Social Communication Competence and Functional Adaptation in a General Population of Children: Preliminary Evidence for Sex-by-Verbal IQ Differential Risk

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ABSTRACT

Objective: The proportion of schoolchildren with mild social communicative deficits far exceeds the number diagnosed with an autistic spectrum disorder (ASD). We aimed to ascertain both the population distribution of such deficits and their association with functional adaptation and cognitive ability in middle childhood. **Method:** The parent-report Social and Communication Disorders Checklist was administered to participants ($n = 8,094$) in the Avon Longitudinal Study of Parents and Children. We correlated impairment severity with independent clinical diagnoses of ASD, cognitive abilities, and teacher-rated maladaptive behavior. **Results:** Social and Communication Disorders Checklist scores were continuously distributed in the general population; boys had mean scores 30% higher than girls. Social communicative deficits were associated with functional impairment at school, especially in domains of hyperactivity and conduct disorders. A sex-by-verbal IQ interaction effect occurred: verbal IQ was protective against social communication impairments across the range of abilities in female subjects only. In male subjects, this protective effect did not exist for those with above-average verbal IQ. **Conclusions:** Social communicative deficits are of prognostic significance, in terms of behavioral adjustment at school, for boys and girls. Their high general population prevalence emphasizes the importance of measuring such traits among clinically referred children who do not meet diagnostic ASD criteria. Above-average verbal IQ seems to confer protection against social communication impairments in female subjects but not in male subjects. *J. Am. Acad. Child Adolesc. Psychiatry*, 2009;48(2):128–137. **Key Words:** autistic spectrum disorder, ALSPAC, Social and Communication Disorders Checklist, sex differences, verbal IQ.

The population prevalence of autism seems to have increased in the last decade, possibly because of better recognition[1]; current estimates range up to 116 per 10,000 children with an autistic spectrum disorder (ASD).[2,3] We propose that population estimates of prevalence may underestimate the importance of autistic characteristics of lesser severity, for two main reasons. First, cases are usually ascertained from secondary screening, based on the initial selection of children who have severe and obvious symptoms. Consequently, mild or moderate deficits in social and communicative competence may be missed, especially if they are

associated with marked degrees of comorbidity in the context of psychiatric disorders such as conduct problems[4] and attention-deficit/hyperactivity disorder (ADHD).[5] Second, methods of ascertainment are designed to maximize the distinction between valid cases of autism, defined according to conventional criteria, and to exclude conditions that do not reach diagnostic significance.[6,7] Yet, recent evidence suggests that ASDs are simply the extreme end of a continuous distribution of one or more dimensions of autistic behaviors. Constantino and Todd[8] measured autistic traits in a large community child sample and found no discontinuity between normality and psychopathology, as would have been evidenced by a bimodal distribution. This finding has since been replicated in a Scandinavian community sample using both parent and teacher report questionnaires.[9] Neither study considered the critical question: at what degree of severity do autistic traits become functionally impairing in the general population of children? We aimed to address this question in the research reported here.

ASDs are associated with elevated risk of a range of impairments to functional adaptation.[10] These include conduct problems,[4] hyperactivity,[11–13] difficulties with peers,[14] and emotional difficulties.[15,16] In addition, there is extensive evidence of an association between autism and low IQ.[17–20] No previous study has sought to quantify a range of functional impairments associated with subclinical social and communication deficits of an autistic character, which may have significant public health and educational costs.[4]

Our investigation was based on a large, geographically defined population of children who have been the subject of intensive scrutiny in terms of their biological and psychological development since before birth. Social and communication deficits were measured in middle childhood, using a parent-report rating scale—the Social Communication Disorders Checklist (SCDC).[21] Approximately 1 year later, we obtained teacher ratings of behavioral and emotional adjustment[22] and antisocial behavior.[23] IQ was measured shortly after SCDC administration.[24] All contributory sources of data were derived independently of each other. We tested the predictions that increased levels of social and communication difficulty would be associated with the following: lower IQ, more conduct problems, greater hyperactivity, more emotional problems, and greater peer relationship problems.

METHOD

Sample

The Avon Longitudinal Study of Parents and Children (ALSPAC) is a prospective longitudinal intensively studied population cohort of children.[25] Initial recruitment targeted all pregnant women living in the geographical region of Avon, England, who were expected to deliver their baby between April 1, 1991, and December 31, 1992, and more than 85% participated (average age was 28 years; range 14–46 years). Approximately 45% were expecting their first child; 6% had 3 or more children. Contact has been maintained with the families of 11,500 of the original cohort of 13,971 surviving children. Further details are given on the ALSPAC Web site.[26] The highest educational qualifications of mothers were recorded as a proxy for socioeconomic status using a five-point classification of achievement, from minimal (14%) to a university degree (16.1%). Approximately 70% of all cohort mothers (8,094/11,500) completed the SCDC screening questionnaire; 16% of the participants (compared with 7% of nonparticipants) had a university degree.

Measures

Social Communication Disorders Checklist. The SCDC[21] is a questionnaire, completed by parents, that measures social reciprocity and verbal/nonverbal characteristics resembling those found in ASD. There are 12 items, rated according to whether the corresponding behavior has been seen during the past 6 months; if so, whether the associated statements are "not true," "quite or sometimes true," or "very or often true." Scores of 0-1-2 apply, so the maximum possible score is 24. In our analysis, a small proportion of cases had missing items (205/8,094); total scores have been prorated. The scale was derived from a principal components analysis of a longer instrument and represents just one factor. The single dimension measured by the instrument has strong internal consistency; Cronbach α is .93.[21] Discriminant validity, measured in a clinical population, predicted autism with a sensitivity of 0.9 and specificity of 0.69 (threshold score of 9/24), which is equivalent to the Social Communication Questionnaire.[27,28] Criterion validation showed modest correlations between the SCDC total score and ADI algorithm scores[29] (0.41 with qualitative abnormalities in reciprocal social interaction, $p <$ .001; 0.3 with qualitative abnormalities in communication, $p <$ .001; 0.21, with restricted, repetitive, and stereotyped patterns of behavior, $p <$ .01). The SCDC-measured trait has high heritability (0.74),[30] which is similar in magnitude to the heritability of autistic traits measured by other screening scales, estimated to be between 0.6 and 0.9.[31]

Strengths and Difficulties Questionnaire. This behavioral screening questionnaire,[22] administered to parents and/or teachers of 4- to 16-year-olds, measures emotional and behavioral difficulties and the resulting functional impairment. It has acceptable reliability and validity. In this study, we used data that had been provided only by teacher report, to avoid contamination between informants. Parents and teachers provide Strengths and Difficulties Questionnaire (SDQ) information of roughly equal predictive value, although information from teachers is slightly more useful for detecting conduct and hyperactivity disorders. The subscale "hyperactivity disorder" corresponds approximately to "any ADHD disorder," according to *DSM-IV*[32] criteria.

Children's Communication Checklist. This 70-item parent- or teacher-report questionnaire[33] measures aspects of communication impairment, mainly in terms of pragmatic competence. It calculates

a "Pragmatic Composite Score" and summarizes in subscales several formal aspects of spoken language. It has acceptable validity and reliability.

Wechsler Intelligence Scale for Children–Third Edition. This standardized widely used measure of intelligence[24] for children age between 6 and 16 years yields scores for verbal, performance, and full-scale IQ. In the present study, a short form was used, involving the administration of alternate items from the 10 subtest standard battery.

Procedures

Parents completed the SCDC[21] when cohort children (4,167 boys and 3,927 girls) were at mean age 7 years 8 months (80% ages 7 years 8–9 months). Teachers were asked to provide detailed information when the ALSPAC cohort children were at mean age 8 years 4 months (SD 3.7 months, total completed $n = 6,279$). Ratings included measures of conduct problems (based on the *International Statistical Classification of Diseases, 10th Revision* [*ICD-10*] classification[23]) and an additional range of troublesome or awkward behaviors that may be interfering with the child's functional adaptation in school. They also completed the SDQ.[22]

Measures of IQ (Wechsler Intelligence Scale for Children–Third Edition[24]) were administered to children in the 8 years' hands-on ("Focus@8") examinations ($n = 7,170$; 51.3% of the original cohort). The Focus@8 examination aimed to assess every eligible child individually in the original cohort on a variety of observational and psychometric measures, using trained observers. Of the 8,094 children with an SCDC score, 5,931 had a measured verbal IQ (VIQ; range 46–155), 5,516 had a performance IQ (range 46–151), and 5,468 a full-scale IQ (range 45–151).

ASD Case Ascertainment. Subsequently, as part of a separate study, children within the ALSPAC sample with an ASD diagnosis were identified.[34] Ascertainment was made on the basis of information from National Health Service (NHS) records, and from Education Service databases, when the children were approximately 11 years of age (approximately 3.5 years after SCDC data were collected for the present study). Data were available for 11,458 (82%) of the original cohort (5,858 male subjects and 5,600 female subjects). These independent data on clinically identified cases of ASD were used to assess the predictive validity of the SCDC in the population sample.

Statistical Analysis

Statistical analyses of interval scale scores included standard comparisons of means using multivariable analyses of variance and other parametric tests. One-way analyses of variance used a Scheffé correction ($p < .05$) in post hoc tests of mean differences between groups. All analyses have been completed using SPSS-14 (SPSS Inc., Chicago, IL). We controlled in further analyses for potentially confounding variables. These variables included standardized measures of intelligence and highest maternal educational qualification. Principal components analysis was used to explore the SCDC's factor structure in this large population sample. A receiver operating characteristic (ROC) plot was generated to evaluate by graphical means the SCDC's capacity to discriminate between those with and without an ASD. A cut point was identified at which the SCDC's sensitivity (proportion of true cases correctly identified) and specificity (proportion of noncases correctly identified) were maximized. The SCDC's positive likelihood ratio and posttest probability in the general population were calculated. Conventional odds ratios (ORs) were calculated. Logistic regression and χ^2 analysis were used for examining the relations between categorical variables. The impact of missing data was explored using a propensity score based on seven factors: maternal education, maternal age, partner status, family adversity index, child life events, housing tenure, and social class.

Role of the Funding Source

The sponsors of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all of the data in the study and took final responsibility for the decision to submit for publication.

Ethical Permissions

The ALSPAC cohort has been the subject of rigorous ethical scrutiny, and ethical permissions have been obtained from the ALSPAC Law and Ethics Committee as well as the Local Health Authority Ethics Committees. Data linkages are anonymous. Scores are not traced back to individuals.

RESULTS

Each of the SCDC symptoms (items) was rated as being "very or often true" (scoring 2), "quite or sometimes true" (scoring 1), or not true (scoring 0). The prevalence of each of the 12 individual symptoms rated as "very or often true" ranged from 0.7% to 3.9% (female) and from 2.3% to 6.2% (male) of the sample. For each symptom item, boys scored significantly higher than girls ($p < .001$). Consequently, the SCDC total score differed by sex: boys mean score 3.25 (SD 4.15), girls mean score 2.39 (SD 3.14, $p < .0001$). An excess of girls scored 0 ($n = 8,094$, $\chi^2_1 = 40.67$, $p < .001$). The distribution of the SCDC scores was positively skewed, following an exponential decay pattern, with boys more likely than girls to have high scores (Fig. 1). Total scores were influenced by mother's educational qualifications (analysis of variance: $F_{4,7858} = 3.445$, $p = .008$) with a trend to higher scores among those with least education, but a post hoc test (Scheffé) showed no significant between-group differences.

Special educational provision had been made, according to the Pupil Level Annual School Census (PLASC) records, for 6.2% ($n = 259$) of the boys and 2.1% ($n = 81$) of the girls for whom there were SCDC data ($n = 8,094$). These proportions are higher than comparable national data (2006), which show, in the same age range, approximately 2.3% of children with special educational needs.[35] An ASD was the primary reason for providing such support for 25 boys and 6 girls and the secondary reason for 4 boys and 1 girl. Fifteen additional cases of ASD were identified from NHS
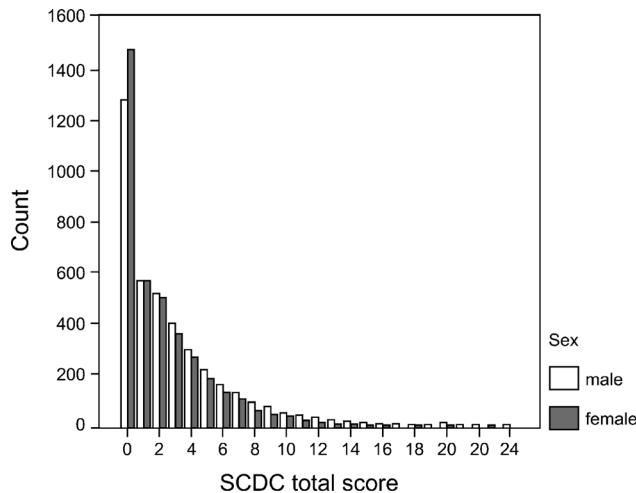
**Fig. 1** Distribution of Social Communication Disorders Checklist (SCDC) scores as a function of sex (*n* = 8,094).

records.[34] Other primary reasons for special educational needs, according to PLASC records, included specific learning difficulties (*n* = 70); moderate learning difficulties (*n* = 92); severe learning difficulties (*n* = 15); profound and multiple learning difficulties (*n* = 2); emotional and behavioral maladjustment (*n* = 57); speech, language, and communication needs (*n* = 25); and physical and sensory disability (*n* = 22).

### Assessment of Psychometric Properties of SCDC in a General Population of 8-Year-Olds

Principal components analysis was used to investigate the factorial structure of the SCDC in a general population. There were no problems with the data with respect to multicolinearity (determinant of correlation matrix = 0.0014) or sphericity (Bartlett test of sphericity, *p* < .001). Similarly, sampling adequacy was shown to be in the "excellent" range (overall Kaiser-Meyer-Olkin = 0.93; all individual item Kaiser-Meyer-Olkin scores >0.88). Given the large sample size, Cattell's "point of inflection" (scree plot) criterion for selecting number of factors was used.[36] This suggested a one-factor solution, which accounted for 44% of total variance. Loadings onto this factor for the 12 SCDC items were between 0.56 and 0.74, and Cronbach α was high (0.88). These data are consistent with our original validation study on clinical samples.[21] We assessed the predictive validity of the SCDC in this general population using an ASD diagnosis that had been the primary or secondary reason for a PLASC statement (full statement or "school action plus") and/or had been as-

certained as a case of ASD by hospital or community NHS services[34] by the time that child was 11 years of age. Fifty-six cases were identified within the subgroup for which we had an SCDC score (ASD prevalence of 69.2 cases per 10,000 screened population, compared with 61.9 per 10,000 for the whole ALSPAC population). Parents of children with ASD were slightly more likely to complete our questionnaires than those of other children (A. Emond, personal communication, August 2008).

To examine the SCDC's capacity correctly to classify cases of ASD, ROC methods were used (Fig. 2). This involves examining the measure's sensitivity versus its false alarm rate (percentage of those identified as having an ASD by the SCDC who do not in fact have an ASD). In an ROC graph, the larger the area under the curve (AUC), the better the instrument can maximize sensitivity and specificity. In this case, the AUC statistic (0.93) for the whole population is excellent according to conventional criteria. Maximum sensitivity and specificity were obtained with a cut point that designated "probable case" status to scores of 8 or more. Sensitivity was 0.88 (95% confidence interval [CI] 0.75–0.94), and specificity was 0.91 (95% CI 0.90–0.91). This yields a positive likelihood ratio of 9.44 and, using recent gold-standard estimates of ASD prevalence,[3] a posttest probability in the general population of 0.10. Selecting
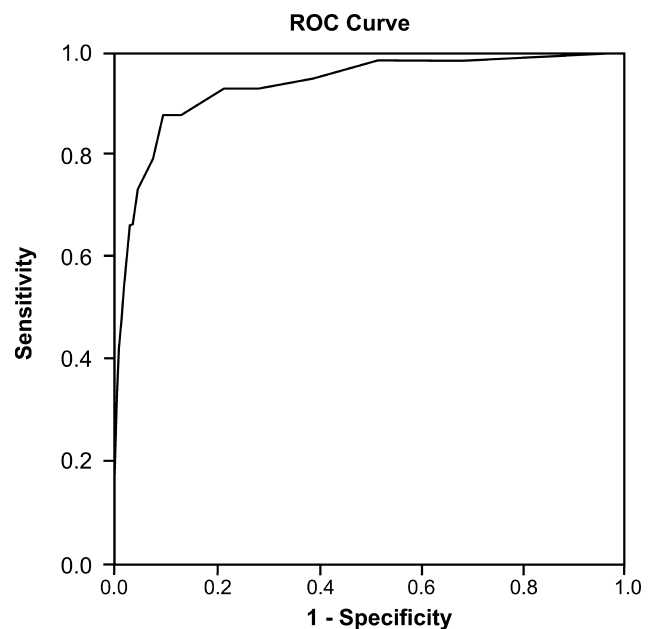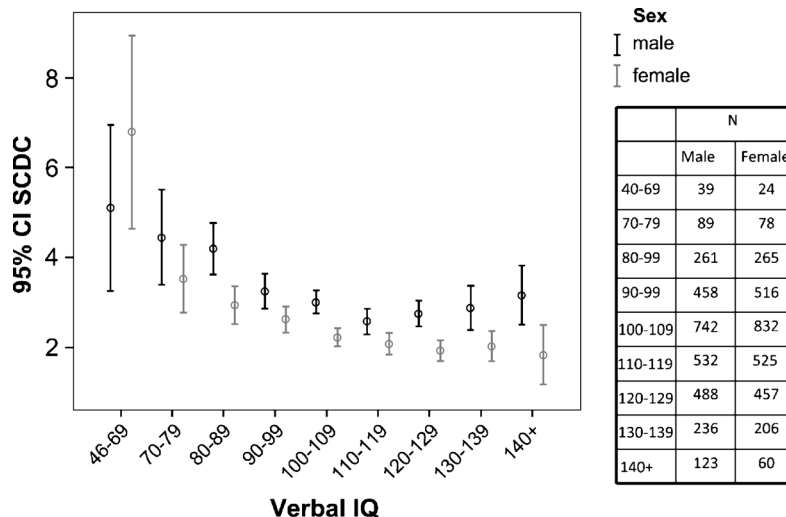

Fig. 2 Receiver operating characteristic (ROC) curve of the Social and Communication Disorders Checklist: validity coefficients refer to an autistic disorder diagnosed by early adolescence; area under the curve = 0.93.
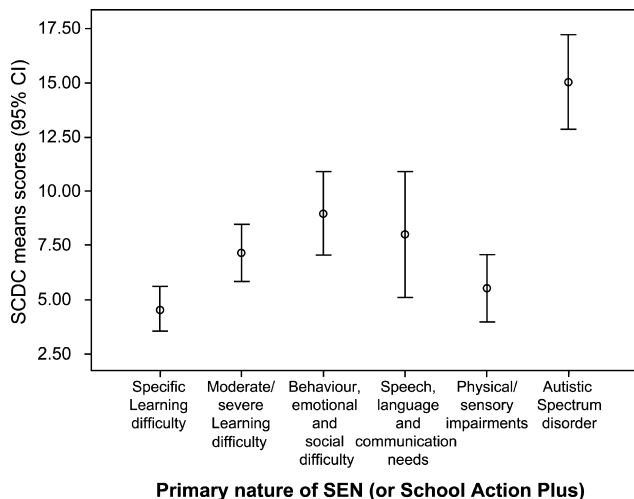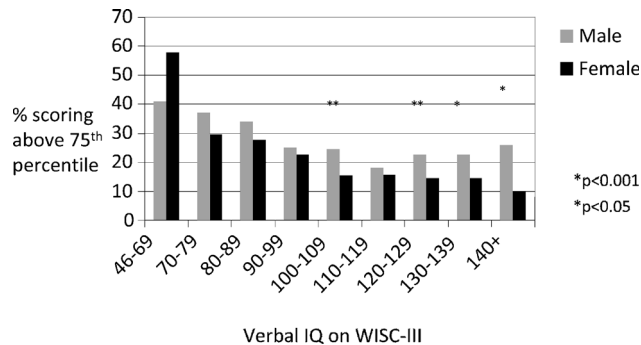
Fig. 3 Social Communication Disorders Checklist (SCDC) scores (mean ± 95% confidence intervals) by Pupil Level Annual School Census categorization (based on 2003–2004 data) in terms of primary domains of special educational needs (SEN; *n* = 340).

Fig. 5 Specified ranges of verbal intelligence plotted against proportions of boys (*n* = 2,968) and girls (*n* = 2,963) scoring above whole group 75th percentile on the Social Communication Disorders Checklist.

children with a full-scale IQ of less than 80 gives an AUC of 0.94, and sensitivity and specificity are almost identical (0.8). The scale has similar predictive value for children with mental retardation, as it does for children with normal-range abilities. The conventional OR for a diagnosis of ASD for children with a score of 8 or more was 68.4 (95% CI 30.9–151.6). For children with PLASC statements (full statement or "school action plus") for which the primary reason was not ASD, the equivalent ratio was only 6.5 (95% CI 5.1–8.3). Mean

SCDC scores were assessed for each main category of statement. The instrument did not merely predict learning or behavioral difficulties in general. Children with an ASD obtained significantly higher scores than for any other category (Fig. 3), confirmed by post hoc tests ($p < .0001$, Scheffé test). The SCDC scores were minimally associated with Children's Communication Checklist (CCC) measures of Speech Output ($r_{6832} = -0.21$, $p < .001$) and Syntax ($r_{6816} = -0.27$, $p < .001$), noting that "impairment" on the CCC and SCDC is scaled in opposite directions. Association between SCDC scores and the CCC Pragmatic Competence Score (associated with language difficulties of an autistic character), however, was large and significant ($r_{6710} = -0.52$, $p < .001$).

Fig. 4 Specified ranges of verbal intelligence plotted against mean Social Communication Disorders Checklist (SCDC) scores (with 95% confidence intervals) for boys and girls (*n* = 2,968 and 2,963, respectively).

SCDC and Measures of Cognitive, Emotional, and Behavioral Functioning

As is shown in Figure 4, the association between IQ and social communication ability was more complex than the linear relation we had hypothesized. In the interest of parsimony, during our exploration of these data, we focused our attention on VIQ. This was chosen because it is the IQ measure most sensitive to social communication competence. Examination of mean SCDC scores and their 95% CIs by sex and VIQ suggested that, among more cognitively able children (i.e., those scoring 100 and above), there was a relation between social communication competence and VIQ, which was not identical for male and female subjects.

We identified children scoring above the 75th percentile of the overall SCDC distribution and compared their distribution across the range of VIQ scores by sex. The results of these analyses are shown in Figure 5. We compared proportions by sex for each VIQ band using χ^2 tests and found that significant sex differences only emerged in the higher VIQ bands. To further test the existence of a sex-by-VIQ interaction effect on SCDC scores, we fitted a sex–VIQ factorial model using logistic regression. Participants were classified into lower (VIQ < 100, $n = 1,730$) and higher (VIQ $\geq$ 100, $n = 4,201$) VIQ groups. The results of this analysis are shown in Table 1. There was a significant interaction between VIQ and sex. Compared with girls, boys in the higher VIQ group had an OR of 1.62 (95% CI 1.38–1.89) of being in the top quartile on the SCDC, whereas the equivalent statistic for boys in the lower VIQ group was 1.22 (95% CI 0.99–1.51). We conducted equivalent logistical regression analyses for performance and full-scale IQ, and found no significant interaction effects between sex and either of these measures of intelligence.

Missing data were initially analyzed in two stages: first for those with missing data on the SCDC ($n = $

6,572), and second for those with completed SCDCs but no VIQ data ($n = 2,163$). The two resultant models were similar, with propensity scores being highly correlated ($r = 0.99$). Consequentially, a single model for missing data was constructed. Covariate adjustment had little impact on the results. Stratified analyses by quintiles of propensity score also suggested that the sex-by-VIQ interaction was resilient to missing data.

Teacher ratings of children's behavior were obtained from subscales of the SDQ, which included prosocial behavior, hyperactivity, emotional symptoms, conduct problems, and peer problems. In a regression model, simultaneously controlling for sex, full-scale IQ, and mother's highest educational level (a proxy for socio-economic status), the SCDC score was associated significantly with each of these behavior outcomes (standardized regression coefficients are shown in Table 2). Social communication deficits correlated positively with peer relationship problems for both boys and girls: SCDC scores contributed 4.4% of the variance for boys ($p < .001$, standardized $\beta = .11$) and 1.9% of the variance for girls ($p < .001$, standardized $\beta = .08$). There was no relatively greater risk of peer problems associated with high SCDC scores; the trend was linear. There was a negative correlation with prosocial behavior in both sexes; SCDC scores contributed to 5.7% of the variance for boys ($p < .001$, standardized $\beta = -.16$) and 2.4% of the variance for girls ($p < .001$, standardized $\beta = -.10$).

We examined these data for discontinuity in the linear relation between SCDC and SDQ scores to investigate the possibility of a "step function" whereby social communication impairment becomes a stronger risk factor for behavioral impairments above a certain threshold. This was done using a regression of the residuals from the linear model with a dummy variable representing the potential step function. In general, there was no evidence for discontinuity. Conduct problems seemed to exhibit two discontinuities at 3/4 and 7/8 points on SCDC ($p < .05$), with those in the range of 4 to 7 showing fewer problems than expected from the linear response. Because of the relatively implausible nature of these associations, we attributed these results to chance events.

Teachers rated specific conduct behaviors as being present or absent in the past year. They included all conduct disorder items associated with this diagnosis within *ICD-10*.[23] The most common were disobedience

TABLE 1

Logistic Regression of Top Quartile of the SCDC Scale Adjusting for Sex, Verbal IQ, and Interaction Effect ($n = 5,931$)

Predictor	OR	95% CI	p
Males	1.22	0.99–1.51	.060
High VIQ	0.51	0.42–0.62	.000
Interaction	1.32	1.01–1.72	.039

Note: SCDC = Social Communication Disorders Checklist; OR = odds ratio; VIQ = Verbal IQ.

TABLE 2
Parameter Estimates From a Multivariable Regression Analysis to Determine Strength of Phenotypic Association Between Teacher-Rated Nonautistic Behavioral and Emotional Problems and Social Communication Traits, Sex, Full-Scale IQ, and Mothers' Highest Education Level (Overall *p* Values Only for the Latter)

SDQ Subscale	SCDC (Range 0–24)	Sex (Male = 0, Female = 1)	Full-Scale IQ (Range 48–151)	Maternal Education
Prosocial behavior (range 0–10)	−0.133***	1.181***	0.015***	(*p* = .104)
Hyperactivity (range 0–10)	0.202***	−1.197***	−0.044***	(*p* = .425)
Emotional symptoms (range 0–10)	0.020*	0.029 (*p* = .661)	−0.022***	(*p* = .394)
Conduct problems (range 0–10)	0.090***	−0.346***	−0.008***	(*p* = .170)
Peer problems (range 0–10)	0.093***	−0.327***	−0.009***	(*p* = .002)**
Total difficulties (range 0–40)	0.405***	−1.835***	−0.083***	(*p* = .348)

Note: Dependent variables were scores on each SDQ subscale, which were associated with the SCDC, Sex, Full-Scale IQ, and mothers' highest educational attainment, entered simultaneously. Sample was *N* = 2,956 to 2,958 (depending on the SDQ variable) on whom all data were available. A high score indicates more evidence of a problem except on the prosocial scale. SDQ = Strenghts and Difficulties Questionnaire; SCDC = Social Communication Disorders Checklist.

*p < .05; **p < .01; ***p < .001.

(10.3% children were reported to exhibit this specific behavior), temper tantrums (8.9%), arguments with adults (8.9%), spiteful behavior (8.6%), lying (8.1%), bullying (5.3%), and starting fights (5.2%). Significant differences in mean SCDC scores, according to presence or absence of the behavior, were found for all conduct disorder items (*p* < .001), with two exceptions. Both occurred rarely in our population: deliberate setting of fires (prevalence 0.13%; mean SCDC scores associated with presence/absence, 4.4 versus 2.7; *p* = .3) and being in trouble with the law (0.15%; mean scores associated with presence/absence, 10.0 versus 2.7; *p* = .1).

DISCUSSION

The prevalence of mild deficits in social and communicative competence has a continuous distribution in the general population of schoolchildren. This is consistent with previous articles, suggesting that traits resembling those seen in ASD are not confined to children with a clinical diagnosis.[8,9] This study is the first to show the existence of a nonlinear sex-specific relation between VIQ and social communication competence. We present preliminary evidence that increased VIQ confers stronger protection against social communication impairments in females than in males. Another novel finding is that subclinical social communication deficits are associated with functional impairments at school in a range of behavioral domains and are positively associated with risk of conduct disorder across the full range of IQ.

Validity of SCDC in a General Population Sample

Before our IQ and teacher report findings can be discussed, it is important to consider the validity of the SCDC as a measure of autistic-like social communication deficits in the general population. The instrument was initially validated in a clinical sample and found to measure a single heritable autistic social communication trait.[21,30] Principal components analysis in the present study confirmed the SCDC's unitary factor structure in a general population sample. As one would predict for a measure of autistic-like social communication impairment, the single dimension measured by the SCDC was minimally associated with difficulties with formal language and strongly associated with a measure of pragmatic language impairment. Despite its brevity compared with other autism screening instruments (e.g., Social Responsiveness Scale,[37] Child Asperger Syndrome Test,[38,39] Social Communication Questionnaire[27,28]), the SCDC has proven to have excellent sensitivity and specificity in relation to independently diagnosed cases of autism and ASD in the general population. In fact, estimates of sensitivity and specificity exceeded those obtained in the original clinical validation of the SCDC. Inevitably, given the relative rarity of autism in the general population, posttest probability (0.10) was low. The mean SCDC score for those children subsequently diagnosed with an ASD in the ALSPAC cohort (14.9 [SD 6.8]) was similar to that obtained in the clinically based SCDC validity study[21] (16.6 [SD 5.7]). The SCDC scores were

significantly higher for children diagnosed with an ASD than for those identified as having other types of learning and behavioral difficulties. The proportion of children in the ALSPAC sample for whom we had SCDC scores, who were found by late childhood to have received a diagnosis of an autistic disorder (69/10,000), was similar to the proportion with ASDs reported by population surveys in the United Kingdom, based on multistage screening (59/10,000 in the study by Chakrabarti and Fombonne,[2] 116/10,000 in the study by Baird and coworkers[3]). At this stage, we do not know the extent to which elevated SCDC scores in those children without such a diagnosis reflect measurement error or whether the children concerned have psychiatric conditions that are not autistic. The prevalence of social and communication deficits in relatively more common conditions, such as ADHD[40] and conduct[4] or bipolar disorders,[41] is also found to be higher than that in the general population.

IQ and Social Communication Difficulties

We have presented data to suggest that VIQ is positively associated with social communication competence across the full range of abilities in the female subjects only. By contrast, for the male subjects, this relation exists only in the below-average VIQ range. Our findings suggest that high VIQ is protective for the female subjects but that it is not protective for the male subjects with respect to social communication traits. This relation is not observed for performance and full-scale IQ.

To confirm and elucidate these findings, it will be important to better characterize the phenomenon reported here, using more comprehensive multimodal assessments to measure autistic symptoms and using a fine-grained analysis with respect to specific aspects of intelligence. The epidemiological findings reported here could be tested in clinical samples. In groups of low-functioning male and female subjects with an ASD, and in high-functioning female subjects with an ASD, we would expect a negative association between VIQ and dimensionally measured autistic symptoms. By contrast, in high-functioning male subjects, no such prediction would be made. Furthermore, any associations between specific autistic traits and specific verbal abilities would promote understanding of the actual mechanisms involved. In addition, longitudinal designs involving young male and female siblings of people with an ASD

will be useful for understanding the relation between VIQ and social communication competence.

Such research would have particular relevance to the causal mechanisms of Asperger syndrome, which is associated with elevated intelligence, unimpaired verbal abilities, and a high (10:1) ratio in favor of males. A related issue is whether Asperger syndrome is a distinct disorder on the autism spectrum and whether high-functioning autism is distinct from low-functioning autism. If there are children who have a social communication disorder despite their elevated VIQ, are they a different population from those who have an ASD in the presence of average or below-average intelligence? One way to address this question would be to compare high-functioning male and female subjects with ASD in terms of their autistic symptoms and cognitive profiles. This would control for IQ but would allow for the differentiation of two putative ASD groups.

Behavioral and Emotional Difficulties and Social Communication Difficulties

Our study also adds to previous investigations the observation that subclinical deficits in social communication are positively correlated across the IQ range, with a range of independently measured educational, social, and behavioral impairments, which are, in general, more severe among boys than girls at age 7 to 8 years. We found no consistent evidence for a step function in the distribution, suggesting that risk is coincident with the strength of the traits across their range.

These findings are compatible with previous research that has investigated the covariation of dimensional measures of conduct problems and social communicative competence in typically developing children. Scourfield and coworkers[42] found a high correlation (0.6) and concluded that this was largely due to latent genetic influences acting on both measures, whereas environmental influences were specific to each domain. In a study of children with conduct disorder within both clinical and population samples, Gilmour et al.[4] found that two thirds had pragmatic language impairments and other behavioral features that were similar in nature and degree to those of children with autism, independent of IQ.

The above findings must be considered in the light of the following three methodological issues. First, although the SCDC predicted nearly 9 of 10 children independently diagnosed with an autistic disorder, the

traits measured in this study were far more common than the clinical ASD diagnosis, and we do not know what proportion of children with scores above our optimal threshold had come to clinical attention for other reasons. The scale does not measure all autistic traits. It is an indicator of current social and communicative competence and excludes historical data on delayed attainment of speech or developmental delay, nor does it measure restricted, repetitive, and stereotyped patterns of behavior. Some previous research has suggested that social communication impairments are affected by genetic influences that are independent of those influencing restricted repetitive behaviors and interests,[43,44] although others claim that there is but one dimension of autistic impairment.[8]

Second, the cases of ASD identified in the ALSPAC cohort were found by experienced clinicians[34] in pediatric and psychiatric practice within the NHS, who relied on detailed but nonstructured assessments using diagnostic criteria from *ICD-10.* Referral bias could have resulted in some missing cases. These would include children referred only to private practitioners or who received special education within a fee-paying school, although there are relatively few such practitioners or special schools in the Bristol area. Of the original birth cohort, approximately 5% had moved from England (the latter would still have been contacted and completed questionnaires but would not have been picked up as having an autistic disorder from either the NHS or PLASC ascertainment). Autistic disorders associated with normal or high intelligence (especially Asperger syndrome) may not have been recognized by age 11 years and could yet be picked up in adolescence or adulthood. However, the predictive validity of the SCDC in the general population is likely to be only slightly altered by these additional data because the false-negative rate was high (as would be expected in any population screen for a rare disorder in which the phenotype is not tightly defined).

Third, our finding on the relation between VIQ and social communication may be influenced by the fact that only 73% of those for whom we had SCDC data completed an IQ test. There is some evidence that autistic children were underrepresented in this sample; of those with a PLASC/NHS-based ASD diagnosis, a high proportion (36/56) failed to attend the IQ assessment at age 8 years. Inquiries suggested that it was usually due to parental reluctance to cause the affected child distress by exposing them to a noisy and bustling clinic. In some cases, the omission may be connected with low abilities and lack of testability, leading to a systematic underrepresentation of autistic children with IQs in the range of mental retardation. Of all children tested, 3.7% had a VIQ lower than 70, which is a proportion comparable to that found in a recent U.K. epidemiological survey of mild mental retardation.[45] Secondary analyses adjusting for an indicator of missing data suggested that its influence was small and did not change the sex-by-VIQ interaction finding.

In conclusion, our findings are consistent with recent reports that autism and autistic-like traits lie on a continuum of impairment, with the male–female ratio increasing toward the extreme high scorers in the distribution.[8] Our study suggests that even subthreshold autistic-like traits are associated with a small elevated risk of teacher-reported problems with socialization, hyperactivity, and conduct problems. This suggests the value of clinicians assessing autistic traits dimensionally and acknowledging the potential impact on function and well-being of even mild autistic difficulties.

In this epidemiological study, we found evidence for elevated VIQ acting as a protective factor with respect to social communication impairment in girls but not boys. This novel finding, which potentially offers insight into the development of Asperger syndrome and high-functioning autism, will need elaboration in future clinical and longitudinal studies.

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