PCA) as the method of extraction and the mean eigenvalue criterion. Parsimony and theoretical convergence were also considered. Due to the nature of the constructs,

it was assumed that factors would be correlated. Therefore, an oblique (Promax) rotation was employed. Criteria for determining factor adequacy were established a priori.

For EQ-C, parallel analysis and scree all suggested that five factors should be retained but MAP indicated that only two factors were required. Therefore, the two-, three-, four- and five- factor solutions were sequentially examined. Considering the relevant theory, the adequacy and common variance(Watkins, 2018), the three-factor solution was adequate and in line with the theoretical model. Following rotation, cognitive empathy factor, social skill factor and affective empathy factor accounted for 15.9%, 14.1%, 9.0% of the total variance and 41.0%, 34.0%, 25.0% of the common variance.

For SQ-C, parallel analysis and scree suggested five factors should be retained but MAP indicated that only three factors were required. Therefore, the three-, four- and five-factor solutions were sequentially examined. Considering the relevant theory, the adequacy and common variance(Watkins, 2018), the four-factor solution was examined for adequacy. Following rotation, the four factors accounted for 14.1%, 12.2%, 9.3% and 5.8% of the total variance and 34.0%, 29.0%, 23.0% and 14.0% of the common variance.

Given these results, the three-factor for EQ-C and four-factor for SQ-C solution was accepted as the most adequate structural representation with these participants and was subsequently found to be robust across alternative extraction and rotation methods. Factors were named based on their item makeup and in relation to the strength of the items that loaded on them.

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