J Autism Dev Disord (2012) 42:625–633
DOI 10.1007/s10803-011-1290-1

ORIGINAL PAPER

The Autism-Spectrum Quotient—Italian Version: A Cross-Cultural Confirmation of the Broader Autism Phenotype

Liliana Ruta · Domenico Mazzone · Luigi Mazzone · Sally Wheelwright · Simon Baron-Cohen

Published online: 28 May 2011

Abstract The Autism Spectrum Quotient (AQ) has been used to define the 'broader' (BAP), 'medium' (MAP) and 'narrow' autism phenotypes (NAP). We used a new Italian version of the AQ to test if difference on AQ scores and the distribution of BAP, MAP and NAP in autism parents (n = 245) versus control parents (n = 300) were replicated in a Sicilian sample. Parents of children with autism spectrum conditions scored higher than the control parents on total AQ, social skills and communication subscales, and exhibited higher rates of BAP, MAP and NAP. We conclude that the Italian AQ is a cross-culturally reliable measure of these different phenotypes, and can be used to identify a phenotypic gradient of severity of autistic traits in families. To understand the molecular basis of these phenotypes will require its use in genetic association studies.

Keywords Autism spectrum conditions · Broader autism phenotype · Autistic traits · Autism-spectrum quotient

Introduction

Autism Spectrum Conditions (ASC) are neurodevelopmental conditions characterised by social and communication difficulties alongside unusually narrow interests and stereotyped patterns of behaviour, including resistance to change (APA 1994). They demonstrate a strong genetic component as evidenced by the 5–8% recurrence rate within families (Szatmari et al. 1998), a concordance of 60% versus 3–5% in monozygotic (MZ) and dizygotic (DZ) twins, respectively (Bailey et al. 1995) and many molecular genetic associations (Abrahams and Geschwind 2008).

The liability for ASC in first degree relatives of people with ASC, expressed as a phenotype that is milder but echoing a similar profile to the defining features of ASC, is referred to as the Broader Autism Phenotype (BAP). The BAP refers to heritable sub-threshold autism-related traits and may be related to different genetic loading in simplex and multiplex autism families (Virkud et al. 2009). The BAP has been conceptualized as a constellation of language, personality, cognitive and behavioral characteristics, mirroring the autism symptom domains subclinically.

Thus far, several studies have reported impairments in social cognition, central coherence and executive function in unaffected relatives of people with ASC (Losh and Piven 2007; Bölte and Poustka 2006; Baron-Cohen and Hammer 1997; Happé et al. 2001; Bolton et al. 1994). Language-related components of the broader autism phenotype have also been reported, including atypical pragmatics in parents (Landa et al. 1992) as well as lower verbal IQ, poorer spelling, and poorer reading scores in a subgroup of parents who reported a history of early language-related cognitive difficulties (Folstein et al. 1999).

Furthermore, familial aggregation for some axis I psychiatric conditions, such as motor tics, OCD, major depressive disorder and social phobia has been reported in these families (Bolton et al. 1998). However, the correlation of these psychiatric conditions to the BAP has not been clearly established. Some studies have reported no

L. Ruta (✉) · S. Wheelwright · S. Baron-Cohen
Department of Psychiatry, Autism Research Centre, University of Cambridge, Cambridge, UK
e-mail: lr315@cam.ac.uk

L. Ruta · D. Mazzone · L. Mazzone
Division of Child Neurology and Psychiatry, Department of Paediatrics, University of Catania, via S. Sofia 78, 95123 Catania, Italy

association between higher rates of depression or social phobia and the BAP (Piven et al. 1991; Smalley et al. 1995), whilst others found that the BAP was a predictor of depressive symptoms in mothers of children with ASC (Ingersoll et al. 2010).

More recently a quantitative, dimensional reconceptualization of ASC, the BAP and typical variation of autistic traits in the general population has been proposed. The concept of the autistic spectrum, originally conceived as a gradient of severity within the clinical range, has been extended to a continuum of autistic traits in the general population (Baron-Cohen et al. 2001; Constantino and Todd 2005; Ring et al. 2008). Twin studies report high heritability for autistic traits in the general population (Hoekstra et al. 2007; Skuse et al. 2005; Constantino and Todd 2003), suggesting that susceptibility genes might also have effects on continuously distributed autism-related traits. Thus, in a continuum of severity of autistic traits in the general population, the BAP would be regarded as a genetically inherited quantitative loading for autistic traits in non affected relatives of subjects with autism.

A variety of instruments, such as structured interviews, rating scales and self-report questionnaires have been developed to assess the BAP both categorically and dimensionally. The Autism Family History Interview (AFHI) was one of the first measures of social and communication impairments and ritualistic-repetitive behaviour in parents of children with ASC. The AFHI consistently demonstrates that parents of children with ASC are more likely to have social deficits characterized by reduced friendship, impaired or limited conversation, social inappropriateness, as well as stereotyped behaviours characterized by rigid or perfectionistic style and circumscribed interests, compared to parents of children with Down syndrome (Bolton et al. 1994; Piven et al. 1997a). Other studies provide additional support for these findings. Piven et al. reported that parents of children with ASC have personality characteristics that echo ASC, namely rigid or perfectionistic personality and socially aloof or tactless personality (Piven et al. 1994, 1997b; Losh et al. 2008). These traits parallel the repetitive and social symptom domains of ASC, respectively.

More recently, the Broad Autism Phenotype Questionnaire (BAPQ) was developed to measure personality and pragmatic language characteristics relevant to the BAP. In line with previous evidence, parents of children with ASC showed significantly higher scores on all three BAPQ subscales: aloof personality, rigid personality, and pragmatic language (Hurley et al. 2007). The BAPQ is simple to administer and requires no clinical expertise. It is suitable as both a screening and a diagnostic tool. One limitation of the instrument is that versions are not available for use across different ages.

Another instrument developed to assess the BAP according to the DSM IV autism core domains is the Broader Phenotype Autism Symptom Scale (BPASS) (Dawson et al. 2007). The BPASS is a combination of family history and direct assessment methods and was developed for use in Quantitative Trait Locus (QTL) analyses. It measures, via parent interview and direct observation, autistic traits along a continuum in four domains: social motivation, expressiveness, conversational skills and flexibility/range of interests. Both parents and their children with ASC show overlapping distributions on all four domains, suggesting the BPASS captures variability in traits across family members with and without a diagnosis. The BPASS provides quantitative indices for each autism domain, thus combining discrete and continuous approaches, and items are appropriate for both children and adults. The main disadvantages of the BPASS are that administrators must be specially trained, and it is time consuming to administer.

Following the single dimension approach, two of the most widely used purely quantitative measures of autistic traits that demonstrated their utility to assess the BAP are the Social Responsiveness Scale (SRS) and the Autism Spectrum Quotient (AQ). These questionnaires, previously designed to measure autistic traits in the general population as well as in clinical samples have been also used in relatives of autistic individuals, in an effort to derive a standardized quantitative system to define the BAP. The Social Responsiveness Scale (SRS) was developed as a quantitative measure of reciprocal social interaction and communication in both clinical and population-based samples (Constantino et al. 2000). It is a 65-item scale, completed by an adult informant, usually a parent or a teacher. Siblings of children with ASC show higher social impairment (Constantino et al. 2006) relative to controls, and in QTL analysis, the SRS is associated with genetic risk variants related to such social traits on chromosome 11 and 17 (Duvall et al. 2007). Cross-cultural validity of the SRS has been demonstrated in a large German sample (Bölte et al. 2008). A weakness of the SRS is that it is not normally distributed.

The Autism Spectrum Quotient (AQ) was designed as a self-administered, forced-choice questionnaire for quantifying the number of autistic traits an individual possesses, across five domains (social skill, attention switching, attention to detail, communication and imagination) in both clinical and non-clinical samples (Baron-Cohen et al. 2001). The AQ shows consistent results across different age groups (Baron-Cohen et al. 2006; Auyeung et al. 2008) across time in independent samples (Wheelwright et al. 2006), and has good cross-cultural stability (Wakabayashi et al. 2006; Hoekstra et al. 2008). These characteristics render the AQ a versatile and reliable tool for measuring

the BAP and it has been used with parents of children with ASC (Bishop et al. 2004; Scheeren and Stauder 2008; Wheelwright et al. 2010).

Bishop et al. (2004) found that the AQ identified significantly higher rates of autistic traits in parents of children with ASC on the social skill and communication subscales. This finding was not confirmed by Scheeren and Stauder (2008), who did not find any difference in AQ scores in 25 parents of children with high-functioning autism compared to 25 parents of typically developing children. A much larger study, with adequate power, was reported by Wheelwright et al. (2010), in which 571 fathers and 1,429 mothers took part. Both mothers and fathers of ASC children scored higher than control parents on total AQ score, and on four out of five of the subscales (social skills, communication, attention switching and imagination). Additionally, the study introduced the concepts of the 'medium autism phenotype' (MAP) and 'narrow autism phenotype' (NAP) to describe phenotypes characterized by a medium or large number of autistic traits, respectively, as detected by AQ scores. More parents of children with ASC scored in the BAP, MAP and NAP ranges.

The aim of the present study was to use the Italian version of the AQ to test if the findings reported by Wheelwright et al. (2010) replicate in a Sicilian sample of parents of children with ASC. We had three main objectives: (a) To examine if the difference on total AQ score and subscales between parents of children with ASC and control parents replicate in a Sicilian sample; (b) To test if sex difference on the AQ found in previous studies replicate in a Sicilian sample; and (c) To investigate the distribution of BAP, MAP and NAP in parents of children with ASC versus control parents.

Methods

Participants and Procedure

Parents of children with ASC (Group 1) and parents of typically developing children (Group 2) were asked to fill in the Italian version of the AQ, referring to them. All parents were biologically related to their child, and of Italian ethnicity. Socioeconomic status defined by parental education did not differ between ASC and control parents ($\chi^2 = 0.93$, $p = 0.82$). A total of n = 545 questionnaires were filled out and returned with complete responses. In Group 1, ASC families included parents (n = 150 fathers and n = 150 mothers) of children diagnosed as having autism (officially Autistic Disorder, or AD) (n = 62), Asperger Syndrome (AS) or High Functioning Autism (HFA) (n = 51) and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) (n = 37) based on the Autism Diagnostic Interview-Revised (ADI-R) (Lord et al. 1994), the Autism Diagnostic Observation Schedule—Generic (ADOS) (Lord et al. 2000) and the DSM-IV diagnostic criteria for AD, AS and PDD-NOS. All the ASC families tested had only one affected child. 18 of these children were females and 132 were males, with a sex ratio (male:female) of 7.3:1. The children's diagnoses and sex ratio in the ASC families are shown in Table 1.

In Group 1, a total of 300 questionnaires were administered in person at the University Hospital Policlinico G. Rodolico in Catania. 28 fathers and 14 mothers did not returned a questionnaire, resulting in a response rate of 81.3 and 90.6%, respectively, while 13 (23.6%) of the returned questionnaires (seven questionnaires from fathers and six questionnaires from mothers) were considered ineligible because of missing data (more than five blank items). If five or fewer items were missing, the total score was corrected using a previously adopted formula: AQ total score + (mean item score x number of missing items) (Auyeung et al. 2008; Hoekstra et al. 2008). 115 fathers and 130 mothers filled out and returned the questionnaires with complete responses.

In Group 2, a total of 430 parents, randomly selected from three large public mainstream schools in the city centre and the province of Catania, were given the AQ, via schoolteachers. In 56 cases questionnaires were sent by email. 150 fathers and 150 mothers returned the complete questionnaires, with a 69.7% of response rate.

All the participants were instructed to answer the questions as quickly as possible, to avoid thinking too long about their choice, and to complete the questionnaire on their own.

Validation of the Italian AQ

The scoring procedure used was exactly the same as for the original AQ version (Baron-Cohen et al. 2001). Each item

Table 1 Child diagnosis and child sex-ratio in the ASC families

	Child diagnosis			Child sex		
	AD	AS/HFA	PDD NOS	Males (M)	Females (F)	M:F Sex-ratio
Number of families	62	51	37	132	18	7.3:1

AD autistic disorder, *AS* asperger syndrome, *HFA* high functioning autism, *PDD NOS* pervasive developmental disorder not otherwise specified

scored 1 point for responses suggesting autistic traits either mildly or strongly, and zero otherwise. To maintain the meaning of words and sentences between English and Italian, a back-translation was conducted as following: first, the AQ was translated into Italian by one of the authors (LR), a native Italian speaker. After that, a native English speaker who was naive to the AQ translated the questionnaire back into English. This translated version of the questionnaire was compared with the original version of the AQ by one of the authors of the published AQ (SW). Points of divergence were corrected to more accurately reflect the intent of the wording in the original language. Hence, the Italian AQ was judged reliably equivalent to the original English version and presented in the same forced-choice format.

Pilot Study

To test if the questionnaire was understandable and easy to fill out, and to assess its principal psychometric properties, a pilot study was conducted with a group of 100 males and 100 females from the general population (mean age = 36.94 years, SD = 6.55, range: 19–57), recruited through advertising in university departments and different companies. All subjects who showed interest in the study were sent the questionnaires by mail and the completed AQ were sent back to the research team.

The mean (and SD) total AQ scores were as follows: 16.2 (SD = 4.94) in males and 15.03 (SD = 5.63) in females, with combined (male and female) mean AQ score of 15.62 (SD = 5.32). Cronbach's α coefficients demonstrated a fair internal consistency (AQ total = 0.76, communication = 0.64, social skills = 0.68, imagination = 0.52, local details = 0.58, attention switching = 0.54). When the internal consistency was analyzed in the control parents, similar results were obtained (Cronbach's α coefficients: AQ total = 0.74, communication = 0.62, social skills = 0.65, imagination = 0.54, local details = 0.61, attention switching = 0.57), confirming an acceptable level of validity of the general construct of the test. A group of 80 control parents were also asked to complete a second questionnaire after a period of 6 months, and good test–retest reliability was obtained (Pearson $r = 0.79$).

BAP, MAP and NAP scores were calculated using the same method as Wheelwright et al. (2010). The combined male and female mean and standard deviation values obtained from the pilot study were used as reference values. BAP was defined as AQ scores between 1 and 2 SDs above the mean (AQ scores of 21–27), MAP was defined as AQ scores between 2 and 3 SDs above the mean (AQ scores of 28–32), and NAP was defined as AQ scores 3 SDs or higher above the mean (AQ scores of 33 +).

Statistical Analysis

Data analysis was performed using the Statistical Package for Social Sciences (SPSS 11.0 for Mac OS-X). Both descriptive and inferential analyses were conducted. Total AQ score and each of the 5 subscales were analyzed using two-way ANOVAs, with sex and group as factors, and post hoc Bonferroni tests. Test results exceeding a threshold of $p < 0.05$ were regarded as statistically significant.

Results

The mean age of ASC fathers was 40 years (SD = 4.4; range 33–55), and of ASC mothers was 39.7 years (SD = 5.2; range 30–49). The mean age of control fathers was 39.3 years (SD = 4.6; range 32–51) and of control mothers was 38.9 years (SD = 4.02; range 28–47). No group differences were found in age ($F(3, 541) = 1.23$; $p = 0.3$).

Table 2 shows the mean (and SD) total AQ scores for controls and ASC parents. The distribution of total AQ scores in ASC fathers versus control fathers, and ASC mothers versus control mothers, are presented in Figs. 1 and 2, respectively. Mean subscale scores in each group are shown in Table 3. Higher scores indicate more autistic traits. F values from ANOVAs with between subject

Table 2 Mean and standard deviation (sd) scores on total AQ for controls and the parent groups

	Males			Females		
	n	Mean	sd	n	Mean	sd
Control individuals	100	16.2	5.32	100	15.03	5.63
Control parents	150	16.77	4.61	150	14.51	5.17
ASC parents	115	18.9	9.16	130	16.39	7.3
Wheelwright et al. (2010)						
Control parents	349	17.7	6.9	658	13.1	6.3
ASC parents	571	19.2	9.5	1429	16.4	9.5

Data from Wheelwright et al. (2010) study are also shown for comparisons

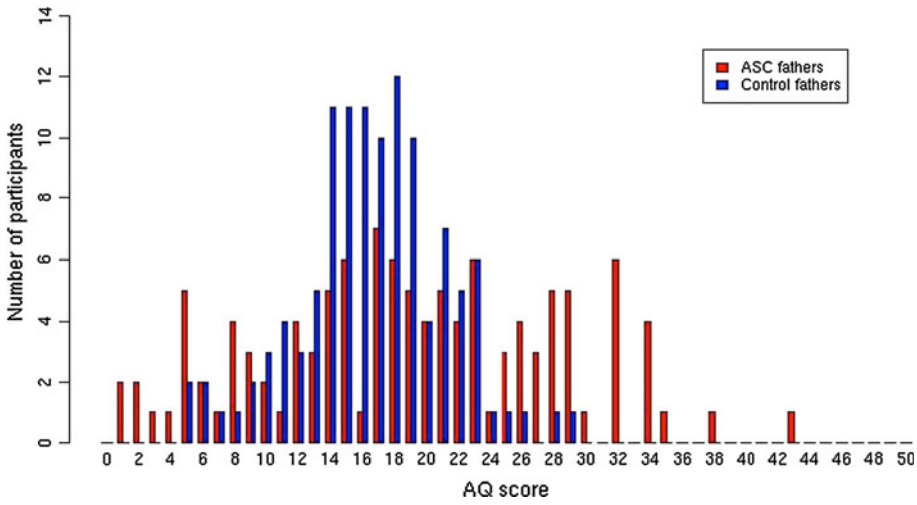

Fig. 1 AQ scores in ASC and control fathers

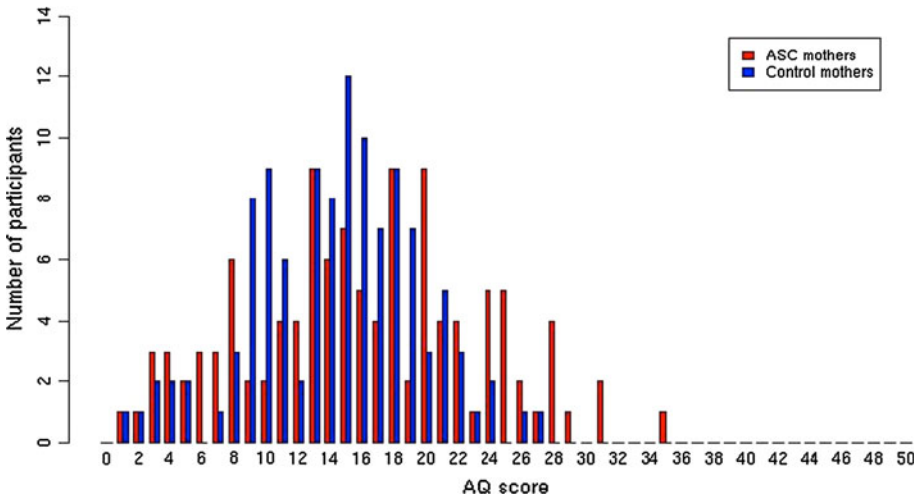

Fig. 2 AQ scores in ASC and control mothers

Table 3 Mean (and standard deviation) scores on the AQ subdomains in the parent groups

	ASC		Control	
	Fathers n = 115	Mothers n = 130	Fathers n = 150	Mothers n = 150
Social skill	2.71 (1.7)	2.2 (1.9)	2.29 (1.6)	1.8 (1.4)
Attention switching	3.97 (1.4)	3.74 (1.5)	3.77 (1.6)	3.69 (1.6)
Local details	5.09 (2)	4.55 (2.3)	4.98 (2.7)	4.49 (2.3)
Communication	3.18 (1.8)	2.12 (1.3)	1.91 (1.5)	1.69 (1.4)
Imagination	3.95 (2)	3.78 (1.8)	3.83 (1.8)	2.84 (1.5)

AQ autism spectrum quotient, *ASC* autism spectrum conditions

factors of Group and Sex and effect sizes are reported in Table 4.

On total AQ and social skill domain, a main effect for group and sex was found, with ASC parents scoring higher than controls ($F(541) = 49.72$; $p < 0.01$ and $F(541) = 8.75$; $p < 0.01$, respectively) and males scoring higher than females ($F(541) = 70.42$; $p < 0.01$ and $F(541) = 12.8$; $p < 0.01$, respectively). Group by Sex interaction did not approach significance ($F(541) = 0.2$; $p = 0.66$ and $F(541) = 0.01$; $p = 0.93$, respectively). On the communication and imagination domains, there was a significant main effect of Group ($F(541) = 42.82$, $p < 0.01$ and $F(541) = 12.2$, $p < 0.01$, respectively) and Sex ($F(541) = 24.29$, $p < 0.01$ and $F(541) = 14.2$, $p < 0.01$, respectively) and a Group by Sex interaction ($F(541) = 10.46$, $p < 0.01$ and $F(541) = 7.28$, $p < 0.01$,

Table 4 Main effects of group, sex and group by sex interaction on Total AQ and each of the AQ subdomains in the parent groups

	Group main effect F (541)	Group effect size Partial η^2	Sex main effect F (541)	Sex effect size Partial η^2	Group by sex interaction F (541)	Group by sex effect size Partial η^2
Total AQ	49.72**	0.02	70.42**	0.03	0.2	0.00
Social skill	8.75**	0.02	12.8**	0.02	0.01	0.00
Attention switching	0.94	0.002	1.4	0.003	0.39	0.001
Local details	0.17	0.00	6.39*	0.01	0.01	0.00
Communication	42.82**	0.07	24.29**	0.04	10.46**	0.02
Imagination	12.2**	0.02	14.2**	0.03	7.28**	0.01

AQ autism spectrum quotient, η^2 eta squared

* $p < 0.05$; ** $p < 0.01$

Table 5 Number of parents with each phenotype

	ASC fathers	ASC mothers	Control fathers	Control mothers	χ^2 (df, 3)	p	Pairwise contrasts
BAP (21–26)	26	25	27	17	4.02	0.26	All N.S.
MAP (27–32)	17	8	3	–	22.02	<0.001	ASC fathers = ASC mothers[a]
							Ctrl fathers = Ctr mothers
							ASC fathers > Ctr fathers**
							ASC mothers > Ctrl mothers**
							ASC mothers = Ctr fathers
NAP (+33)	7	1	–	–	10.13	0.017	ASC fathers = ASC mothers[b]
							ASC fathers > Ctr parents**
							ASC mothers = Ctrl parents

Total χ^2(df, 6) = 102.8, p-value < 0.001

N.S. not statistically significant

* $p < 0.05$; ** $p < 0.01$

[a] Statistical trend (χ^2 (df, 1) = 3.23, $p = 0.072$)

[b] Trend approaching statistical significance (χ^2 (df, 1) = 3.61, $p = 0.057$)

respectively). For the communication subscale, simple effect tests indicated that the Group difference (higher scores in ASC parents) held up in both fathers (t = 6.8, $p < 0.01$) and mothers (t = 2.38, $p = 0.02$) while the Sex differences (higher scores in fathers) held up only within the ASC group (t = 5.5, $p < 0.01$).

On the imagination subscale, contrasts demonstrated a significant Group difference (higher scores in ASC) only for mothers (t = 4.45, $p < 0.01$), and a significant Sex difference (higher scores in fathers) exclusively in the control group (t = 4.83, $p < 0.01$). No significant differences for Group (F(541) = 0.94; $p = 0.33$) and Sex (F(541) = 1.4; $p = 0.24$) were reported on the attention switching subscale. On the local details subcategory, a main effect of Sex was found, with males scoring significantly higher than females (F(541) = 6.39; $p = 0.01$). No Group by Sex interaction was reported (F(541) = 0.01; $p = 0.91$). The effect sizes for group, sex and group by sex interactions were all small except for communication where a medium effect size for group was obtained (see Table 4).

The frequencies of BAP, MAP and NAP, the corresponding chi-square (χ^2) and p-values and the pairwise contrasts are shown in Table 5.

Interestingly, whilst the proportion of fathers and mothers in the ASC and control groups did not significantly differ in the BAP range ($\chi^2 = 4.02$ (df 3), $p = 0.26$), significantly more ASC fathers and ASC mothers fell in the MAP range compared to control fathers and control mothers respectively ($\chi^2 = 11.33$ (df 1), $p < 0.001$ and $\chi^2 = 6.93$ (df 1), $p < 0.01$). In the NAP range, the group difference was determined by the rate of ASC fathers: none of the control parents and only 1 ASC mother (0.77%) scored in that range ($\chi^2 = 6.7$ (df 1), $p < 0.001$ for control fathers and control mothers, and $\chi^2 = 3.6$ (df 1), $p = 0.057$ for ASC mothers, respectively).

Discussion

This study set out to test if the Autism Spectrum Quotient (AQ) results would replicate in a Sicilian sample using an Italian translation. Results from the present study suggest the Italian AQ is a valid psychometric tool to investigate the distribution of autistic traits and the BAP. These results replicate the findings reported by Wheelwright et al. (2010) in a linguistically different culture. In the Sicilian sample, parents of children with ASC scored significantly higher than controls on total AQ, social skill and communication domain, and ASC mothers scored significantly higher than control mothers on the imagination subscale. These results are in line with Bishop et al. (2004) who reported that parents of people with ASC obtained higher scores than controls on two of the five subscales of the AQ (social skills and communication), and with Wheelwright et al. (2010) who found that ASC parents scored significantly higher than controls on total AQ and on four out of five of the sub-categories (social skills, communication, attention switching and imagination). In contrast to Wheelwright et al. (2010) study, in the Sicilian sample we did not find any between group difference for the attention switching and attention to details subcategories. We also found a sex difference (with males scoring higher than females) in the latter, not reported by Wheelwright et al. (2010).

Looking at sex differences on the other AQ domains, we found that AQ total and social skill differentiated between males and females in the predicted directions (fathers scoring higher than mothers) in both groups while the communication domain differentiated between males and females within the ASC group and the imagination subscale differentiated between males and females only in the control group. In line with these results, Dawson et al. (2007), using the Broader Phenotype Autism Symptom Scale, found that ASC fathers scored significantly higher (more impaired) than ASC mothers on the Expressiveness and Conversational skills domains. Impairments in social-communication skills in parents of children with ASC have been reported in other studies as a clear indicator of the BAP (Losh and Piven 2007; Piven et al. 1997a, b). Our results from the social skill and communication domains of the AQ confirm this distinctive feature. The effect sizes were small in almost all the AQ domains, except for communication where a medium effect size for group was obtained. This result may be expected given that the BAP is not likely to be present in all ASC parents.

This study also demonstrated that the rates of BAP, MAP and NAP, as measured by the AQ, were higher in ASC parents than in controls. Also, ASC fathers displayed the highest rate of MAP and NAP. The categories of MAP and NAP are purely dimensional concepts based on the AQ scores, but it is likely that some of the parents displaying the MAP or the NAP would also have received a clinical diagnosis on the autism spectrum if referred. That they had not been referred may indicate that their behavioural traits did not cause impairment, interference or distress in their personal and working life such that they actually needed or sought a diagnosis.

The MAP and NAP dimensions may be useful to identify a different loading of quantitative traits within the more general concept of the broader phenotype in autism families and to relate these quantitative endophenotypes to susceptibility genes. A candidate gene association study of autistic traits using the AQ has been conducted in the general population indicating differences in allele frequency in common single nucleotide polymorphisms (SNPs) related to neural growth, sex steroid hormones, and social reward (Chakrabarti et al. 2009). The same approach might be applied to autism families with high incidence of MAP and NAP to stratify the samples for autism risk loci analyses.

Several limitations of this study should be noted. First, the return rate was higher in the autism parents than in the control parents, leading to the possibility of an ascertainment bias. For example, it could be that controls with a high AQ are less likely to return questionnaires. However, the return rate of nearly 70% in the control parent group is well above the typically expected return rate of 33% reported in other population studies (Baron-Cohen et al. 2009). Also in our study, the Italian AQ demonstrated some weakness in internal consistency (of some AQ subscales). Further studies in larger Italian samples are required to confirm the test structure validity. Finally, the new concepts of MAP and NAP have been introduced exclusively on the basis of the AQ scores. Future work should test the external validity of these concepts.

This study replicates the findings from the English version of the AQ to assess the BAP, in a culturally different, independent sample. In particular, the AQ social skill and communication scales appear to be the most sensitive to the BAP, and this result replicates previous findings. We also confirmed the finding that males report more autistic traits compared to females, in line with previous findings. Finally, this study highlights that heritability of autistic traits is independent of culture, instead showing good cross-cultural stability. Future studies are warranted to further investigate the broader autism phenotype in other close relatives (such as siblings) and to relate AQ scores to molecular genetic differences.

Acknowledgments SBC, SW, and LR were supported by a grant from the MRC UK and the Nancy Lurie Marks Family Foundation during the period of this work. This work was conducted in association with the NIHR CLAHRC for Cambridgeshire and Peterborough NHS Foundation Trust. The authors thank all the parents who participated to the study. We are grateful to Dr. Valeria Mannino and Dr.

Nunzia Russo for helping with parents' recruitment. LR submitted the study in part fulfilment of her degree of PhD at the University of Catania, Italy. Some data from this work was first presented at the International Meeting for Autism Research (IMFAR), Chicago, 2009.

References

Abrahams, B. S., & Geschwind, D. H. (2008). Advances in autism genetics: On the threshold of a new neurobiology. *Nat Rev Genet, 9*, 341–355.

APA. (1994). *DSM-IV diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Auyeung, B., Baron-Cohen, S., Wheelwright, S., & Allison, C. (2008). The autism spectrum quotient: children's version (AQ-child). *Journal of Autism and Developmental Disorders, 38*(7), 1230–1240.

Bailey, A., Le Couteur, A., Gottesman, I., Bolton, P., Simmonoff, E., Yuzda, E., et al. (1995). Autism as a strongly genetic disorder: evidence from a British twin study. *Psychological Medicine, 25*, 63–77.

Baron-Cohen, S., & Hammer, J. (1997). Parents of children with Asperger syndrome: what is the cognitive phenotype? *Journal of Cognitive Neuroscience, 9*, 548–554.

Baron-Cohen, S., Hoekstra, R. A., Knickmeyer, R., & Wheelwright, S. (2006). The autism-spectrum quotient (AQ)—Adolescent version. *Journal of Autism and Developmental Disorders, 36*(3), 343–350.

Baron-Cohen, S., Scott, F. J., Allison, C., Williams, J., Bolton, P., Matthews, F. E., et al. (2009). Prevalence of autism-spectrum conditions: UK school-based population study. *British Journal of Psychiatry, 194*(6), 500–509.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5–17.

Bishop, D. V., Maybery, M., Maley, A., Wong, D., Hill, W., & Hallmayer, J. (2004). Using self-report to identify the broad phenotype in parents of children with autistic spectrum disorders: A study using the autism-spectrum quotient. *Journal of Child Psychology and Psychiatry, 45*(8), 1431–1436.

Bölte, S., & Poustka, F. (2006). The broader cognitive phenotype of autism in parents: How specific is the tendency for local processing and executive dysfunction? *Journal of Child Psychology and Psychiatry, 47*(6), 639–645.

Bölte, S., Poustka, F., & Constantino, J. N. (2008). Assessing autistic traits: Cross-cultural validation of the social responsiveness scale (SRS). *Autism Research, 1*(6), 354–363.

Bolton, P., Macdonald, H., Pickles, A., Rios, P., Goode, S., Crowson, M., et al. (1994). A case-control family study of autism. *Journal of Child Psychology and Psychiatry, 35*, 877–900.

Bolton, P. F., Pickles, A., Murphy, M., & Rutter, M. (1998). Autism, affective and other psychiatric disorders: patterns of familial aggregation. *Psychological Medicine, 28*(2), 385–395.

Chakrabarti, B., Dudbridge, F., Kent, L., Wheelwright, S., Hill-Cawthorne, G., Allison, C., et al. (2009). Genes related to sex steroids, neural growth, and social-emotional behavior are associated with autistic traits, empathy, and Asperger syndrome. *Autism Research, 2*(3), 157–177.

Constantino, J. N., Lajonchere, C., Lutz, M., Gray, T., Abbacchi, A., McKenna, K., et al. (2006). Autistic social impairment in the siblings of children with pervasive developmental disorders. *American Journal of Psychiatry, 163*, 294–296.

Constantino, J., Przybeck, T., Friesen, D., & Todd, R. D. (2000). Reciprocal social behavior in children with and without pervasive developmental disorders. *Journal of Developmental and Behavioral Pediatrics, 21*, 2–11.

Constantino, J. N., & Todd, R. D. (2003). Autistic traits in the general population: A twin study. *Archives of General Psychiatry, 60*, 524–530.

Constantino, J., & Todd, R. (2005). Intergenerational transmission of subthreshold autistic traits in the general population. *Biological Psychiatry, 57*, 655–660.

Dawson, G., Estes, A., Munson, J., Schellenberg, G., Bernier, R., & Abbott, R. (2007). Quantitative assessment of autism symptom-related traits in probands and parents: Broader phenotype autism symptom scale. *Journal of Autism and Developmental Disorders, 37*(3), 523–536.

Duvall, J. A., Lu, A., Cantor, R. M., Todd, R. D., Constantino, J. N., & Geschwind, D. H. (2007). A quantitative trait locus analysis of social responsiveness in multiplex autism families. *American Journal of Psychiatry, 164*(4), 656–662.

Folstein, S. E., Santangelo, S. L., Gilman, S. E., Piven, J., Landa, R., Lainhart, J., et al. (1999). Predictors of cognitive test patterns in autism families. *Journal of Child Psychology and Psychiatry, 40*(7), 1117–1128.

Happé, F., Briskman, J., & Frith, U. (2001). Exploring the cognitive phenotype of autism: weak central coherence in parents and siblings of children with autism: I. Experimental tests. *Journal of Child Psychology and Psychiatry, 42*, 299–307.

Hoekstra, R. A., Bartels, M., Cath, D. C., & Boomsma, D. I. (2008). Factor structure, reliability and criterion validity of the autism-spectrum quotient (AQ): A study in Dutch population and patient groups. *Journal of Autism and Developmental Disorders, 38*, 1555–1566.

Hoekstra, R. A., Bartels, M., Verweij, C. J., & Boomsma, D. I. (2007). Heritability of autistic traits in the general population. *Archives of Pediatrics and Adolescent Medicine, 161*(4), 372–377.

Hurley, R. S., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The broad autism phenotype questionnaire. *Journal of Autism and Developmental Disorders, 37*, 1679–1690.

Ingersoll, B., Meyer, K., & Becker, M. W. (2010). Increased rates of depressed mood in mothers of children with ASD associated with the presence of the broader autism phenotype. *Autism Research, 3*, 1–6.

Landa, R., Piven, J., Wzorek, M. M., Gayle, J. O., Chase, G. A., & Folstein, S. E. (1992). Social language use in parents of autistic individuals. *Psychological Medicine, 22*(1), 245–254.

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr., Leventhal, B. L., DiLavore, P. C., et al. (2000). The autism diagnostic observation schedule generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*, 205–223.

Lord, C., Rutter, M., & LeCouteur, A. (1994). Autism diagnostic interview-revised: A revised versions of a diagnostic interview for caregivers of individuals with possibile pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659–685.

Losh, M., Childress, D., Lam, K., & Piven, J. (2008). Defining key features of the broad autism phenotype: a comparison across parents of multiple- and single-incidence autism families. *American Journal of Medical Genetics Part: B Neuropsychiatric Genetics, 147B*(4), 424–433.

Losh, M., & Piven, J. (2007). Social-cognition and the broad autism phenotype: Identifying genetically meaningful phenotypes. *Journal of Child Psychology and Psychiatry, 48*(1), 105–112.

Piven, J., Landa, R., Gayle, J., Cloud, D., Chase, G., & Folstein, S. (1991). Psychiatric disorders in the parents of autistic

individuals. *Journal of the American Academy of Child and Adolescent Psychiatry, 30*, 471–478.

Piven, J., Palmer, P., Jacobi, D., Childress, D., & Arndt, S. (1997a). Broader autism phenotype: Evidence from a family history study of multiple-incidence autism families. *American Journal of Psychiatry, 154*(2), 185–190.

Piven, J., Palmer, P., Landa, R., Santangelo, S., Jacobi, D., & Childress, D. (1997b). Personality and language characteristics in parents from multiple-incidence autism families. *American Journal of Medical Genetics, 74*, 398–411.

Piven, J., Wzorek, M., Landa, R., Lainhart, J., Bolton, P., Chase, G. A., et al. (1994). Personality characteristics of parents of autistic individuals. *Psychological Medicine, 24*, 783–795.

Ring, H., Woodbury-Smith, M., Watson, P., Wheelwright, S., & Baron-Cohen, S. (2008). Clinical heterogeneity among people with high functioning autism spectrum conditions: Evidence favouring a continuous severity gradient. *Behavioral and Brain Functions, 20*, 4–11.

Scheeren, A. M., & Stauder, J. E. (2008). Broader autism phenotype in parents of autistic children: Reality or myth? *Journal of Autism and Developmental Disorders, 38*(2), 276–287.

Skuse, D. H., Mandy, W. P., & Scourfield, J. (2005). Measuring autistic traits: Heritability, reliability and validity of the social and communication disorders checklist. *British Journal of Psychiatry, 187*, 568–572.

Smalley, S., McCracken, J., & Tanguay, P. (1995). Autism, affective disorders, and social phobia. *American Journal of Medical Genetics, 60*, 19–26.

Szatmari, P., Jones, M., Zwaigenbaum, L., & Maclean, J. (1998). Genetics of autism: Overview and new directions. *Journal of Autism and Developmental Disorders, 28*, 351–368.

Virkud, Y. V., Todd, R. D., Abbacchi, A. M., Zhang, Y., & Constantino, J. N. (2009). Familial aggregation of quantitative autistic traits in multiplex versus simplex autism. *American Journal of Medical Genetics Part: B Neuropsychiatric Genetics, 150B*(3), 328–334.

Wakabayashi, A., Baron-Cohen, S., Wheelwright, S., & Tojo, Y. (2006). The autism-spectrum quotient (AQ) in Japan: A cross-cultural comparison. *Journal of Autism and Developmental Disorders, 36*(2), 263–270.

Wheelwright, S., Auyeung, A., Allison, C., & Baron-Cohen, S. (2010). Defining the broader, medium and narrow autism phenotype among parents using the autism spectrum quotient (AQ). *Molecular Autism, 1*, 1–10.

Wheelwright, S., Baron-Cohen, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., et al. (2006). Predicting autism spectrum quotient (AQ) from the systemizing quotient-revised (SQ-R) and empathy quotient (EQ). *Brain Research, 1079*, 47–56.