

The Autism Spectrum Quotient: Children's Version (AQ-Child)

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Abstract The Autism Spectrum Quotient—Children's Version (AQ-Child) is a parent-report questionnaire that aims to quantify autistic traits in children 4–11 years old. The range of scores on the AQ-Child is 0–150. It was administered to children with an autism spectrum condition (ASC) ($n = 540$) and a general population sample ($n = 1,225$). Results showed a significant difference in scores between those with an ASC diagnosis and the general population. Receiver-operating-characteristic analyses showed that using a cut-off score of 76, the AQ-Child has high sensitivity (95%) and specificity (95%). The AQ-Child showed good test–retest reliability and high internal consistency. Factor analysis provided support for four of the five AQ-Child design subscales. Future studies should evaluate how the AQ-C performs in population screening.

Keywords

Autism Spectrum Quotient—Children's Version ·
Autism · Sex differences

Introduction

The Autism Spectrum Quotient (AQ-Adult) was developed to quantitatively measure traits associated with the autistic spectrum in adults of normal intelligence. The AQ-Adult is a brief, self-administered, 50-item questionnaire. Results from the AQ-Adult demonstrate that those with an autism

spectrum condition (ASC) diagnosis score significantly higher than a sample from the general population. 80% of individuals with a diagnosis of Asperger Syndrome (AS) or high functioning autism (HFA) scoring at or above a cut-off of 32 (out of 50), whilst only 2% of controls score at or above this cut-off (Baron-Cohen et al. 2001).

The AQ-Adult shows strong heritability as demonstrated in a general population twin study (Hoekstra et al. 2007), and in family genetic studies of parents of children with ASC, who score higher than unrelated individuals (Bishop et al. 2004; Wheelwright and Baron-Cohen, submitted). As such it not only identifies the narrow autism phenotype (i.e., individuals with a diagnosis of childhood autism) but also the broader autism phenotype¹ (Bolton et al. 1994; Landa et al. 1992; Le Couteur et al. 1996; Sears et al. 1999). The AQ-Adult has also been found to predict a diagnosis of AS in a clinic sample (Woodbury-Smith et al. 2005). It shows high inter-rater and test–retest reliability (Baron-Cohen et al. 2001). The norms reported in the 2001 sample have been replicated very closely in independent samples in the UK (Austin et al. 2002; Wheelwright et al. 2006), in a Dutch sample (Hoekstra et al., submitted) and several Japanese samples (Kurita et al. 2005; Wakabayashi et al. 2004, 2006). In the Dutch sample there was also a test of the clinical specificity of the AQ-Adult, where it was found that adults with AS or HFA scored significantly higher than general adult psychiatric clinical controls (Hoekstra et al. 2007).

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¹ The concept of the broader autism phenotype has emerged from research which suggests that in addition to causing autism, the genetic liability for this disorder may also be expressed, in the nonautistic relatives of autistic individuals, through behavioral and cognitive characteristics that are milder but qualitatively similar to the defining features of autism.

An adolescent version of the AQ has also been developed (AQ-Adol) (Baron-Cohen et al. 2006). The AQ-Adol is completed by a parent about their child, but in almost all respects items on the AQ-Adol are the same as the AQ-Adult. Results showed that adolescents scored very similarly to adults, with individuals with ASC scoring significantly higher than matched controls (Baron-Cohen et al. 2006). For the AQ-Adol, 90% of adolescents with a clinical diagnosis of an ASC scored at or above the cut-off of 30, compared to 0% of controls (maximum score = 50). Sex differences were found on both the adult and adolescent versions of the AQ, with typical males scoring higher than females. Specifically, the mean score for males on the AQ-Adult was 17.8 (SD = 6.8) and for females was 15.4 (SD = 5.7), which is comparable to the mean score for males ($M = 20.2$, $SD = 4.8$) and females ($M = 15.3$, $SD = 5.7$) on the AQ-Adol.

Given the similar results on the AQ-Adult and the AQ-Adol, it is of interest to design a child version of the AQ (AQ-Child). A questionnaire of similar structure would allow for comparison with adolescent and adult data for individual items or sub-domains. Over a longer period it may also be possible to measure any changes in the profile of autistic traits with age. This might help to determine how stable autistic traits are across the lifespan. In addition, if the AQ-Child is found to predict the presence of a clinical diagnosis of an ASC in clinical samples, this brief questionnaire may be a useful screening measure that could identify children at risk for ASC in a clinical setting as well as being invaluable for epidemiological research that requires large samples.

The AQ-Adult and AQ-Adol are divided into five different domains or categories of autistic traits. These are: social skills, attention to detail, attention switching, communication and imagination. Each domain is assessed by ten questions. AQ items consist of statements that are answered in a Likert scale (Definitely Agree, Slightly Agree, Slightly Disagree and Definitely Disagree). The minimum score on the AQ-Adult and AQ-Adol is 0 and the maximum score is 50. These questionnaires have demonstrated good internal consistency indicated by high α coefficients for items measuring each of the five sub-domains.

The present study aimed to develop a version of the Autism Spectrum Quotient suitable for children (AQ-Child). The questionnaire format is maintained and questions are modified in order to identify autistic traits through parent report. The psychometric properties of this measure are investigated by administering the AQ-Child to $n = 1,225$ control and $n = 540$ children with an ASC diagnosis. Data from these samples are analyzed to identify an appropriate cut-off that may predict the presence of ASC as well as to analyze the factor structure for

comparison with the AQ-Adult and AQ-Adol. It was expected that similar scoring patterns would be found in children as has been found previously in older populations: children with ASC scoring the highest, followed by control males then by control females (Baron-Cohen et al. 2001, 2006).

Method

The AQ-Child

The AQ-Child is a 50-item parent-report questionnaire developed to detect autistic traits in children at 4–11 years of age. The AQ-Child was designed to be a parent-report questionnaire, since self-report by children might be restricted by reading and comprehension difficulties. It was adapted from the adult and adolescent versions of the AQ, and items that were not age-appropriate in the adult questionnaires were revised accordingly. Items in the AQ-Child were kept as close to the AQ-Adult and AQ-Adol as possible, with most questions aimed at the same behaviors (see Appendix 1). Items were worded to produce an approximately equal agree/disagree response in order to avoid a response bias.

The AQ-Child consists of a series of descriptive statements designed to assess five areas associated with autism and the broader phenotype: social skills (items 1, 11, 13, 15, 22, 36, 44, 45, 47, 48), attention switching (items 2, 4, 10, 16, 25, 32, 34, 37, 43, 46), attention to detail (items 5, 6, 9, 12, 19, 23, 28, 29, 30, 49), communication (items 7, 17, 18, 26, 27, 31, 33, 35, 38, 39) and imagination (items 3, 8, 14, 20, 21, 24, 40, 41, 42, 50), each represented by ten items. Higher scores correspond to more ‘autistic-like’ behavior.

In the scoring system of Baron-Cohen et al. (2001) items are scored as 1 for a response in the ‘autistic’ direction and 0 for a ‘non-autistic’ response. The response scale in the present study adopted the scoring scheme used in recent studies of the AQ-Adult (Austin 2005; Hoekstra et al. 2007) where the response scale is treated as a 4-point Likert scale. Parents rate to what extent they agree or disagree with the statements about their child, with the following answer categories: 0 representing definitely agree; 1 slightly agree; 2 slightly disagree; and 3 definitely disagree. Items were reverse scored as necessary. This method was used because it was felt that the degree of endorsement of each item contained additional information and was therefore retained. Total AQ scores were represented by the sum of each item score. The minimum AQ score (0) indicates no autistic traits; the maximum score (150) suggests full endorsement on all autistic items.

Participants

Group 1 ($n = 1,225$, 618 girls, 607 boys) included children who were participating in a large epidemiological study of social and communication skills in children aged 4–9 years old (Scott et al. 2002; Williams et al. 2005). Children were excluded if the child had any of the following conditions: ASC ($n = 34$), language delay ($n = 58$), dyspraxia ($n = 13$), epilepsy ($n = 3$), or ADHD ($n = 28$). Twin births ($n = 32$) or siblings ($n = 62$) of children with an ASC were also excluded. In the case where more than one child in a family was participating, the child whose age was closest to the mean age of the control group ($M = 9.82$, $SD = 1.27$) was retained, and the other siblings were excluded ($n = 48$). Siblings and twin births were excluded to ensure independence of data. Initially, 2,777 questionnaires were sent out by post, resulting in a response rate of approximately 50%. This sample was drawn from primary schools in Cambridgeshire, UK. Results from a smaller sample of 89 control children (42 girls, 47 boys) suggest that IQ [measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999)] was not correlated to the AQ-Child, therefore IQ data were not collected ($r = -0.10$, $p > 0.5$).

Group 2 comprised children diagnosed with an ASC by psychiatrists using established DSM-IV criteria (APA 1994). Children with a diagnosis of autism [$n = 192$, mean age = 7.58 ($SD = 2.43$)] or AS/HFA ($n = 348$) were included in the study, mean age = 9.31 ($SD = 2.10$). Children with a diagnosis of PDD-NOS ($n = 26$) or atypical autism ($n = 4$) were excluded from the study due to the small sample sizes. Children with a diagnosis of autism were grouped separately from the children with an AS/HFA diagnosis. Mothers of these children were recruited via the University of Cambridge Autism Research Centre website and completed the questionnaires online (<http://www.autismsresearchcentre.com>).

Questionnaires with more than five blank items were considered incomplete and these data were discarded in subsequent analyses ($n = 57$). If five or fewer answers were missing, the AQ-Child score was corrected for missing items by making the following calculation: total AQ-Child score + (mean item score \times number of missing items) (Hoekstra et al. 2007).

Results

Item Analysis

An item analysis was conducted to examine scoring patterns on each item (see Table 1). Inspection of these scores showed that there were three items where controls scored

Table 1 Item analysis—mean scores for each item by group each group

| Item | Subdomain | Controls ($n = 1,225$) | AS/HFA ($n = 348$) | Autism ($n = 191$) |
|------|-----------|-----------------------------|-------------------------|-------------------------|
| AQ1 | S | 0.89 | 1.89 | 2.08 |
| AQ2 | A | 1.06 | 2.48 | 2.50 |
| AQ3 | I | 0.61 | 1.47 | 1.99 |
| AQ4 | A | 1.75 | 2.77 | 2.68 |
| AQ5 | D | 1.23 | 2.51 | 2.31 |
| AQ6 | D | 1.38 | 2.20 | 1.98 |
| AQ7 | C | 0.45 | 2.41 | 2.51 |
| AQ8 | I | 0.46 | 1.70 | 2.16 |
| AQ9 | D | 0.82 | 1.43 | 1.09 |
| AQ10 | A | 0.97 | 2.63 | 2.76 |
| AQ11 | S | 0.70 | 2.69 | 2.61 |
| AQ12 | D | 1.78 | 2.52 | 2.36 |
| AQ13 | S | 0.34 | 1.48 | 1.32 |
| AQ14 | I | 0.74 | 1.79 | 2.30 |
| AQ15 | S | 0.93 | 2.21 | 2.18 |
| AQ16 | A | 1.57 | 2.74 | 2.59 |
| AQ17 | C | 0.58 | 2.33 | 2.49 |
| AQ18 | C | 1.49 | 2.30 | 1.53 |
| AQ19 | D | 1.10 | 1.70 | 1.48 |
| AQ20 | I | 0.59 | 2.20 | 2.32 |
| AQ21 | I | 0.46 | 1.50 | 1.54 |
| AQ22 | S | 0.60 | 2.50 | 2.45 |
| AQ23 | D | 1.10 | 2.05 | 1.87 |
| AQ24 | I | 0.83 | 1.45 | 1.56 |
| AQ25 | A | 0.80 | 2.32 | 2.22 |
| AQ26 | C | 0.42 | 2.43 | 2.57 |
| AQ27 | C | 1.08 | 2.66 | 2.68 |
| AQ28 | D | 1.25 | 2.40 | 2.51 |
| AQ29 | D | 1.86 | 1.72 | 1.23 |
| AQ30 | D | 2.02 | 1.67 | 1.77 |
| AQ31 | C | 1.07 | 2.62 | 2.64 |
| AQ32 | A | 0.75 | 2.46 | 2.32 |
| AQ33 | C | 0.54 | 2.20 | 2.26 |
| AQ34 | A | 0.55 | 2.18 | 1.87 |
| AQ35 | C | 0.80 | 2.24 | 2.46 |
| AQ36 | S | 0.74 | 2.49 | 2.38 |
| AQ37 | A | 0.70 | 2.18 | 1.96 |
| AQ38 | C | 0.57 | 2.63 | 2.75 |
| AQ39 | C | 1.18 | 2.61 | 1.97 |
| AQ40 | I | 0.67 | 2.43 | 2.63 |
| AQ41 | I | 1.18 | 2.17 | 1.52 |
| AQ42 | I | 0.97 | 2.40 | 2.39 |
| AQ43 | A | 1.39 | 1.85 | 1.46 |
| AQ44 | S | 0.32 | 1.90 | 1.72 |
| AQ45 | S | 1.10 | 2.61 | 2.58 |
| AQ46 | A | 1.36 | 2.64 | 2.43 |
| AQ47 | S | 0.69 | 1.93 | 1.88 |

Table 1 continued

| Item | Subdomain | Controls (<i>n</i> = 1,225) | AS/HFA (<i>n</i> = 348) | Autism (<i>n</i> = 191) |
|------|-----------|---------------------------------|-----------------------------|-----------------------------|
| AQ48 | S | 0.64 | 2.35 | 2.45 |
| AQ49 | D | 1.69 | 1.36 | 1.04 |
| AQ50 | I | 0.48 | 2.12 | 2.42 |

Key: *C* communication, *S* social skills, *A* attention switching, *D* attention to detail, *I* imagination

higher than Group 2 (items 29, 30, 49). All three of these items focus on ‘attention to detail’. Closer inspection suggests that these items may be difficult to examine for young children and so these were eliminated in subsequent analyses.

Internal Consistency

Cronbach’s α coefficients were calculated and for the measure as a whole, the α coefficient was high ($\alpha = 0.97$). The internal consistency of the five AQ-Child subscales were also satisfactory (social skills = 0.93; attention to detail = 0.83; attention switching = 0.89; communication = 0.92; and imagination = 0.88).

Test–Retest Reliability

A random selection of 500 parents were asked to complete a second copy of the AQ-Child to examine test–retest reliability, resulting in 272 test–retest pairs (141 girls, 131 boys). The mean time interval between the first and second test was 12.3 weeks (SD = 2.01). For the AQ-Child, the correlation between the two tests was good ($r = 0.85$, $p < 0.001$).

Factor Analysis of the AQ-Child

The retained 47 items of the AQ-Child were subjected to principal components analysis (PCA). Prior to performing PCA, the suitability of the control AQ-Child data for factor analysis was assessed. Inspection of the correlation matrix revealed the presence of many coefficients of 0.3 and above. Diagnostic checks suggested that the data were suitable for analysis: the Kaiser–Meyer–Oklin value was 0.93, and the Bartlett’s test of sphericity reached statistical significance ($\chi^2 = 19841.29$, $df = 1081$, $p < 0.001$).

An oblique rotation was used, since it is reasonable to assume that the autism sub-components would be related. Five components arose explaining 21.8, 8.9, 5.1, 4.2 and

3.2% of the variance. An inspection of the scree plot revealed a clear break after the first, second and fourth components. It was decided to retain four components for further investigation. Before rotation, the four-component solution explained a total of 40% of the variance. A correlation ($r = 0.33$) was found between the first and third factors, confirming that the factors are not independent. To aid in the interpretation of these components, oblimin rotation was performed. All items with factor pattern matrix elements greater than 0.3 are included. The factors were named mind-reading, attention to detail, social skills and imagination. These factors were found to be respectively highly correlated with the original AQ sub-scales of communication ($r = 0.97$, $p < 0.001$), attention to detail ($r = 0.95$, $p < 0.001$) social skills ($r = 0.97$, $p < 0.001$), and imagination ($r = 0.97$, $p < 0.001$). Table 2 presents the items of the four scales in order of loadings on the components (highest first). The eigen values of the rotated factors and the percentages explained by each of the factors

Table 2 Factor structure of the AQ-Child

| Item | Content | Loading |
|--|--|---------|
| <i>Mind-reading</i> —Cronbach’s $\alpha = 0.96$, eigen value = 6.73, % variance = 21.77 | | |
| 39 | Keeps going on and on about the same thing | 0.663 |
| 45 | Finds it difficult to work out people’s intentions | 0.590 |
| 18 | Does not let others to get a word in edgeways | 0.577 |
| 35 | Often the last to understand a joke | 0.555 |
| 31 | Knows how to tell if someone bored | 0.539 |
| 37 | Can switch back after an interruption | 0.529 |
| 4 | Gets strongly absorbed in one thing | 0.484 |
| 27 | Finds it easy to ‘read between the lines’ | 0.468 |
| 36 | Finds it easy to work out feelings by looking at faces | 0.455 |
| 2 | Prefers to do things the same way | 0.454 |
| 7 | Is impolite, even though s/he thinks it is polite | 0.410 |
| 10 | Can easily keep track of several conversations | 0.402 |
| 32 | Finds it easy to do more than one thing at once | 0.376 |
| 42 | Finds it difficult to imagine being someone else | 0.376 |
| 33 | Does not know when it is their turn on the phone | 0.355 |
| 48 | Is a good diplomat | 0.331 |

Table 2 continued

| Item | Content | Loading |
|--|--|---------|
| <i>Attention to detail</i> —Cronbach's $\alpha = 0.85$, eigen value = 4.73, % variance = 8.85 | | |
| 6 | Notices numbers or strings of information | 0.783 |
| 23 | Notices patterns | 0.735 |
| 9 | Fascinated by dates | 0.714 |
| 19 | Fascinated by numbers | 0.700 |
| 12 | Notices details that others do not | 0.690 |
| 5 | Notices small sounds when others do not | 0.548 |
| 41 | Likes to collect information | 0.529 |
| 43 | Likes to plan activities carefully | 0.436 |
| 16 | Tends to have very strong interests | 0.421 |
| <i>Social skills</i> —Cronbach's $\alpha = 0.94$, eigen value = 7.59, % variance = 5.12 | | |
| 44 | Enjoys social occasions | -0.777 |
| 38 | Good at social chit-chat | -0.744 |
| 47 | Enjoys meeting new people | -0.707 |
| 17 | Enjoys social chit-chat | -0.694 |
| 11 | Finds social situations easy | -0.636 |
| 22 | Finds it hard to make new friends | -0.635 |
| 1 | Prefers to do things with others | -0.533 |
| 15 | Finds it hard to make new friends | -0.515 |
| 26 | Does not know how to keep up a conversation | -0.510 |
| 13 | Would rather go to a library than a party | -0.503 |
| 46 | New situations make him/her anxious | -0.422 |
| 34 | Enjoys doing things spontaneously | -0.405 |
| 25 | Gets upset when daily routine is disturbed | -0.294 |
| 24 | Would rather go to the theatre than the library | -0.279 |
| 28 | Concentrates on the whole picture rather than details | -0.222 |
| <i>Imagination</i> —Cronbach's $\alpha = 0.90$, eigen value = 4.80, % variance = 4.20 | | |
| 14 | Finds making up stories easy | 0.751 |
| 8 | Can easily imagine what story characters look like | 0.698 |
| 3 | Finds it very easy to create a mental picture | 0.654 |
| 21 | Does not particularly enjoy reading fiction | 0.548 |
| 50 | Finds it easy to play games that involve pretending | 0.511 |
| 20 | Finds it difficult to work out the characters' intentions in a story | 0.480 |
| 40 | Enjoyed playing games involving pretending | 0.447 |

are also shown. The internal reliabilities of the new factors were 0.96, 0.85, 0.94 and 0.90 respectively.

Group Differences

Group differences were examined using both the original AQ-Child subscales and on scores for the factors discussed above. Mean AQ scores (total) for each group, broken down by sex and by subdomain, are shown in Table 3.

Examination of the original subscales using an ANOVA of Total AQ score by group (control, AS/HFA and autism) and sex showed a significant effect of group [$F(2, 1759) = 1277.66, p < 0.001$]. Post hoc Dunnett T3 tests revealed that the two clinical groups scored significantly higher than the typically developing group ($p < 0.0001$), but that the two clinical groups did not differ from each other. The main effect of sex was also significant [$F(1, 1759) = 6.33, p = 0.01$]. The interaction between group and sex was also significant [$F(2, 1759) = 3.56, p < 0.05$].

T-tests confirmed that there was a significant sex difference [$t(1154.11) = 7.02, p < 0.001$, equal variances not assumed] in the control group (males scoring higher than females), confirming the same effect reported with the AQ-Adult and AQ-Adol. There were no significant sex differences in the clinical groups [Autism group: $t(190) = 0.26, p > 0.05$; AS/HFA group: $t(346) = 0.15, p > 0.05$]. See Fig. 1 for a visual representation of AQ distribution scores for control girls and boys and for the AS/HFA and Autism groups. The clinical groups differed from the control group on all subdomain scores (for *t*-tests results see Table 3). No association between age and AQ total was found ($r = 0.03, p > 0.05$) suggesting that AQ scores are independent of age in this sample.

Cut-off Scores

Figure 2 shows the receiver-operating-characteristic (ROC) curve. The area under the ROC curve was 0.99 (95% C.I.: 0.98–0.99), indicating that total score is a good indicator of ASC diagnosis.

Table 4 also shows sensitivity and specificity values for a range of potential cut-offs as well as the percentage of each group (by sex) scoring at or above each cut-off (maximum obtainable score = 141 when only using retained items). Adult (Baron-Cohen et al. 2001) and adolescent (Baron-Cohen et al. 2006) data are also shown. The ROC analysis showed that a score of 76 showed both high sensitivity (95%) as well as high specificity (95%). With a cut-off of 76, less than 2% of control girls and 7% of control boys scored at or above the ASC cut-off,

Table 3 Mean scores for subscales and total by group

| | AQ total | Communi- cation | Attention to detail | Social skills | Imagination | Attention switching | Factor1- mind-reading | Factor 2-Atten- tion to detail | Factor3- social skills | Factor4- imagination |
|---------------------------------|----------|--------------------|------------------------|------------------|-------------|------------------------|--------------------------|--------------------------------------|---------------------------|-------------------------|
| Controls (<i>n</i> = 1,225) | | | | | | | | | | |
| <i>x</i> | 41.7 | 8.2 | 8.7 | 7.0 | 7.0 | 10.9 | 15.3 | 11.6 | 10.8 | 4.0 |
| SD | 18.6 | 5.0 | 4.5 | 5.0 | 4.6 | 5.1 | 7.9 | 5.7 | 7.4 | 3.7 |
| Control boys (<i>n</i> = 607) | | | | | | | | | | |
| <i>x</i> | 45.7 | 9.0 | 8.9 | 7.8 | 8.5 | 11.5 | 16.6 | 12.0 | 12.0 | 5.1 |
| SD | 20.0 | 5.4 | 4.7 | 5.3 | 4.9 | 5.6 | 8.5 | 6.0 | 7.8 | 4.0 |
| Control girls (<i>n</i> = 618) | | | | | | | | | | |
| <i>x</i> | 37.7 | 7.4 | 8.5 | 6.1 | 5.5 | 10.3 | 14.0 | 11.1 | 9.7 | 2.9 |
| SD | 16.1 | 4.4 | 4.4 | 4.6 | 3.7 | 4.6 | 7.1 | 5.4 | 6.7 | 3.1 |
| AS/HFA (<i>n</i> = 348) | | | | | | | | | | |
| <i>x</i> | 104.8 | 24.4 | 14.7 | 22.1 | 19.2 | 24.2 | 39.4 | 19.2 | 33.0 | 13.2 |
| SD | 15.6 | 4.0 | 4.0 | 5.1 | 5.4 | 4.2 | 5.7 | 4.9 | 7.0 | 4.7 |
| AS/HFA boys (<i>n</i> = 312) | | | | | | | | | | |
| <i>x</i> | 104.8 | 24.4 | 14.9 | 21.9 | 19.4 | 24.2 | 39.3 | 19.4 | 32.8 | 13.3 |
| SD | 15.7 | 4.0 | 4.0 | 5.1 | 5.2 | 4.2 | 5.6 | 4.9 | 7.1 | 4.6 |
| AS/HFA girls (<i>n</i> = 36) | | | | | | | | | | |
| <i>x</i> | 104.7 | 24.9 | 13.7 | 23.4 | 17.9 | 24.7 | 40.2 | 17.7 | 34.6 | 12.2 |
| SD | 15.7 | 4.2 | 3.5 | 4.4 | 6.7 | 3.6 | 5.8 | 4.3 | 6.1 | 5.7 |
| Autism (<i>n</i> = 192) | | | | | | | | | | |
| <i>x</i> | 103.0 | 23.9 | 13.7 | 21.7 | 20.9 | 10.9 | 38.1 | 16.7 | 32.7 | 15.4 |
| SD | 16.3 | 4.1 | 4.4 | 5.1 | 5.4 | 22.8 | 5.9 | 5.5 | 7.2 | 4.2 |
| Autism boys (<i>n</i> = 156) | | | | | | | | | | |
| <i>x</i> | 103.6 | 24.0 | 13.7 | 21.7 | 21.3 | 22.9 | 38.2 | 16.9 | 32.9 | 15.7 |
| SD | 15.1 | 3.9 | 4.4 | 4.8 | 4.7 | 4.2 | 5.7 | 5.5 | 6.5 | 4.0 |
| Autism girls (<i>n</i> = 36) | | | | | | | | | | |
| <i>x</i> | 100.2 | 23.5 | 13.3 | 21.8 | 19.2 | 22.4 | 38.1 | 15.9 | 32.0 | 14.2 |
| SD | 20.8 | 5.0 | 4.8 | 6.2 | 6.2 | 5.3 | 6.6 | 5.9 | 9.6 | 4.7 |
| Controls vs. AS/HFA | | | | | | | | | | |
| <i>t</i> | 57.89** | 56.02** | 22.92** | 49.17** | 42.27** | 44.62** | 53.08** | 22.68** | 59.99** | 38.25** |
| Controls vs. autism | | | | | | | | | | |
| <i>t</i> | 43.26** | 41.71** | 14.22** | 37.72** | 38.61** | 30.59** | 38.35** | 11.69** | 38.47** | 38.75** |
| AS/HFA vs. autism | | | | | | | | | | |
| <i>t</i> | 1.25 | 1.47 | 3.12* | 0.75 | 3.51** | 3.70** | 2.47* | 5.35** | 0.37 | 5.42** |

* *p* < .01

** *p* < .001

whereas 95% of children with AS/HFA and 95% of children with Autism scored at or above this cut-off.

For the AQ-Adult, a score of 32 or above was chosen as the cut-off since 79.3% of the clinical group scored at or above this score, whereas only 2% of the control adults did so. The AQ-Adol used a cut-off of 30.

Discussion

This study examined the psychometric properties of the Autism Spectrum Quotient-Children’s version (AQ-Child)

The AQ-Child showed excellent test–retest reliability and high α coefficients for the questionnaire as a whole as well as for each of the original five sub-scales (communication, attention to detail, social skills, imagination and attention switching). Factor analysis provided support for four factors which were highly correlated with four of the original subscales: communication (renamed mind-reading), attention to detail, social skills and imagination. All of these four factors also showed high reliability coefficients.

A cut-off of 76 was adopted and showed high sensitivity (0.95) and specificity (0.95). In addition, 95% of the AS/HFA and 95% of the autism group scored at or above this

Fig. 1 Scoring patterns on the AQ-Child by group

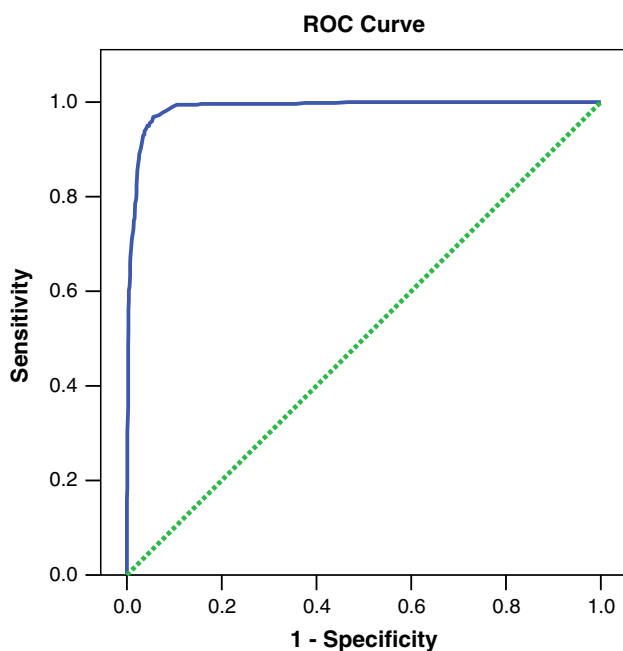
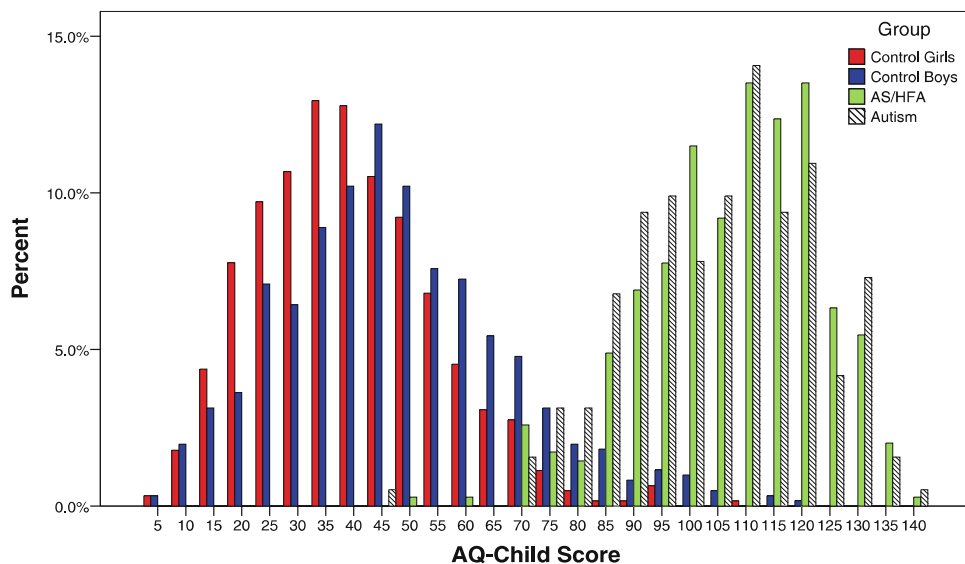


Fig. 2 ROC curve of the sensitivity and specificity of AQ-Child Score. Area under the curve = 0.99

cut-off, whereas only 4% of controls did so. These results demonstrate that the AQ has good construct validity as those with a diagnosis score significantly higher than those without a diagnosis. Figure 1 shows the clear differentiation of total score between those with and without a clinical diagnosis. However, caution should be exercised when using any cut-off to indicate diagnosis because diagnosis is not dependent on an absolute score but on whether the traits cause impairments in everyday functioning (APA 1994; ICD-10 1994). A further limitation is that we have no confirmation that individuals in Group 1

with no clinical diagnosis do not have an ASC, and future population-based studies could assess those who score above the cut-off to see whether those without a diagnosis would warrant one. Such studies would inform the psychometrics of the AQ.

Comparisons between the AS/HFA and autism group showed no significant difference in total AQ-Child score. This may be because as a whole, this instrument is not biased toward language skills. However, several items (e.g., 10, 27, 33) concern behaviors that may require some conversational competence, and we recommend that the AQ would be most useful for individuals with some speech, and with an intelligence in the borderline average range (70) or above. It would be interesting for future researchers to examine the relationship between AQ-Child score and severity of symptoms, as this was outside the scope of this study.

Sex differences in the control group were found, with typically developing boys scoring higher than girls. Similar results are reported in many measures of ASCs. No sex differences were found in the AS/HFA or autism group. This may be because in the clinical groups, many more boys were in the study than girls. This is a common issue since the high male to female ratio of ASC limits the number of females available to participate in research studies. It would be beneficial for future research to obtain larger samples that can more closely examine scoring patterns between males and females with ASC.

Age was not associated with AQ-Child score. These results are consistent with those obtained from the Adolescent version of the AQ (Baron-Cohen et al. 2006). The items in the AQ-Child were designed to be appropriate for children between the ages of 4 and 11, which is the broadest range that the AQ has measured. Our results

Table 4 Comparison of cut-off points

| Indices | AQ-Child cut-off points | | | | AQ-Adult cut-off score | | AQ-Adol cut-off score | |
|----------------------------------|-------------------------|-------|------|------|------------------------|------|-----------------------|------|
| | <i>n</i> | 66 | 76 | 86 | <i>n</i> | 32 | <i>n</i> | 30 |
| Sensitivity | – | 0.99 | 0.95 | 0.86 | – | – | – | – |
| Specificity | – | 0.90 | 0.95 | 0.98 | – | – | – | – |
| % Controls scoring above cut-off | 1,225 | 9.7 | 4.3 | 2.2 | 174 | 2.3 | 50 | 0.0 |
| % Control females | 618 | 4.7 | 1.6 | 1.0 | 98 | 1.0 | 25 | 0.0 |
| % Control males | 607 | 14.8 | 7.1 | 3.5 | 76 | 3.9 | 25 | 0.0 |
| % AS/HFA scoring above cut-off | 348 | 98.9 | 95.1 | 87.1 | 58 | 79.3 | 52 | 90.4 |
| % AS/HFA females | 36 | 97.2 | 94.4 | 94.4 | 13 | 92.3 | 14 | 92.3 |
| % AS/HFA males | 312 | 99.0 | 95.2 | 86.2 | 45 | 75.6 | 38 | 89.5 |
| % Autism scoring above cut-off | 192 | 99.5 | 94.8 | 82.8 | – | – | 79 | 88.6 |
| % Autism females | 36 | 97.2 | 86.1 | 80.6 | – | – | 16 | 81.3 |
| % Autism males | 156 | 100.0 | 96.8 | 83.3 | – | – | 63 | 90.5 |

Adult data from Baron-Cohen et al. 2001

Adolescent data from Baron-Cohen et al. 2006

suggest that the AQ-Child measures traits that are consistent throughout the age groups. It would be useful in future studies to test the correlation between the AQ-Child and related measures (such as the Childhood Autism Spectrum Test²) (Scott et al. 2002; Williams et al. 2005) which has been used in primary school age children, and to test if one instrument is more sensitive than another.

The use of a Likert format for responses in the questionnaire allowed parents to express the severity of a particular trait in their child. This was believed to be more appropriate for conditions like ASC where individuals lie on a spectrum of conditions. Eaves et al. (2006) comment on how a categorical ‘yes/no’ response can lead to missing data where the parent skips or misses questions or responds with a written answer in similarly designed questionnaires.

In summary, the AQ-Child is a strong measure that is able to discriminate the presence of ASC in a clinical sample and will be an important research tool for investigating autistic traits. The AQ-Child could also be a useful tool for researchers to follow the developmental trajectory in clinical samples, or as a measure of the broader autism phenotype in epidemiological samples. Future work needs to consider whether scores on the AQ-Child or AQ-Adol predict AQ-Adult score, and the potential value of the AQ as a developmentally sensitive screening instrument used to detect ASC in the general population.

² Formerly known as the Childhood Asperger syndrome test, but renamed keeping the same acronym because it can be used for all subgroups on the autistic spectrum.

Conclusions

This study reports the development of the AQ-Child, a new instrument that aims to quantify autistic traits in children aged 4–11 years. This 50-item parent-report questionnaire records a child’s behavior on a range of autistic traits. Factor analysis identified four subscales (named mind-reading, attention to detail, social skills and imagination). These were highly correlated with four of the original five designed subscales for the AQ-Child (communication, attention to detail, social skills and imagination, respectively). The high test–retest and reliability coefficients further support the structure of the questionnaire. The measure was administered to a group with an ASC diagnosis ($n = 540$) and a control group with no history of ASC in their immediate family ($n = 1,225$). Scoring patterns show a very clear differentiation between those with ASC and a control group. The questionnaire may be useful in screening for ASC rather than as a diagnostic tool, and is not a substitute for a clinical diagnosis. The development of the AQ-Child also presents the possibility of following autistic traits throughout an individual’s lifetime in a longitudinal study. Understanding the nature of the AQ continuum, in terms of its components and how it can be derived and predicted from these (Wheelwright et al. 2006), is an important goal for future research.

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Appendix 1: The Autism Spectrum Quotient—Children’s Version (AQ-Child)

| | Definitely Agree | Slightly Agree | Slightly Disagree | Definitely Disagree |
|---|------------------|----------------|-------------------|---------------------|
| 1. S/he prefers to do things with others rather than on her/his own | | | | |
| 2. S/he prefers to do things the same way over and over again | | | | |
| 3. If s/he tries to imagine something, s/he finds it very easy to create a picture in her/his mind | | | | |
| 4. S/he frequently gets so strongly absorbed in one thing that s/he loses sight of other things | | | | |
| 5. S/he often notices small sounds when others do not | | | | |
| 6. S/he usually notices house numbers or similar strings of information ^a | | | | |
| 7. S/he has difficulty understanding rules for polite behavior ^a | | | | |
| 8. When s/he is reading a story, s/he can easily imagine what the characters might look like ^a | | | | |
| 9. S/he is fascinated by dates | | | | |
| 10. In a social group, s/he can easily keep track of several different people’s conversations | | | | |
| 11. S/he finds social situations easy | | | | |
| 12. S/he tends to notice details that others do not | | | | |
| 13. S/he would rather go to a library than a birthday party ^a | | | | |
| 14. S/he finds making up stories easy | | | | |
| 15. S/he is drawn more strongly to people than to things ^a | | | | |
| 16. S/he tends to have very strong interests, which s/he gets upset about if s/he cannot pursue | | | | |
| 17. S/he enjoys social chit-chat | | | | |
| 18. When s/he talks, it is not always easy for others to get a word in edgeways | | | | |
| 19. S/he is fascinated by numbers | | | | |
| 20. When s/he is reading a story, s/he finds it difficult to work out the characters’ intentions or feelings ^a | | | | |
| 21. S/he does not particularly enjoy fictional stories ^a | | | | |
| 22. S/he finds it hard to make new friends | | | | |
| 23. S/he notices patterns in things all the time | | | | |
| 24. S/he would rather go to the cinema than a museum ^a | | | | |
| 25. It does not upset him/her if his/her daily routine is disturbed | | | | |
| 26. S/he does not know how to keep a conversation going with her/his peers ^a | | | | |
| 27. S/he finds it easy to “read between the lines” when someone is talking to her/him | | | | |
| 28. S/he usually concentrates more on the whole picture, rather than the small details | | | | |
| 29. S/he is not very good at remembering phone numbers | | | | |

continued

| | Definitely Agree | Slightly Agree | Slightly Disagree | Definitely Disagree |
|--|------------------|----------------|-------------------|---------------------|
| 30. S/he does not usually notice small changes in a situation, or a person's appearance | | | | |
| 31. S/he knows how to tell if someone listening to him/her is getting bored | | | | |
| 32. S/he finds it easy to go back and forth between different activities ^a | | | | |
| 33. When s/he talks on the phone, s/he is not sure when it is her/his turn to speak | | | | |
| 34. S/he enjoys doing things spontaneously | | | | |
| 35. S/he is often the last to understand the point of a joke. | | | | |
| 36. S/he finds it easy to work out what someone is thinking or feeling just by looking at their face | | | | |
| 37. If there is an interruption, s/he can switch back to what s/he was doing very quickly | | | | |
| 38. S/he is good at social chit-chat | | | | |
| 39. People often tell her/him that s/he keeps going on and on about the same thing | | | | |
| 40. When s/he was in preschool, s/he used to enjoy playing games involving pretending with other children ^a | | | | |
| 41. S/he likes to collect information about categories of things (e.g., types of car, types of bird, types of train, types of plant, etc.) | | | | |
| 42. S/he finds it difficult to imagine what it would be like to be someone else | | | | |
| 43. S/he likes to plan any activities s/he participates in carefully | | | | |
| 44. S/he enjoys social occasions | | | | |
| 45. S/he finds it difficult to work out people's intentions | | | | |
| 46. New situations make him/her anxious | | | | |
| 47. S/he enjoys meeting new people | | | | |
| 48. S/he is good at taking care not to hurt other people's feelings ^a | | | | |
| 49. S/he is not very good at remembering people's date of birth | | | | |
| 50. S/he finds it very to easy to play games with children that involve pretending | | | | |

Note: Aside from the self-report to parent-report format change, items were changed as little as possible

^a Denotes items that were changed substantially

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