Psychometric Properties of the Autism Spectrum Quotient: Children's Version (AQ-Child)

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Rapson Gomez, [1]

Vasileios Stavropoulos, [1,2✉,4]

Phone +61450903687 Email vasilisstavropoylos80@gmail.com

Alasdair Vance, [3]

[1] School of Psychology, The Cairnmillar Institute, 105/1011 Toorak Road, Camberwell, Melbourne, VIC, 3124 Australia

[2] Faculty of Philosophy, Department of Psychology, National and Kapodistrian, University of Athens, Athens, Greece

[3] The Royal Children's Hospital Melbourne & The University of Melbourne, Melbourne, Australia

[4] Present Address: 391-393 Tooronga Road Hawthorn East, Melbourne, VIC, 3123 Australia

Abstract

Confirmatory factor analysis (CFA) and exploratory and factor analysis (EFA) aimed to determine the optimum Autism Spectrum Quotient—Children (AQ-Child) model. Initial CFA of parent ratings of the AQ-Child for 404 clinic-referred children with ADHD, aged between 4 and 11 years, revealed mixed/moderate support for the implied AQ-Child five-factor model and the past statistically supported four-factor model (Auyeung et al., J Autism Dev Disord 38:1230–1240, 2008). Interestingly, EFA findings indicated most support for a four-factor model, with factors reflecting "mind-reading", "social skills", "attention to details", and "imagination". The items loading in these factors were different from those proposed originally for similar factors (Auyeung et al., J Autism Dev Disord 38:1230–1240, 2008). The factors in the model showed acceptable internal consistency-reliability and discriminant validity. Clinical and research implications are discussed.

AQ1
AQ2
AQ3

Keywords

Autism Spectrum Quotient–Children's Version
Factor analysis
Factor structure
Four-factor model

Electronic supplementary material

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Introduction

According to DSM-IV, autism is a neurodevelopmental condition, characterized by serious deficits in three core areas: social communication, social interaction across multiple contexts, and restricted repetitive patterns of behaviors, interests, or activities [American Psychiatric Association (APA) 1994]. Specifically, DSM-IV classified autism related disorders into: (a) Autistic Disorder; (b) Asperger's Disorder; (c) Childhood Disintegrative Disorder and; (d) Pervasive Developmental Disorder Not Otherwise Specified. In contrast, DSM-5 [American Psychiatric Association (APA) 2013] considers Autism related presentations as a single disorder, called Autism Spectrum Disorder (ASD), with the deficits in social communication and social interaction combined into a single group of clinical manifestations, and restricted repetitive patterns of behaviors, interests, or activities conceived as another group of clinical manifestations. Interestingly, the ASD trait(s) is/are conceptualized on a continuum (e.g. Baron-Cohen 2008b; Robinson et al. 2011), with a rather normalized distribution in the general community, and higher levels characterizing the presence of ASD. Reflecting this, in recent years, several questionnaires and measures for autism have been developed for assessing the autism trait(s) in the general community, and at the same time facilitating the diagnosis of ASD (Broderick et al. 2015). One such measure for use with adults (> 16 years of age) is the self-rating questionnaire called Autism-Spectrum Quotient (AQ: Baron-Cohen et al. 2001). As mentioned by the developers (Baron-Cohen et al. 2001), the AQ measures the DSM-IV specified "triad" of autistic symptoms, as well as demonstrated areas of cognitive impairment interwoven with ASD presentations.

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Subsequent to the development of the AQ, comparable versions have been developed for adolescents [the Autism Spectrum Quotient–Adolescent Version (AQ-Adol), Baron-Cohen et al. 2006], and children [the Autism Spectrum Quotient–Children's Version (AQ-Child), Auyeung, et al. 2008]. Both the AQ-Adol (used with adolescents between 12 and 15 years of age) and AQ-Child (adapted from the adult and adolescent version and used with children between 4 and 11 years of age) involve parent rating scales.

The adult version of the AQ has been suggested as a valid and useful autism screening instrument (Baron-Cohen et al. 2001; Kloosterman et al. 2011) for clinical research and practice, including epidemiological and cross-cultural research on autism (Wakabayashi et al. 2007). Indeed, worldwide, the AQ is one of the most frequently used measures for screening autism related behaviors (Broderick et al. 2015). In view of this, it is conceivable that the AQ-Adol and AQ-Child could also be considered as suitable measures for clinical and research practice within the relevant age groups. Consequently, it is critical that there is a good understanding of these instruments (AQ, AQ-Adol and AQ-Child) factor structures and other related psychometric properties. To partially address this need, the current study aimed to examine various psychometric features/properties of the AQ-Child.

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AQ Child Questionnaire

The format and the specific item content of the AQ, AQ-Adol and AQ-Child, are highly comparable. Each of the three questionnaires has 50 items, and each item provides a description of a characteristic behavior of individuals presenting with autism. The 50 items of each of the three different AQ age versions inform five subscales, which capture five distinct theoretical areas of ASD manifestations. As noted earlier, the AQ-Child, adapted from the adult and adolescent versions of the AQ, is a parent rating questionnaire for measuring autistic traits in children between 4 and 11 years of age. Considering the AQ-Child in particular, which is the AQ age version of interest in the present study, these areas refer to: (a) social skills (10 items; item numbers 1, 11, 13, 15, 22, 36, 44, 45, 47 and 48); (b) attention switching (10 items; item numbers 2, 4, 10, 16, 25, 32, 34, 37, 43 and 46); (c) attention to detail (10 items; item numbers 5, 6, 9, 12, 19, 23, 28, 29, 30 and 49); (d) communication (10 items; item numbers items 7, 17, 18, 26, 27, 31, 33, 35, 38 and 39) and (e) imagination (items 3, 8, 14, 20, 21, 24, 40, 41, 42 and 50). Each item of the AQ-Child is rated on a 4-point Likert scale (0 = definitely agree; 1 = slightly agree; 2 = slightly disagree; and 3 = definitely disagree). Approximately half of scale items are reversed scored, and their responses are re-coded such that higher scores represent higher levels of autistic traits. The total AQ-Child score is obtained by summing the scores of all the items resulting to a range of 0–150, where higher scores indicate more severe ASD related behaviors. Similarly, the AQ subscales' scores are obtained by summing items in the specific subscales resulting in a range of 0–30 for each subscale, with higher scores revealing higher ASD behaviors.

AQ Child Questionnaire Factor Structure

To date at least two studies have examined the psychometric properties of the AQ-Child: the initial development and validation study of the AQ-Child by Auyeung et al. (2008) and a study conducted in Japan by Wakabayashi et al. (2007). Auyeung et al. (2008) reported high internal consistencies (Cronbach's alpha; α) for the total scale, as well as each of the five subscales (total = .97, communication = .92; social skills = .93; imagination = .88; attention to details = .83; attention switching = .89), and discriminative validity (ability to differentiate those with and without ASD) for the five theoretical subscales composing the AQ-Child. Interestingly, at the item level, out of the 50 items, three items (items 29, 30, and 49) failed to discriminate between those with and without ASD presentations. Surprisingly, for the remaining 47 items, principal component analysis (PCA) yielded four (and not five) factors, namely "mind-reading" (16 items; item numbers 39, 45, 18, 35, 31, 37, 4, 27, 36, 2, 7, 10, 32, 42, 33, and 48), "attention to detail" (9 items; item numbers 6, 23, 9, 19, 15, 5, 41, 43 and 16), "social skills" (15 items; item numbers 49,38, 47, 17, 11, 22, 1, 15, 26, 13, 46, 34, 24, 25, and 28), and "imagination" (7 items; item numbers 14, 8, 3, 21, 50, 20, and 40). It is to be noted that although the labels of "attention to detail", "social skills" and "imagination" for the PCA derived model correspond to that of the labels for the initially proposed theoretical subscales, the items in corresponding factors (and their scales) are not identical. The study by Auyeung et al. (2008) also provided support for the discriminative validity (ability to differentiate those with and without ASD presentations) for the four factors revealed in their PCA. Similarly, the study by Wakabayashi et al. (2007), involving all 50 items of the AQ-Child, demonstrated further support for the discriminative validity of the total AQ score and the three subscale scores defined as "social skills", "communication", and "imagination". The Cronbach α internal reliability-consistency coefficients, while lower than those reported by Auyeung et al. (2008), were still acceptable (total AQ = 0.84, communication = 0.79; social skill = 0.81; imagination = 0.76; attention to detail = 0.69; and attention switching = 0.74).

Overall, therefore, only one study (including the initial validation study of the instrument) has examined the factor structure of the AQ-Child, and this study did not find support for a model corresponding to the theorized five subscales for the AQ-Child. Instead for 47 out of the 50 items, it supported a 4-factor model. Nevertheless, existing data provide support for the internal consistency reliabilities of the both the total and the five subscale scores of AQ 50, and their ability to discriminate children with and without ASD presentations. Despite these, for a measure that could potentially be seen as a suitable measure for clinical research and practice in autism in children internationally, it can be reasonably argued that there is limited psychometric information for the AQ-Child, and that therefore, further research in this respect is required.

Given that there has been a dearth of studies examining the factor structure of the AQ-Child, one could assume that there is inadequate data for the stability of the instrument's factorial structure. This is a significant concern in the context of the numerous studies involving the AQ adult version, as there appears to be a lack of a generally accepted factor model for this measure (Austin 2005; Hurst et al. 2007; Hoekstra et al. 2008; Lau et al. 2013a, b; Stewart and Austin 2009; Kloosterman et al. 2011). Specifically, across these studies, several factor models, with varying number of items with salient loadings, have been proposed, ranging from two to five factors, with most studies supporting factors for social skills, attention to detail, and communication/mindreading (Austin 2005; Hurst et al. 2007; Hoekstra et al. 2008; Kloosterman et al. 2011; Lau et al. 2013a, b; Stewart and Austin 2009). On the basis of these findings for the AQ adult version, it can be hypothesized that this could also be the case with the AQ-Child (given their shared theoretical conceptualization, item content and format).

AQ Child Questionnaire Internal Consistency-Reliability

In addition to factor structure, the level of internal consistency reliability of the AQ-Child could also be questionable. It needs to be noted that the minimum level of acceptable internal consistency reliability has been suggested as .70 (that is a minimum of 70% of the observed score variance being attributed to true score variance; Nunnally 1978). The initial scale development and validation study of the AQ (adult version) by Baron-Cohen et al. (2001) reported internal consistency reliability values (Cronbach α) ranged from .63 to .77 for the five subscales. Similarly, most of the subsequent studies have generally reported low Cronbach α values, especially for the factors related to "attention to detail", "attention switch" and "imagination". For example, the study by Kloosterman et al. (2011) reported Cronbach α values of .85, .65, .40, .57, and .59 for "social skills", "communicating/mindreading", "restrictive/repetitive behaviors", "imagination", and "attention to details", respectively. Lau et al. (2013b) reported Cronbach α values of .88, .77, .63, .54, and .60 for "socialness", "mindreading", "patterns", "attention to details", and "attention switching", respectively. Thus, although the studies involving the AQ-Child by Auyeung et al. (2008) and Wakabayashi et al. (2007) have both reported adequate internal consistency reliability values for this measure, it is possible that future studies with the AQ-Child could also follow the general trend noted for the AQ adult version in terms of lower reliability values.

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The Present Study

Given the possibility that the four-factor model proposed for the AQ-Child may not be a stable structure, the first aim of the current study was to examine, through the implementation of confirmatory factor analyses (CFA), the support for both the five- and four-factor models previously suggested (Wakabayashi et al. 2007; Auyeung et al. 2008). Aligning with past studies considering these models, all 50 items were included in the five-factor model, and only 47 out of the 50 AQ items were included for the four-factor model included. The excluded items were item numbers 29, 30, and 49, as these have been reported to present with low discriminant validity in past studies (did not adequately distinguish those with and without ASD presentations; Auyeung et al. 2008). For the five-factor model, the 50 items examined loaded on factors for "communication", "social skills", "attention to detail", "attention switching", and "imagination", as proposed by Auyeung et al. (2008). For the four-factor model, the appropriate 47 items were assessed in relation to the factors of "mind-reading", "social skills", "attention to detail" and "imagination", as suggested found in the PCA reported by Auyeung et al. (2008). These models are depicted in Supplementary Fig. 1. As we wished to establish a simple structure (for easy of interpretation and for parsimony), we decided that in case neither of these models being adequately supported by the relevant CFAs, the optimum factor structure of the AQ-Child would be further explored using exploratory factor analyses (EFA). Given that Auyeung et al. (2008) found that items 29, 30, and 49 did not discriminate between those with and without ASD presentations, the EFA involved in the current study would involve only the remaining 47 AQ-Child items.

The second aim of the present study was to examine the internal consistency reliability of the factors in the model defined (based on the results of aims 1) as the optimum (best fit) model. It is to be noted that all internal consistency-reliability rates in the previous studies of the AQ and AQ-Child have reported only Cronbach α values. Although this is one of the most often used measures of internal consistency-reliability, it has been argued that the Cronbach α coefficient has limitations for responses that are on an ordinal interval. First, Cronbach's alpha assumes that the responses to an item are continuous, 18 para 3; and is based on Pearsons covariance matrix.. Thus in the context of the AQ-Child, Cronbach's alpha does not account for the ordinal characteristics of the AQ-Child, and as a consequence it will underestimate the scale's internal consistency reliability (Sijtsma 2009). An alternative to Cronbach's alpha that is suited for scales that are on an ordinal interval is ordinal alpha (Zumbo et al. 2007). Ordinal alpha takes account of the ordinal interval in a scale, and is based on polychoric correlations matrix. It is known to provide more accurate estimates of internal consistency reliability than coefficient α (Timmerman and Lorenzo-Seva 2011). Second, Cronbach α assumes tau-equivalent or equal factor loadings of the items comprising the scale under examination—(an unrealistic assumpption; Zinbarg et al. 2005). In contrast, omega coefficient (ω; McDonald 1999) allows items in the scale to have their own unique loadings (congenic model). In that line, coefficient ω is conceived as the true score variance accounted for by a factor and therefore, it is has been suggested as a more accurate indication of internal consistency-reliability levels than the coefficient α (Zinbarg et al. 2005). Thus, it could be possible that considering AQ child, ω coefficient could provide a more realistic estimation of the internal reliabilities of the AQ factors than the coefficient α applied in past studies.

The third aim of the present study was to examine the concurrent and discriminant validities of the AQ latent factors

The third aim of the present study was to examine the concurrent and discriminant validities of the AQ latent factors (in the optimum model revealed) in terms of their unique associations with all eight Child Behavior Checklist (CBCL) syndrome scale scores ("anxious/depressed", "withdrawn/depressed", "somatic complaints", "social problems", "thought problems", "attention problems", "rule-breaking behavior" and "aggressive behavior"; Achenbach, and Rescorla 2001). Existing data show that the CBCL syndrome scales/dimensions for "social problems", "withdrawn/depressed", "thought problems" and also (to a lesser degree) "attention problems" are generally associated with ASD manifestations in both community and clinic-referred samples (Biederman et al. 2010; Bölte et al. 1999; Duarte et al. 2003; Hoffmann et al. 2016; Ooi et al. 2011). Although less often, studies have also found associations between ASD manifestations and the other CBCL syndrome scale scores. For example, studies have reported positive ASD manifestations' associations with the "anxious/depressed" dimension (Hoffmann et al. 2016) and negative associations with the "somatic complaints" dimension (Biederman et al. 2010; Bölte et al. 1999). Indeed, Hartini et al. (2016) found positive associations between ASD manifestations and all the CBCL scales/ dimensions except "somatic complaints". Overall, these findings raise the possibility that the CBCL syndromes for the "withdrawn/depressed", "social problems", "thought problems" and "attention problems" dimensions will be positively and more strongly associated with one or more of the AQ-Child latent factors/ subscales, compared to the CBCL scores for the "anxious/depressed", "rule-breaking behavior", and "aggressive behavior" dimensions. Additionally, the CBCL dimension of "somatic complaints" could be negatively associated with one or more of the AQ-Child latent factors/ subscales.

These three aims were examined in the current study using in a large group of clinic-referred children. Given the heterogeneity of this initial clinical sample/group in terms of psychopathology and comorbidity, and to secure higher homogeneity, evaluations were targeted to those with a diagnosis of Attention Deficit/Hyperactivity Disorder (79.3% of the initial clinical group/ sample; ADHD, APA 2003). Like ASD, ADHD is also considered a neurodevelopmental disorder. The core symptoms for ADHD are inattention, hyperactivity and impulsivity (APA 2003). Many studies have shown that ADHD and ASD co-occur at relatively high rates, ranging from around 20–70% (Gargaro et al. 2011; Leyfer et al. 2006; Matson et al. 2013; Reiersen and Todd 2008; Simonoff et al. 2008), and ADHD is considered to be the second most common comorbid disorder in individuals with ASD (Simonoff et al. 2008). Unlike DSM-IV (APA 2000) that did not permit concurrent diagnosis of ADHD and ASD, this is enabled in the current DSM-5 edition (APA 2013).This and the general recognition that the clinical distinction between ASD and ADHD is difficult because of the presence of attention symptoms in both these disorders (Jensen et al. 1997) highlight the need for a measure that can facilitate the identification of ASD traits, when these are comorbid with the ADHD traits. Thus establishing the factor structure of the AQ-Child in children with a diagnosis of ADHD could entail a significant clinical contribution in this respect.

In terms of predictions, some support was envisaged for either a five- or a four-factor model. In terms of internal consistency reliability we expected support for these factors in terms of omega coefficient (ω). As for the concurrent and discriminant validities of the AQ latent factors, significant unique correlations were expected between some of the CBCL syndrome scores (especially withdrawn/depression, though problems, and attention problems) and the AQ-Child factors, and also for these associations to differ for the different AQ factors.

Method

Participants

The current study used archival data collected at the Academic Child Psychiatry Unit (ACPU) of the Royal Children's Hospital, Melbourne, Australia. The ACPU is an out-patient psychiatric unit that provides services for children and adolescents with behavioral, emotional, and learning problems. For the present study, records of children and adolescents, aged between 4 and 11 years, with a diagnosis of ADHD, referred between 2008 and 2017, who had parent rating scores for the Autism Spectrum Quotient—Children's Version (AQ-Child) were used. In all, there were 404 parent ratings (314 of boys and 90 of girls).

Supplementary, Table 1 provides the sociodemographic characteristics and clinical diagnoses of children who were involved in the present study. As shown in the table, most fathers were employed, and most mothers were mainly employed or involved in home duties. Close to 50% of participants had mothers and fathers who had attended at least secondary schools, and most were from families with income more than $50,000 per year. These figures correspond close to the Australian population. In terms of parental relationship, approximately 54% were living together, 42.3% were separated or divorced, and the others were in single relations for other reasons (e.g., death). In relation to clinical disorders (diagnostic procedure described below), in adjunct to ADHD, around 69.4% of the participants had Oppositional Defiant Disorder (ODD). Around 52.9%, 40.0%, 30.0%, and 40.0% of the participants were diagnosed with Generalized Anxiety Disorder (GAD), Specific Phobia (SPP), Dysthymia (DYSTH) and SOP (Social Phobia), respectively. Panic Disorder (PD), Post-Traumatic Stress Disorder (PTSD), and AG (Agoraphobia) were relatively rare.

Table 1

Fit values for the one- to five-factor models tested in the EFA

Models	WLSMVχ^2	*df*	RMSEA (90% CI)	CFI	TLI
One-factor	4420.34	1034	0.090 (.087–.093)	.667	.652
Two-factor	3034.83	988	0.072 (.069–.075)	.799	.780
Three-factor	2136.14	943	0.056 (.053– 0.059)	.883	.865
Four-factor	1771.00	899	0.049 (.046–.052)	.914	.897
Five-factor	1591.07	856	0.046 (.043–.050)	.928	.909
All MLRχ^2 values were significant ($p < .001$)					
WLSMVχ^2 robust maximum likelihood Chi square (Satorra-Bentler Chi square), *RMSEA* root mean square error of approximation, *CFI* comparative fit index, *TLI* Tucker-Lewis Index					

Measures

The Autism Spectrum Quotient–Children'sVersion (AQ-Child)

The AQ-Child has been described in detail in the introduction.

Child Behavior Checklist/6–18

The syndromes scores for the Child Behavior Checklist/6–18 (CBCL) were used in the study to examine the concurrent and discriminant validities of the factors in the optimum (highest fit) AQ-Child model. The CBCL is a measure in the Achenbach System of Empirically Based Assessment (Achenbach and Rescorla 2001). Completed by parents, it has 113 items, and is used to rate children between 4 and 18 years of age. Respondents indicate the degree or frequency of each behavior described in the item on a scale of 0 (not true), 1 (somewhat or sometimes true), or 2 (very true or often true). The standard rating period for the CBCL is 6 months. The CBCL includes scales for various behaviour and emotional problem syndromes (Achenbach and Rescorla 2001). The syndromes include the dimensions/subscales of "anxious/depressed", "withdrawn/depressed", "somatic complaints", "social problems", "thought problems", "attention problems", "rule-breaking behaviour", and "aggressive behaviour". The CBCL has excellent psychometric properties, and are summarized in Achenbach and Rescorla (2001) and Achenbach et al. (2008).The average internal consistency- reliability alpha values across the CBCL for the original US sample was around .82 across the syndrome scales, whilst the average CBCL dimensions for samples from 33 societies was around .76 (Achenbach et al. 2008). The syndrome/ dimensions' scores are derived by summing the responses of the items in the respective scales, and then converting these raw scores to *T* scores.

Anxiety Disorders Interview Schedule for Children (ADISC-IV; Silverman and Albano 1996)

The ADISC-IV is a semi-structured interview, based on the DSM-IV-TR diagnostic system (APA 2000). The diagnoses reported earlier (see sample description) were derived from this diagnostic schedule. Although ADISC-IV has been designed primarily to facilitate the diagnosis of the major childhood internalizing disorders, it can also be used for diagnosing the major childhood externalizing disorders. The ADISC-IV guidelines for diagnosis clarify that the child assessed should be given diagnosis of all disorders meeting the diagnostic criteria. The subscale scores of ADISC-IV have sound psychometric properties (Silverman et al. 2001). Test–retest reliability for the ADISC-IV scores over a 7 to 14-day interval has demonstrated good to excellent values. Kappa (an index of inter-rater agreement) values for interviews with parents ranged from 0.65 to 1.00 (Silverman et al. 2001). At this point it should be noted that there are different ADISC-IV versions for parent interview and for child interview, and clinical diagnosis can be based either on parent or child interview or on both interviews considered together (Silverman and Albano 1996). All diagnoses reported in this study were based on parent interviews for two reasons highlighted in past literature: (a) There is evidence of poor levels of agreement for diagnosis between information across the child and parent versions of the ADISC-IV (Grills and Ollendick 2003) and; (b) Clinical interviews of children can lead to unreliable diagnosis (Jensen et al. 1999).

Procedure

The study was approved by the RCH ethics committee as part of ACPU's comprehensive examination of children and adolescents referred for psychological problems. Each legal guardian and participant provided informed written consent for any data provided by them (in relation to their children examination) to be used in future research studies. This is a standard part of the ACPU assessment procedure.

All participants and their parents participated in separate interviews and testing sessions which were held over 2 days. Breaks were provided as necessary. In all cases, parental consent forms were completed prior to the assessment. The parent and child data collected covered demographic, medical (primarily neurological and endocrinological manifestations), child related educational performance indicators (including standardized measures of IQ and academic achievement tests of reading, arithmetic and language), child psychological indicators (standardized

measures of behavioral and emotional self-rating and parent rating scales, diagnostic interviews using the child and parent versions of the ADISC-IV, and neuropsychological measures), family related measures (standardized measures of family maladjustment, and marital satisfaction), and maternal/parental mental health measures (standardized measures of behavioral and emotional symptoms) of the participants and the participants' family. Information was also obtained from teachers using various checklists and questionnaires, such as the Teacher Report Form (Achenbach and Rescorla 2001) and the Conners 3-Teacher (Conners 2008). However, for the current study only the information for the ADISC-IV from parents and parent completed AQ-Child and CBCL ratings were used. These measures were administered to the same parent, with the ADISC-IV administered before the CBCL and AQ-Child, and the CBCL administered before the AQ-Child.

All psychological data were collected by research assistants, who were advanced masters or doctoral students in clinical psychology, and were placed under the supervision of two registered clinical psychologists. Prior to data collection, the research assistants were provided with extensive supervised training and practice by the two ACPU employed registered psychologists. The training for the ADISC-IV-P included observations of the interview process being administered by the psychologists. The research assistants commenced administering the ADISC-IV only after they attained competence in its administration, as assessed by their supervisors. There was adequate inter-rater reliability for the diagnoses made between the research assistants and the supervisors, and between the research assistants themselves (kappa = .88). Standard procedures were used for the administration of all measures. Where necessary (due to visual deficits and/or English literacy reasons) researchers read the items to participants (approximately 5% of the sample). Approximately 95% of the parent ADISC-IV interviews involved mothers only, and the rest involved fathers only or both fathers and mothers together. Using the categorical data from the parent ADISC-IV, clinical diagnosis was determined by two consultant child and adolescent psychiatrists, who independently reviewed the assessment data. The inter-rater reliability for diagnoses of the two psychiatrists was high (kappa = .90). As noted earlier, for the current study, only the records of children who had scores for the AQ-Child, rated by mothers were used.

Statistical Procedures

Confirmatory Factor Analysis

All the CFA models in the study were conducted using M*plus* (Version 7) software (Muthén and Muthén 2013). As there are three ordered response categories for all the AQ-Child items, the mean and variance-adjusted weighted least squares (WLSMV) extraction was used for all the CFA analyses (Rhemtulla et al. 2012).This is a robust estimator, recommended for CFA with ordered-categorical scores. This method does not assume normally distributed variables. According to measurement experts, relative to other estimators, the WLSMV estimator provides the best option for modeling categorical data (Beauducel and Herzberg 2006; Lubke and Muthen 2004; Millsap and Yun-Tein 2004). Brown (2014) has indicated that the estimator performs well for variables with floor or ceiling effects. Thus the WLSMV estimator is well suited for evaluating the ratings of the AQ-Child because they involved categorical scores, and as this study utilized a community sample, some level of floor effect could be expected in the ratings.

Exploratory Factor Analysis (EFA)

In the EFA, conducted with M*plus* (Version 7) software, we tested for one to five-factor solutions. For these analyses, WLSMV estimation, with promax (i.e., oblique) rotation was applied. As per Norris and Lecavalier (2010), scree plot, model fit indices, the content and interpretability of the factors, salience of item loadings, items with cross-loadings, and number of salient items in the factors were used concurrently to ascertain the number of factors to be retained. In addition, we also conducted parallel analysis (PA), using the FACTOR program (Lorenzo-Seva and Ferrando 2006). The PA in this program was based on minimum rank factor analysis (MRFA), involving unweighted least squares, polychoric correlations, and promin rotation. As per Tabachnick and Fidell (2007), we decided to use a loading of .45 (20% variance overlap between variable and factor) or more as salient loadings. Items with cross-loadings (an item having loadings of .45 or more on two or more factors) were eliminated from all factors, and the minimum number of items required for an acceptable factor was set at three (Brown 2006; Costello and Osborne 2005; Tabachnick and Fidell 2007). Thus factor models with less than three items in any one of its factors were not considered.

Evaluation of Model Fit

At the statistical level all the CFA/EFA models were evaluated using χ^2 values (WLSMVχ^2 values in the current case). As all types of χ^2 values, including WLSMVχ^2, are inflated by large sample sizes, the fit of the models tends to be generally interpreted by researchers using approximate fit indices, such as the root mean squared error of approximation (RMSEA), the comparative fit index (CFI), and Tucker-Lewis Index (TLI).

For models based on maximum likelihood estimation, the guidelines suggested by Hu and Bentler (1998) are that RMSEA values close to .06 or below can be taken as good fit, close to .07 to < .08 as moderate fit, close to .08 to .10 as marginal fit, and close to > .10 as poor fit. For the CFI and TLI, values close to .95 or above are taken as indicating good model-data fit, and values of .90 and < .95 are taken as acceptable fit. These fit values have also been found applicable for order-categorical data (Muthen and Muthen 2013). When considering the approximate fit indices, it is worth noting that despite the widespread use of the CFI, TLI and RSMEA values, a simulation study by Nye and Drasgow (2011) concluded that appropriate indices cut-off values for WLSMV estimation can vary across conditions.

For the current study, these appropriate approximate fit indices, and not the χ^2 statistic were used as evidence of model fit.

Internal Consistency-Reliability

Cronbach's alpha, ordinal alpha and coefficient ω were computed for the factors corresponding to the optimum model. Cronbach's alpha values were computed using SPSS. Ordinal alpha values were computed using the program developed by Olvera Astivia (downloaded from https://psychometroscar.com/shiny-apps-resources/ on 17th ly 2018). The ωs were computed using the program developed by Watkins (2013).

Concurrent and Discriminant Validities

To test the concurrent and discriminant validities of the factors in the optimum model, the CBCL syndrome scale scores were correlated with the AQ factors of the optimum model. As unique associations between these constructs were targeted, multiple regression analysis was used. For each of the AQ-Child optimum model factors, the total score was regressed on all the eight CBCL syndrome total scores simultaneously. The standardized beta values and the partial correlation values from the outputs for these analyses were examined. Support for concurrent validities for the AQ-Child factors were interpreted as adequate if the partial correlation *r* values were > 0.55 (Muñiz 2008), and support for discriminant validities were inferred if there were differences in the pattern of beta for the CBCL syndromes with the AQ factors. In this respect, the bootstrapping approach proposed by Cummings (2009) was used to test for significant difference between beta coefficients in the models.

Results

Preliminary Analyses

Prior to conducting the factor analyses, missing values and multivariate skewness and kurtosis for the present data set were examined.

Missing Values

Out of 81,800 scores (404 participants × 50 items × 4 response categories), there were 402 (approximately 0.49%) missing scores. The lowest covariance coverage for each pair of variables (obtained using M*plus*) was .9631. As this value is well above the minimum threshold of .10 for model convergence, the missing values in the data set can be considered to be within acceptable limits. Full information maximum likelihood estimation, available in M*plus*, was used to statistically manage missing values. This procedure, which assumes that data are missing at random, is a widely accepted approach for handling missing data (Schafer and Graham 2002).

Multivariate Skewness and Kurtosis

For ratings of all 50 items, the two-sided multivariate skewness and kurtosis values were 457.11 and 2945.21, respectively. For the ratings involving only the 47 items (excluding the lower in discriminant validity items 29, 30 and 49), the two-sided multivariate skewness and kurtosis were 397.66 and 2547.12, respectively. All skewness and kurtosis values were significant ($p < .001$). Thus, the scores in the present data set for the models involving all the 50 as well as only the 47 items were both non-normally distributed, thereby, justifying the application of a robust errors (in the present case WLSMV) factor extraction procedure (Muthén and Asparouhov 2015).

Confirmatory Factor Analysis

Supplementary Table S2 shows the correlation matrix for ratings of all the 50 items in the AQ-Child, and Supplementary Table S3 shows item mean and *SD* scores. The fit indices for the 5-factor model were as follows: [χ^2 ($df = 1165$) = 3764.06, $p < .001$; RMSEA = .074 (90% CI .072–.077); CFI = .747; TLI = 724; and WRMR = 2.099]. The fit indices for the 4-factor model were as follows: [χ^2 ($df = 1028$) = 2848.93, $p < .001$; RMSEA = .066 (90% CI .063–.069); CFI = .821; TLI = .812; and WRMR = 1.827]. Thus the RMSEA value indicated moderate model fit, and the CFI, TLI and WRMR values indicated poor model fit. Thus there was minimal support for either model. Given this outcome, we used EFA to ascertain an alternate better fitting model for the AQ-Child, using the same sample.

Exploratory Factor Analysis

The scree plot from M*Plus* for the EFA (see Supplementary Figure S2) suggested the possibility of three or four factors for valuable interpretation of the AQ-Child variance. The PA from the FACTOR program indicated that five factors would be retained.

The fit values for the 1- to 5-factor solutions are presented in Table 1. As shown, the 1-factor model showed poor fit in terms of the CFI and TLI values, and marginal fit in terms of the RMSEA value. The 2-factor model showed poor fit in terms of the CFI and TLI values, and moderate fit in terms of the RMSEA value. The 3-factor model showed poor fit in terms of the CFI and TLI values, and good fit in terms of the RMSEA value. Both the 4-factor and 5-factor models showed acceptable fit in terms of the CFI and TLI values, and good fit in terms of the RMSEA value. Thus, taken together, the scree plot and the fit values showed some support for the 3-, 4- and 5-factor models. In order to

ascertain the preferred (optimum) model, the patterns of factor loadings in these models were examined.

Supplementary Table S3 shows the factor loadings of 3- to 5-factor EFA solutions.

In relation to the item allocated in the theoretically proposed five factor model, for the three-factor model, factor one had four items from the social skills (22, 36, 45 and 48), three items from the attention switching (10, 32 and 37), 8 items from the communication (7, 18, 26, 27, 31, 33, 35 and 39) and 5 items from the imagination (8, 20, 21, 42 and 50) subscales; factor two had six items from the social skills (1, 11, 13, 15, 44 and 47), one item from the attention to detail (34), and two items from the communication (17 and 38) subscales; and factor-three had five items from the attention to detail (6, 9, 12, 19 and 23) and one item from the attention switching (41) subscales. Thus although the second and third factors were somewhat comparable to the social skills and attention to detail factors in the previously proposed four- and five-factor models, the first factor was a mixed factor and had little resemblance to any factor in these proposed models.

For the five-factor model, factor one had six items from the social skills (1, 11, 13, 15, 44 and 47), one item from the attention switching (34), and two items from the communication (17 and 38) subscales; factor two had one items from the social skills (22), one item from attention switching (4), one item from the attention to detail (5), and one item from the communication (26) subscales; factor-three had five items from the attention to detail (6, 9, 12, 19 and 23) and one item from the imagination (41) subscales. Factor 4 had one item from the social skills (36), two items from the attention switching (32 and 37), two items from the communication (27 and 31) subscales; and factor 5 had six items from the imagination (3, 8, 14, 20, 21 and 50) scale. Thus although the first, third, and fifth factors were somewhat comparable to the social skills, attention to detail, and imagination factors, respectively, in the previously proposed four- and/or five-factor models, the second and fourth factors had little resemble to any factor in these proposed models.

For the four-factor model, factor one had three items from the social skills (36, 45 and 48), five items from the attention switching (4, 10, 16, 32 and 37), and seven items from the communication (7, 18, 27, 31, 33, 35 and 39) subscales; factor two had six items from the social skills (1, 11, 13, 15, 44 and 47), one item from the attention switching (34), and two items from the communication (17 and 38) subscales; factor-three had five items from the attention to detail (6, 9, 12, 19 and 23) and one item from the imagination (41) subscales; and factor 4 had five items from the imagination (3, 8, 20, 21 and 50) sunscale. Thus the second, third, and fourth factors were somewhat comparable to the social skills, attention to detail, and imagination factors, respectively, in the previously proposed four- and five-factor models. Although the first factor was a mixed factor the item content corresponded very closely to the mind-reading factor in the previously proposed four-factor models. Indeed, of 15 items in this factor for our model, there were 14 items that were the same in the mind-reading factor in the proposed four-factor model. Additionally for the 9 items in the second factor in our model, there were 8 items that were the same in the comparable factor (attention switch) for the proposed four-factor model. For the 6 items in the third factor in our model, there were 5 items that were the same in the comparable factor (attention to detail) for the proposed four-factor model; and for the 5 items in the fourth factor in our model, there were 4 items that were the same in the comparable factor (imagination) for the proposed four-factor model. Thus our four-factor model was conceptually similar to the four-factor model proposed previously for the AQ-Child. Given this, and the findings from the scree plot, and the acceptable fit for the four-factor model, we concluded that the four-factor model from our EFA was the optimum model. Also, corresponding to proposed four-factor model, we labelled factors 1, 2, 3 and 4 as “mind-reading”, “social skills”, “attention to details” and “imagination”, respectively. However as will be noticed our four-factor model is not identical to the previous proposed four-factor model in terms of item content within factors, and comprised only 32 items (of the 47 items), as 12 items (22, 2, 25, 43, 46, 5, 28, 26, 14, 24, 40 and 42) did not show salient loadings (≥ .45) on any factor.

Internal Consistency Reliabilities of the Factors in the EFA Proposed 5-Factor Model

The internal consistency-reliability Cronbach α values for “mind-reading/imagination”, “attention to detail”, “social skills” and imagination were .82, .85, .80 and .75, respectively. The ordinal alpha values were .86, .88, .84, amd .80, respectively. The internal consistency-reliability ω values for “mind-reading”, “attention to detail”, “social skills” and imagination were .91, .84, .79 and .87, respectively.

Concurrent and Discriminant Validities

Given that the four-factor model from the EFA was adopted as the optimum fit model, the concurrent and discriminant validities for the AQ-Child factors in this model were examined. Table 2 shows the results for the validity analyses. As shown, for the criteria used her to ascertain significance ($p < .01$), the CBCL attention problems and thought problems dimensions were uniquely and positively associated with the AQ-Child factor for mind-reading. However (although details are not presented here), the beta coefficient involving attention problems was higher than thought problems The CBCL thought problems dimension was uniquely and positively associated with the AQ-Child dimension attention to details, and this association was significantly higher than the other CBCL dimensions with attention to details. The CBCL withdrawn/depressed dimension was uniquely and positively associated with AQ-Child dimension social skills, and this association was significantly higher than the other CBCL dimensions with social skills. None of the CBCL dimensions was associated significantly with AQ-Child imagination dimension. These results indicate differential associations for the CBCL dimensions with the AQ-Child dimensions, thereby supporting the discriminant validities of the AQ-Child factors. However, as none of the correlations was > .55, concurrent validity for all the AQ-Child factors

cannot be inferred.

AQ7

Table 2

Beta coefficients (and partial correlations) in the multiple regression analyses for the predictions of the AAQ-child factor scores by the CBCL scale scores ($N = 348$)

CBCL scale score	Autism spectrum quotient—child factors			
	Mind-reading	Attention to details	Social Skills	Imagination
Anxious/depressed	– .04 (– .04)	– .01 (– .01)	.01 (.01)	– .03 (– .03)
Withdrawn/depressed	.11 (.10)	– .01 (– .01)	.56*** (.49)	.17** (.15)
Somatic complaints	– .06 (– .06)	– .02 (– .02)	– .19*** (– .19)	– .06 (– .05)
Social problems	.17 (.13)	.16 (.11)	.07 (.06)	.17 (.11)
Thought problems	.17** (.14)	.33*** (25)	.15 (.14)	.06 (.05)
Attention problems	.31*** (.28***)	– .18 (– .14)	– .03 (– .03)	.09 (.07)
Rule breaking behavior	.03 (.02)	.07 (.04)	– .07 (– .04)	.10 (.06)
Aggressive behavior	.07 (.06)	– .13 (– .07)	– .11 (.07)	.01 (.00)
Values in parenthesis are partial correlations from the multiple regression analyses outputs				
$^{**}p < .01$; $^{***}p < .001$				

Discussion

The major aim of the current study was to examine the factor structure of the AQ-Child, based on parent ratings of a large group of clinic-referred children with ADHD. CFA was used to evaluate the fit of the theorized five-factor model. Given that in the initial development and validation study of the AQ-Child, a four factor model was proposed (for 47 items), this four factor model was also tested. The findings showed minimal support for both models. Given this outcome, EFA was applied to ascertain an alternate better fitting model for the AQ-Child, using the same sample. As the initial development and validation study of the AQ-Child inidcated that items 29, 30, 49 did not adequately discriminate between those with and without ASD (Auyeung et al. 2008), EFA was applied on the remaining 47 items to assess an alternate better fitting model for the AQ-Child. For this, the present study tested one- to five-factor oblique models. The scree plot and the fit values showed some support for the 3-, 4- and 5-fctor models. In order to confirm the preferred (optimum) model, the patterns of factor loadings in these models were additionally examined. Overall, the findings showed most support for the four-factor model, with factors for “mind-reading”, “attention to details”, “social skills”, and “imagination”. The present findings showed that the internal consistency-reliability (based on Cronbach α, ordinal alpha and ω values) for all four factors in our model were above the recommended critical value (.70), that is generally considered the minimum level for acceptable internal consistency-reliability (Nunnally 1978). This adds further support for our preferred four-factor model. There was also support for the discriminant validities of the factors in the four-factor model revealed, as these factors were differently associated with the CBCL dimension scores.

AQ Child Factor Structure

The lack of support for the originally proposed five- and four-factor models is in line with existing data of the adult version of the AQ, as those studies have also not been able to demonstrate a generally accepted factor model for that measure, with different studies reporting different factor structures (Austin 2005; Hurst et al. 2007; Hoekstra et al. 2008; Lau et al. 2013a, b; Stewart and Austin 2009; Kloosterman et al. 2011). However, it is worthy of note that the present findings’ support for the inclusion of factors relevant to “social skills”, “attention to detail”, “mindreading” and “imagination” is consistent with studies involving the AQ (Austin 2005; Hurst et al. 2007).

Although the four factors in our four-factor model corresponded conceptually to the four-factors proposed by Auyeung et al. (2008), it is to be noted that our four factors are not identical to that proposed by Auyeung et al. (2008) in terms of item content within factors, Our model compriseg only 32 items (of the 47 items), as 12 items (22, 2, 25, 43, 46, 5, 28, 26, 14, 24, 40 and 42) did not show salient loadings (≥ .45) on any factor. Thus, the present EFA findings provide most support for a model not proposed previously for the AQ-Child, thereby suggesting a degree of potential instability for the factor structure of the AQ-Child.

AQ8

Implications

The findings in the study have implications for the utilization of the AQ-Child in clinical practice and research. As will be recalled, three items (29, 30 and 49) were excluded prior to conducting the EFA. The optimum four-factor model, based on the remaining 47 items, had 32 items with salient loadings (≥.45). Thus, from the total pool of items, 13 items can be removed from the AQ-Child when it is used. Overall, unlike existing practice, our findings indicated that a 32 item version of the AQ-children can be used, and that the ratings could be organized into four factors. The item content of the factors in the present supported four-factor model is as follows: "mind-reading" involves items 36, 45. 48, 4, 19, 16, 32, 37, 7, 18, 27, 31, 33, 35, and 39; "attention to detail" factor involves items 6, 9, 12, 19, 23 and 41; "social skills" factor involves items 11, 13, 15, 44, 47, 34, 17 and 38, and "imagination factor" involves items 3, 8, 29, 21 and 50.

AQ9

The findings in the study also have implications on understanding the relationship of autism constructs with constructs for behavioral and emotional problems, as well as the use of the CBCL scale for screening ASD behaviors. In particular, the findings indicated that high levels attention problems are associated with high levels of the ASD trait of poorer mind-reading. Similarly, high levels of the thought problems are associated with high levels of the ASD trait of poorer attention to details, and high levels of withdrawn/depressed are associated high levels of social problems. In that line, the present findings are generally consistent with available data showing that, CBCL withdrawn/depressed, thought problems and attention problems dimensions are generally associated with ASD behaviors in both community and clinic-referred samples (Biederman et al. 2010; Bölte et al. 1999; Duarte et al. 2003; Hoffmann et al. 2016; Hartini et al. 2016; Ooi et al. 2011). However, the present findings also extend existing findings as, unlike previous studies, they additionally involve the subdomain levels of the ASD constructs. Also, we examine unique associations between the autism constructs with constructs for behavioral and emotional problems. As the emotional and behavioral constructs used here were from the CBCL, the present findings can be interpreted to indicate that the CBCL scales for withdrawn/depressed, thought problems and attention problems can be used for screening ASD behaviors, as proposed by others (Biederman et al. 2010; Bölte et al. 1999; Duarte et al. 2003; Havdahl et al. 2016; Hoffmann et al. 2016; Hartini et al. 2016; Mazefsky et al. 2011; Ooi et al. 2011).

AQ10

A significant research implication of the present findings is that it will be worthwhile that future studies of the AQ measures examine and report the internal consistency reliabilities of its factors using ordinal alpha and coefficient ω.

Limitations and Further Research

Although the current study has provided useful new psychometric information about the AQ-Child, the present findings and their interpretations embrace certain limitations. First, it is possible that factors such as cultural background (Australian population is a multicultural population) and maternal psychopathology could influence ratings of the AQ-Child. The failure to control for these effects in this study could have confounded the results. Second, as a clinic-referred sample of children with ADHD was examined, it is uncertain if the findings could be applicable to the general community or general clinc-referred children. This is an important limitation as the AQ-Child was developed to also measure ASD trait(s) in these groups. On the flip side, as the psychometric properties of the AQ-Child were examined here in children with ADHD, they may be seen as directly applicable to children with ADHD. This is useful given that ADHD and ASD tend to co-occur at relatively high rates, (Gargaro et al. 2011; Leyfer et al. 2006; Matson et al. 2013; Reiersen and Todd 2008; Simonoff et al. 2008). Third, all the participants in this study were from the same clinic, and therefore they did not constitute a random sample. Thus, it is likely that this may constitute a bias for the sample recruited, limiting the generalizability of the findings and the conclusions made in this study (even in relation to children with ADHD). Fourth, as the current sample was highly comorbid for other disorders, the findings may have been confounded. Finally, as archival data was used, typical related limitations are involved (summarized by Jones 2010). In view of these weaknesses, some may wish to consider the present findings and the interpretations made in this study as tentative. It would be useful if future studies examine the psychometric properties of the AQ-Child, taking into consideration the limitations highlighted in the present work. Despite these, it is envisaged that the results and the information provided in this paper would contribute meaningfully towards better understanding of the factor structure of the AQ-Child, and in that way to clinical practice and research involving the instrument.

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Author Contributions RG contributed to the literature review, hypotheses formulation, data collection and analyses, and the structure and sequence of theoretical arguments. VS contributed to the literature review, hypotheses formulation, data collection and analyses, and the structure and sequence of theoretical arguments. AV contributed to the data collection and analyses.

Compliance with Ethical Standards

Conflict of interest The authors of the present study do not report any conflict of interest.

Ethical Approval All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

Electronic supplementary material

Below is the link to the electronic supplementary material.

Supplementary material 1 (DOCX 166 KB)

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