

# The Childhood Autism Spectrum Test (CAST): Sex Differences

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**Abstract** The Childhood Autism Spectrum Test (CAST) (formally known as the Childhood Asperger Screening Test) identifies autism spectrum conditions by measuring social and communication skills. The present study explored the sex distribution of scores. The CAST was distributed to 11,635 children aged 4–9 years in Cambridgeshire primary schools (UK). 3,370 (29%) were returned. The median score was significantly higher in boys (median test,  $P < 0.001$ ) (Boys, median = 5 (IQR: 3,8); girls, median = 4 (IQR: 2,6)). There was a predominance of boys ( $n = 81$  (79.4%) over girls ( $n = 21$  (20.6%)) amongst those scoring  $\geq 15$ . Exclusion of children with ASC did not significantly affect

the results. We conclude that different profiles of social and communication skills in boys and girls must be taken into account when measuring these skills in the general population.

**Keywords** Communication · Social behaviour · Autism · Asperger syndrome · Sex differences

## The Childhood Autism Spectrum Test (CAST): Sex Differences

This study examines sex differences in The Childhood Autism Spectrum Test (CAST) (Scott et al. 2002). The CAST is a 37 item parental self-completion questionnaire developed to detect subtler manifestations of Autism Spectrum Conditions (ASC), including Asperger Syndrome (AS) in primary school children. The CAST measures difficulties and preferences in social and communication skills covering: initiation and maintenance of conversation and specific language difficulties; social interaction with adults and peers, including eye contact; choice of play activities; presence of rigid or repetitive behaviours; choice of interests and sharing interests with others.

Results using the CAST suggest that those with a diagnosis of AS score significantly higher than controls (Scott et al. 2002). The cut-point for concerns of possible ASC is at 15 (out of a maximum of 31, as 6 items are not scored) or higher. At that cut-point sensitivity of the CAST is 100%, specificity 97%, and positive predictive value 50% (Williams et al. 2005). The test–retest reliability is good, indicated by a Spearman’s rho correlation of 0.82 (Williams et al. 2006). The stability of scores around the screening cut-point is moderate, indicated by a Spearman’s rho correlation of 0.67 (Allison et al. 2007). An important

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aspect of developing any screening test for ASC is an understanding of whether there are any differences between the sexes, due to the consistent finding of a higher prevalence of ASC in boys (Ehlers and Gillberg 1993; Wing 1981), and the growing evidence of sex differences in traits related to ASC and in typical development.

The Extreme Male Brain (EMB) theory (Baron-Cohen 1999, 2002; Baron-Cohen and Hammer 1997) has been suggested as a possible explanation for the predominance of males to females in studies of ASC. This theory proposes that males and individuals with ASC are impaired in their ability to empathize, whilst being at least average or superior in tasks that require systemizing. Evidence supporting this theory comes from the finding that individuals with ASC are better than typical individuals on systemizing or pattern-recognition tasks on which males out-perform females, such as the Embedded Figures Task (Jolliffe and Baron-Cohen 1997) or the Intuitive Physics Test (Lawson et al. 2004). Conversely, individuals with ASC perform worse on empathy tasks on which females out-perform males, such as the Faux Pas Test (Baron-Cohen et al. 1999) or the Reading the Mind in the Eyes task (Baron-Cohen et al. 1997).

Typically developing boys and girls have different patterns of behaviour and development in social skills and communication. Despite considerable overlap, sex differences have been found in the amount of eye contact made by 12 month old human infants (Lutchmaya et al. 2002), types of play (Knickmeyer et al., in press), approaches to friendship formation (Baron-Cohen and Wheelwright 2003), in the degree of empathy shown to others (Baron-Cohen and Wheelwright 2004), choice of topics to talk about, and chosen focus of attention (Baron-Cohen 2003). Such differences are in part accounted for by differences in foetal testosterone levels (Chapman et al. 2006; Auyeung et al. 2006; Knickmeyer et al. 2005).

Whilst various tests have been developed to assess a range of social and communication skills and to screen for ASC and related social and communication difficulties (Williams and Brayne 2006), few studies have examined sex differences. One exception to this was a study of the Autism Spectrum Screening Questionnaire (ASSQ). The ASSQ was administered to a large population sample of 7–9 year olds and showed significantly higher mean scores for boys. Girls scored lower than boys across the whole score distribution, indicating that girls had less difficulties than boys (Posserud et al. 2006). Another study used the Social Responsiveness Scale (SRS) to examine autistic traits in children aged 7–15 years old (Constantino and Todd 2003). Again, boys scored on average 25% higher than girls on this measure.

Sex differences in the number of autistic traits in the general population was also examined using the Autism Spectrum Quotient (AQ), a self-administered questionnaire covering social skills, attention switching, attention to

detail, communication, and imagination. A higher frequency of autistic traits was found in males, indicated by a higher score on this measure (Baron-Cohen et al. 2001). Child and adolescent versions of the AQ have been developed, and sex differences were found on both versions, with typical males scoring higher than females (Auyeung et al. in press; Baron-Cohen et al. 2006). This pattern of sex differences in autistic traits has been confirmed in children as young as 18 months, using the Q-CHAT (a revised version of the Checklist for Autism in Toddlers (Allison et al. in press; Baron-Cohen et al. 1992; Baron-Cohen et al. 1996)). Since these measures have all shown a sex difference in the distribution of scores, it is important to examine whether the CAST also reveals a different psychometric profile in girls and boys, and if so, what the possible explanations for this may be.

The aim of the study reported below was to examine score distributions on the CAST by sex and age for the total population as well as typically developing boys and girls, as part of a further examination of the utility of the CAST as a screening instrument for ASC.

## Methods

### Procedure

The CAST questionnaires in this analysis were from the SCORE (Social Communication Research and Epidemiology) study. The study had full ethical approval from the Cambridge Local Ethics Committee. 136 mainstream primary schools, including independent schools but not special schools (for this phase), in Cambridge City, East and South Cambridgeshire and Fenland in the UK, were invited to participate in the research, of whom 68% agreed. These schools cover a broad cross-section including urban and rural areas across the county. There were no noted differences in geographical distributions of schools that participated versus schools that refused. Each school was asked to distribute the CAST to all children in years 1 to 4 inclusive (typically age 5–9 years) to take home to their parent or guardian. Distribution spanned a 15-month period. The questionnaires were returned to the research team using a Freepost envelope.

Basic personal information, including the child's date of birth, sex, and school, was requested. The child's school year was calculated based on date of birth and date questionnaire completed or returned. Questionnaires were excluded if the child was more than one year older or younger than the target age range. These criteria led to some children aged 4 or 10 years remaining in the sample. Information was collected about which parent completed the CAST. The scoring range is from 0 to 31, with the

remaining 6 items being control questions on general development which are not scored (see Table 1 for direction of scoring). Differences in CAST scores were investigated using total score and within three score groups ( $\leq 11$ , 12–14,  $\geq 15$ ) as in previous studies examining the questionnaire's performance (Williams et al. 2005, 2006). The questionnaire included a series of items about previous diagnoses of medical conditions or special needs.

### Analysis

Initially missing data were recoded as zero to give an observed score. Differences between scores according to age and sex were investigated. The distribution of scores was described using medians, inter-quartile ranges (IQR) and ranges, since the score distribution was extremely skewed. Whether the two samples by sex were from the same underlying distribution was tested using Kolmogorov–Smirnov test for equality of the distribution. The median test assessed the null hypothesis that the samples were drawn from populations with the same median. Pearson chi-squared tests were used to test differences between proportions. A test for trend of the proportion of boys and girls across the three score groups was carried out using logistic regression. The score data were transformed to a normal distribution and the effect of sex and age was examined using ANOVA and linear regression.

Three sensitivity analyses were carried out:

- (1) Missing data. To calculate the maximum score that could have been received had all items been answered, missing data were recoded to one. The analyses were repeated using observed score for boys and maximum score for girls, to model the most extreme effect of missing data on any observed sex difference in scores.
- (2) ASC. Analyses were repeated using observed scores having excluded children with a reported previous diagnosis of an ASC.
- (3) All special needs. Analyses were repeated having excluded children with any reported special need, medical condition, or developmental difficulty.

## Results

### Response and Data Completeness

Of 11,635 questionnaires distributed, 3,370 (29%) were returned. 36 questionnaires were excluded: age and sex were not reported for 8 children, 24 fell outside the study age range, and 4 were from schools outside the study, siblings of those invited into the study. This left 3,334

questionnaires for analysis. There were an equal number of boys ( $n = 1,667$ ) and girls ( $n = 1,667$ ) in the final sample. This compares to a proportion of boys of this age of 51.2% in the Cambridgeshire population. There was no significant difference between the number of boys and girls excluded from the sample (chi-squared,  $P = 0.259$ ). 2,718 (81.5%) had complete data on scoring CAST questions. 585 (17.6%) had between 1 and 4 missing questions, and 31 (0.9%) had between 5 and 27 missing. 41 of the 3,334 questionnaires had age missing and were excluded from analyses based on age, leaving a sample size of 3,293.

### Distribution of Scores in the Whole Sample

The median score was 4 (IQR: 2,7, range: 0,29) ( $n = 3,334$ ). Boys had a higher median score (Median: 5; IQR: 3,8; range: 0,29) than girls (Median: 4; IQR: 2,6; range: 0,29). This difference between the score distributions was highly significant (Kolmogorov–Smirnov  $P < 0.001$ ; median test,  $P < 0.001$ ), (Fig. 1). The shapes of the score distributions were different, with a longer tail at the upper end of the distribution for boys, whereas only one girl scored above 24, shown on the cumulative graph in Fig. 2. The differences between the scores increased with increasing score. The difference between the two distributions is constant on the logarithm scale, showing that differences between the boys and girls increases with increasing score. Data were transformed to normality using the zero-skewness log with a transformation ( $\ln(\text{score} + 2.022091)$ ). The gender difference had a regression coefficient of  $\beta = -0.21$ . There was a significant difference in the proportion of girls and boys across three score groups (chi-squared,  $P < 0.001$ ) with more boys in the higher score groups (test for trend,  $P < 0.001$ ) (Table 2).

The distribution of scores was very similar across the ages represented (Table 3) ( $P = 0.31$ ). The differences between the sexes was still observed ( $\beta = -0.21$ ) and there was no indication of an interaction between age and sex ( $P = 0.30$ ).

### Sensitivity Analyses

#### (1) Missing data

There was no change in the results using the maximum score including missing data. The co-efficient for the sex difference remained unchanged ( $\beta = -0.21$ ) The number of boys in the highest score group ( $\geq 15$ ) remained high ( $n = 93$  boys (78.2%);  $n = 26$  girls (21.8%)).

#### (2) ASC

37 children were reported to have a diagnosis of ASC, of whom 27 (73.0%) were boys. Excluding these children did not change the effects of the sex difference ( $\beta = -0.20$ ).

**Table 1** Endorsement of each question by sex ( $n = 3334$ )

Q	Question wording	Scoring response	Boys			Girls		
			No Score <i>N</i> (%)	Score <i>N</i> (%)	Missing <i>N</i> (%)	No Score <i>N</i> (%)	Score <i>N</i> (%)	Missing <i>N</i> (%)
1	Does s/he join in playing games with other children easily?	No	1,492 (89.5)	167 (10.0)	8 (0.5)	1,556 (93.3)	99 (5.9)	12 (0.7)
2	Does s/he come up to you spontaneously for a chat?	No	1,606 (96.3)	53 (3.2)	8 (0.5)	1,631 (97.8)	35 (2.1)	1 (0.1)
3	Was s/he speaking by 2 years old?	Not scored	Yes = 1,451 (87.0)	No = 209 (12.5)	7 (0.4)	Yes = 1,563 (93.8)	No = 97 (5.8)	7 (0.4)
4	Does s/he enjoy sports?	Not scored	Yes = 1,453 (87.2)	No = 197 (11.8)	17 (1.0)	Yes = 1,473 (88.4)	No = 174 (10.4)	20 (1.2)
5	Is it important to him/her to fit in with the peer group?	No	1,312 (78.7)	332 (19.9)	23 (1.4)	1,415 (84.9)	221 (13.3)	31 (1.9)
6	Does s/he appear to notice unusual details that others miss?	Yes	654 (39.2)	980 (58.8)	33 (2.0)	663 (39.8)	953 (57.2)	51 (3.1)
7	Does s/he tend to take things literally?	Yes	675 (40.5)	942 (56.5)	50 (3.0)	733 (44.0)	883 (53.0)	51 (3.1)
8	When s/he was 3 years old, did s/he spend a lot of time pretending (e.g., play-acting being a superhero, or holding teddy's tea parties)?	No	984 (59.0)	668 (40.1)	15 (0.9)	1,318 (79.1)	338 (20.3)	11 (0.7)
9	Does s/he like to do things over and over again, in the same way all the time?	Yes	1,205 (72.3)	436 (26.2)	26 (1.6)	1,230 (73.8)	411 (24.7)	26 (1.6)
10	Does s/he find it easy to interact with other children?	No	1,476 (88.5)	167 (10.0)	24 (1.4)	1,540 (92.4)	113 (6.8)	14 (0.8)
11	Can s/he keep a two-way conversation going?	No	1,590 (95.4)	68 (4.1)	9 (0.5)	1,622 (97.3)	37 (2.2)	8 (0.5)
12	Can s/he read appropriately for his/her age?	Not scored	Yes = 1,445 (86.7)	No = 209 (12.5)	13 (0.8)	Yes = 1,552 (93.1)	No = 105 (6.3)	10 (0.6)
13	Does s/he mostly have the same interests as his/her peers?	No	1,445 (86.7)	200 (12.0)	22 (1.3)	1,486 (89.1)	163 (9.8)	18 (1.1)
14	Does s/he have an interest which takes up so much time that s/he does little else?	Yes	1,438 (86.3)	215 (12.9)	14 (0.8)	1,579 (94.7)	79 (4.7)	9 (0.5)
15	Does s/he have friends, rather than just acquaintances?	No	1,499 (89.9)	155 (9.3)	13 (0.8)	1,569 (94.1)	87 (5.2)	11 (0.7)
16	Does s/he often bring you things s/he is interested in to show you?	No	1,556 (93.3)	105 (6.3)	6 (0.4)	1,599 (95.9)	64 (3.8)	4 (0.2)
17	Does s/he enjoy joking around?	No	1,588 (95.3)	71 (4.3)	8 (0.5)	1,569 (94.1)	91 (5.5)	7 (0.4)
18	Does s/he have difficulty understanding the rules for polite behaviour?	Yes	1,396 (83.7)	250 (15.0)	21 (1.3)	1,519 (91.1)	138 (8.3)	10 (0.6)
19	Does s/he appear to have an unusual memory for details?	Yes	892 (53.5)	745 (44.7)	30 (1.8)	1,044 (62.6)	594 (35.6)	29 (1.7)
20	Is his/her voice unusual (e.g. overly adult, flat, or very monotonous)?	Yes	1,554 (93.2)	96 (5.8)	17 (1.0)	1,582 (94.9)	73 (4.4)	12 (0.7)
21	Are people important to him/her?	No	1,601 (96.0)	48 (2.9)	18 (1.1)	1,627 (97.6)	29 (1.7)	11 (0.7)
22	Can s/he dress him/herself?	Not scored	Yes = 1,642 (98.5)	No = 20 (1.2)	5 (0.3)	Yes = 1,656 (99.3)	No = 5 (0.3)	6 (0.4)

**Table 1** continued

Q	Question wording	Scoring response	Boys			Girls		
			No Score N(%)	Score N(%)	Missing N(%)	No Score N(%)	Score N(%)	Missing N(%)
23	Is s/he good at turn-taking in conversation?	No	1,285 (77.1)	349 (20.9)	33 (2.0)	1,442 (86.5)	198 (11.9)	27 (1.6)
24	Does s/he play imaginatively with other children, and engage in role-play?	No	1,511 (90.6)	144 (8.6)	12 (0.7)	1,625 (97.5)	35 (2.1)	7 (0.4)
25	Does s/he often do or say things that are tactless or socially inappropriate?	Yes	1,296 (77.7)	345 (20.7)	26 (1.6)	1,412 (84.7)	237 (14.2)	18 (1.1)
26	Can s/he count to 50 without leaving out any numbers?	Not scored	Yes = 1,422 (85.3)	No = 216 (13.0)	29 (1.7)	Yes = 1,463 (87.8)	No = 178 (10.7)	26 (1.6)
27	Does s/he make normal eye-contact?	No	1,595 (95.7)	63 (3.8)	9 (0.5)	1,644 (98.6)	14 (0.8)	9 (0.5)
28	Does s/he have any unusual and repetitive movements?	Yes	1,533 (92.0)	121 (7.3)	13 (0.8)	1,609 (96.5)	53 (3.2)	5 (0.3)
29	Is his/her social behaviour very one-sided and always on his/her own terms?	Yes	1,420 (85.2)	216 (13.0)	31 (1.9)	1,511 (90.6)	138 (8.3)	18 (1.1)
30	Does s/he sometimes say “you” or “s/he” when s/he means “I”?	Yes	1,540 (92.4)	118 (7.1)	9 (0.5)	1,570 (94.2)	94 (5.6)	3 (0.2)
31	Does s/he prefer imaginative activities such as play-acting or story-telling, rather than numbers or lists of facts?	No	777 (46.6)	834 (50.0)	56 (3.4)	1,075 (64.5)	554 (33.2)	38 (2.3)
32	Does s/he sometimes lose the listener because of not explaining what s/he is talking about?	Yes	1,048 (62.9)	588 (35.3)	31 (1.9)	1,157 (69.4)	485 (29.1)	25 (1.5)
33	Can s/he ride a bicycle (even if with stabilisers)?	Not scored	Yes = 1,591 (95.4)	No = 70 (4.2)	6 (0.4)	Yes = 1,624 (97.4)	No = 43 (2.6)	0
34	Does s/he try to impose routines on him/herself, or on others, in such a way that it causes problems?	Yes	1,501 (90.0)	152 (9.1)	14 (0.8)	1,567 (94.0)	91 (5.5)	9 (0.5)
35	Does s/he care how s/he is perceived by the rest of the group?	No	1,247 (74.8)	388 (23.3)	32 (1.9)	1,367 (82.0)	275 (16.5)	25 (1.5)
36	Does s/he often turn conversations to his/her favourite subject rather than following what the other person wants to talk about?	Yes	1,174 (70.4)	469 (28.1)	24 (1.4)	1,358 (81.5)	296 (17.8)	13 (0.8)
37	Does s/he have odd or unusual phrases?	Yes	1,475 (88.5)	183 (11.0)	9 (0.5)	1,557 (93.4)	101 (6.1)	9 (0.5)

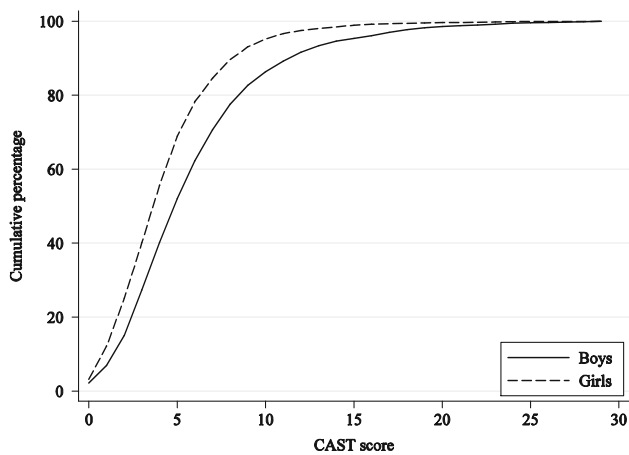
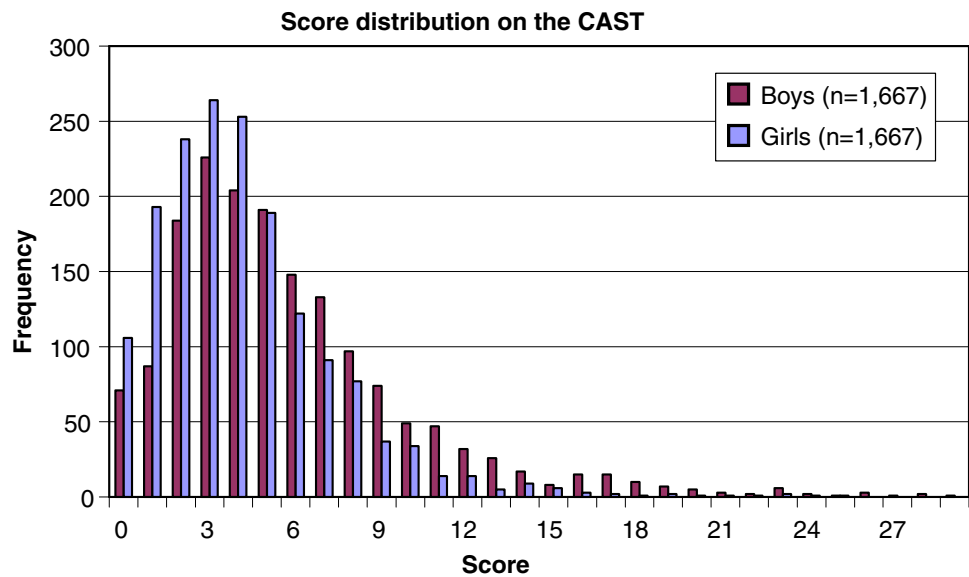
In the highest score group ( $\geq 15$ ), the number of boys (58 (80.6% of score group)) still far exceeded the number of girls (14 (19.4%)).

(3) All special needs

819 children were reported to have one or more special needs: 269 (8.1%) language delay; 27 (0.8%) ADHD; 33 (1.0%) dyspraxia; 468 (14.0%) hearing or visual difficulties; 37 (1.1%) ASC; 31 (0.9%), a physical disability; 13 (0.4%) a medical condition (e.g. Down’s syndrome, chromosomal abnormality); and 172 (5.2%) other special needs. Of the 819 reported to have some kind of special

need, there was a significantly higher proportion of boys (30% of boys versus 19% of girls) (chi-squared  $P < 0.001$ ). Having excluded children with any special need or medical condition ( $n = 819$ ) and those with missing special needs responses ( $n = 26$ ), 2,489 remained. The median scores dropped by one in both sexes, to 4 for boys (IQR: 3,7; range 0,28) ( $n = 1,162$ ) and 3 for girls (IQR: 2,5; range: 0,20) ( $n = 1,353$ ), but there was still a highly significant difference between the sexes (median test,  $P < 0.001$ ). The number of boys still exceeded the number of girls in the highest score group with 21 (81% of group) boys and 5 (19%) girls scoring  $\geq 15$ . The coefficient

**Fig. 1** The distribution of scores in boys and girls



**Fig. 2** Cumulative percentage of the distribution by sex and score

**Table 2** Proportion of boys and girls within score groups

	CAST score, <i>N</i> (%)			Total
	≤12	12–14	≥15	
Boys	1,511 (48.3%)	75 (72.8%)	81 (79.4%)	1,667
Girls	1,618 (51.7%)	28 (27.2%)	21 (20.6%)	1,667
Total	3,129	103	102	3,334

for the difference between the sexes was slightly reduced ( $\beta = -0.17$ ), there were still no age differences.

## Discussion

In this population sample from mainstream primary schools, boys had significantly higher scores on the CAST

than girls, at all ages between 4 and 10 years. This was observed having taken account of missing data, and when children with known ASC and with any special needs were excluded. This finding of higher scores in boys on the CAST is consistent with results using other measures that aim to examine autistic traits in the population, for example the ASSQ (Posserud et al. 2006), the SRS (Constantino et al. 2003), the AQ (adult, adolescent and child versions (Auyeung et al., in press; Baron-Cohen et al. 2006; Baron-Cohen et al. 2001)) and the Q-CHAT (Allison et al., in press). The non-linear relationship is interesting in that the scores get wider apart with increasing scores, reflecting the long tail of the distribution for the boys.

There are various possible explanations that may account for this finding. First, the CAST may be detecting preferences in social and communication skills, rather than abilities/difficulties. This is consistent with the fact that some questions asked about preferences, such as Q31 “Does s/he prefer imaginative activities such as play-acting or story-telling, rather than numbers or lists of facts?” and had strong sex differences (50.0% boys and 33.2% of girls responded “No”). Second, boys may exhibit more difficulties in social and communication skills in childhood. For example, more boys (15.0%) compared to girls (8.3%) scored on Q18, “Does s/he have difficulty understanding the rules for polite behaviour?” Third, the CAST may be more effective at detecting difficulties in social and communication development in boys than girls, and perhaps additional questions would be required that are more sensitive to detect more subtle difficulties in girls (such as levels of anxiety in unpredictable social situations, being able to manage a large social group (such as a party)), or the extent to which the person tries hard to fit in, by ‘pretending to be normal’ (Holliday-Willey 1999). In

**Table 3** Distribution of scores by school year group on the CAST ( $n = 3,293$ )<sup>a</sup>

Year	All				Boys				Girls				Difference between sexes (95% confidence interval) <sup>c</sup>
	N	Median	IQR <sup>b</sup>	Range	N	Median	IQR <sup>b</sup>	Range	N	Median	IQR <sup>b</sup>	Range	
Reception	76	5	3,8	0,28	42	6	4,9	0,28	34	4.5	2,6	1,12	0.69 (0.3–1.0)
1	868	4	2.5,6	0,29	440	5	3,7	0,26	428	4	2,6	0,29	0.84 (0.8–0.9)
2	876	4	2,7	0,26	447	5	3,8	0,26	429	4	2,5	0,24	0.75 (0.7–0.8)
3	796	4	2,6	0,29	399	5	3,8	0,29	397	3	2,5	0,19	0.70 (0.6–0.8)
4	644	4	2,7	0,27	303	5	3,7	0,27	341	4	2,6	0,23	0.81 (0.7–0.9)
5	33	5	2,8	1,18	17	7	3,10	1,18	16	4	2,5	1,8	0.59 (0.1–1.0)
Total	3,293	4	2,7	0,29	1,648	5	3,8	0,29	1,645	4	2,6	0,29	0.78 (0.7–0.8)
Mean <sup>c</sup>		4.1				4.8				3.5			

Reception = age 4.0 to 4.11; year 1 = age 5.0 to 5.11; Year 2 = age 6.0 to 6.11; year 3 = age 7.0–7.11; year 4 = age 8.0–8.11; year 5 = age 9.0–9.11 on 1st September of the academic year of recruitment

<sup>a</sup> 41 children were excluded from this analysis due to missing data on age

<sup>b</sup> Inter-quartile range

<sup>c</sup> Scores transformed using  $\ln(\text{score} - 2.01)$

extreme cases such as ASC, the behavioural phenotype may be different for girls than for boys, although the core features may be as common in girls as boys. For example, circumscribed interests may be more social in nature in girls than in boys, such as animals, dolls, or pop-groups (Kopp and Gillberg 1992; Wolff and McGuire 1995), making them less obvious to identify. This could also help to explain the finding that the sex ratio is higher for broader ASC than for classic autism (Scott et al. 2002). Whilst all these possibilities may partly account for the difference between boys and girls in scores on the CAST, there is evidence from this study that points towards a true difference in social and communication development.

A strong sex difference was observed across the score groups on the CAST, with a higher proportion of boys in the higher score groups, even after exclusions. It is possible that this predominance of boys scoring at or above 15 on the CAST indicates that boys show a higher prevalence of difficulties in social and communication development than girls. It is also possible that there are a number of high-functioning (e.g. Asperger) undetected cases of ASC in the population which may be represented by boys with high scores ( $\geq 15$ ). This was found in our prevalence study using the CAST (Baron-Cohen et al., submitted). The current sex difference was however found across all groups, so if more cases were excluded due to a current ASC diagnosis, the sex difference would still remain, even in the lower score groups.

Constantino and Todd (2003) assert that the sex difference found using the SRS to measure autistic traits may have arisen from discrepant phenotypic manifestations of genetic and environmental influences that are common to both sexes. Further work using a variety of tests that quantitatively measure autistic traits across the lifespan is required in order to establish the role of environmental and

heritable factors (Ronald et al. 2006a). Further research may also help to delineate whether there is a difference between boys and girls in their sensitivity to early interventions. Furthermore, additional research is required in order to resolve whether sex differences influencing the behaviours measured by the CAST in the general child population also operate in the clinical population of ASC.

Limitations

Observer bias may have been introduced since in the majority of cases, the CAST informant was the mother. It would be useful to examine whether the sex difference still held depending on which parent completed the CAST. Second, the CAST only comprises of 37 questions, and uses a dichotomous scale. Data are required using a more quantitative scale to see if the sex difference remains in this sample when the informant has a graded scale to endorse behaviours. Data have been collected on a proportion of this sample using the child version of the AQ and results will be reported elsewhere. Third, some items in the CAST do not discriminate well; over 50% of boys and girls scored on questions 6 and 7, and for question 31, over 50% of boys scored on this item. It would appear that these items are less valuable in this issue regarding sex differences as well as in discriminating those with an ASC from the general population. An item analysis has been carried out separately which has examined the discriminant validity of all CAST items, together with a latent trait analysis of items, and this too will be reported separately. Lastly, the response to the original mailing to participating schools was only 29%. No information was available on non-responders to investigate response bias. Ignoring missing sectors of the population will lead to potentially gross bias in the results reported. Posserud et al.

(2006) found that there were significantly more high scorers on the ASSQ completed anonymously by teachers than in children whose parents completed the questionnaire. This is consistent with other studies that found a higher prevalence of diagnosed cases and high scorers in non-participants than participants in child and adult psychiatry research (Hansen et al. 2001; Rutter et al. 1975). However, there is no reason to suspect that there was an interaction between the child's sex and parental uptake of the questionnaires since the sexes were equally represented, broadly reflecting the proportion of boys and girls in the Cambridgeshire population.

### Strengths

A particular strength of this study was the large sample size which made it possible to detect small score differences between boys and girls that were highly statistically significant. The difference in the proportion of boys and girls in the higher score groups was very marked. This is clearly an important difference, with over 2.5 times more boys than girls scoring at or above 15, even once those with special needs had been excluded. Furthermore, the external validity of scores at or above 12 on the CAST has been established through full diagnostic assessment in a previous study (Williams et al. 2005), and scores at this level on the test clearly have meaningful correlation to some areas of social and communication difficulty.

A second strength of this study is that when the effect was examined by modelling the most extreme effect of missing data on observed sex difference in scores, the result was entirely consistent. Therefore we can be confident that the sex difference in scores is real and is not affected by missing data.

Within this study it was possible to look at the potential role of measurement artifacts. This was important as the difference between median scores was only one point. Three pairs of questions on the CAST have very similar wording (Q5 & Q35; Q6 & Q19; Q1 & Q10), and as a result responses are likely to be highly correlated. This was indicated by very similar endorsement prevalence of each item in these pairs. The impact of correlated questions appears to be small, as a strong sex difference in scores was still observed when one of each pair was omitted from analyses.

### Implications

When considering population screening for autism spectrum conditions, we need to bear in mind that the norms may be different for boys and girls. For example, further research could be conducted to examine whether the cut-point on the CAST (and other autism screening

instruments) for boys should be higher than for girls for a research diagnosis of ASC. The results from this and previous studies point towards boys being more vulnerable to the 'condition' end of the continuum, reflected by shift of boys towards the tail of the distribution. Since scores on the CAST show strong heritability (Ronald et al. 2006b), this raises questions about whether the relevant genes are sex-linked. It is of interest that whilst sex differences in the general population are found on measures of autistic traits, in those with a formal diagnosis of ASC no sex differences have been reported (Baron-Cohen et al. 2001, 2006). There is no evidence from the current study that the scores were different between girls and boys in those that have a diagnosis of ASC, though there are only nine girls ( $P = 0.3$ ). This may suggest that whatever biological mechanism causes the apparent neural and cognitive hyper-masculinization related to these measures, by the point at which individuals have a formal diagnosis both males and females may have reached a similar end-point. Whether there are different dosage-effects of the causal factors needed to result in males and females ending up in the clinical range in terms of autistic traits are questions for future research (Baron-Cohen et al. 2005).

### Conclusions

In a large population sample, boys scored higher than girls on measures of autistic traits. This was true even when extreme scorers (children with ASC and other special needs) were excluded from analyses. This supports previous evidence that boys and girls have different profiles of social and communication development, and suggests a higher prevalence of difficulties in social and communication skills in boys. These observations contribute to our understanding of sex differences in social and communication development. We conclude that baseline sex differences must be taken into account when measuring social and communication skills in population studies.

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