

Broader Autism Phenotype and Nonverbal Sensitivity: Evidence for an Association in the General Population

Brooke Ingersoll

Published online: 20 November 2009
© Springer Science+Business Media, LLC 2009

Abstract This study examined the relationship between characteristics of the Broader Autism Phenotype (BAP) and nonverbal sensitivity, the ability to interpret nonverbal aspects of communication, in a non-clinical sample of college students. One hundred and two participants completed a self-report measure of the BAP, the Autism Spectrum Quotient (AQ), and two tests of nonverbal sensitivity, the Test of Nonverbal Cue Knowledge (TONCK), and the Diagnostic Analysis of Nonverbal Accuracy 2 (DANVA2). AQ score was correlated with TONCK performance and number of errors on the adult faces subtest of the DANVA2, but not adult paralanguage or postures. These findings suggest that characteristics of ASD in the general population are associated with differences in both explicit and implicit knowledge of nonverbal cues.

Keywords Broader autism phenotype · Nonverbal sensitivity

Introduction

Individuals with autism spectrum disorders (ASD), including Autistic Disorder, Asperger's Disorder, and Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), exhibit pervasive deficits in three domains: Social interaction, communication, and restricted and repetitive behaviors (APA 2000). There is growing evidence that autistic deficits exist on a spectrum, from clinical to sub-clinical manifestations (Skuse et al. 2005). The Broader

Autism Phenotype (BAP) has been used to describe personality characteristics and subclinical symptoms often found in first and second degree relatives of individuals with ASD which represent a genetic liability for the disorder (Piven et al. 1997). The original work on the BAP found that up to 20% of siblings of probands with autism exhibited a deficit in one or more core areas associated with ASD, social interaction, communication, and restricted and repetitive behaviors (Bolton et al. 1994), as determined by extensive family history interviews and cognitive and language testing. Subsequent studies of family members has suggested that the BAP is associated with specific personality features, such as rigidity, aloofness, and anxiety (Murphy et al. 2000; Piven et al. 1997), interpersonal difficulties, such as deficits in the number and quality of friendships (Piven et al. 1997; Santangelo and Folstein 1995), pragmatic language deficits (Landa et al. 1992; Piven et al. 1997), and cognitive deficits, such as impaired executive functioning (Hughes et al. 1997; Ozonoff et al. 1993) and weak central coherence (Happé et al. 2001). Research suggests the BAP is more likely to be found in male relatives and family members of verbal as opposed to nonverbal individuals with ASD (Bolton et al. 1994).

More recently, it has been proposed that the BAP is not restricted to family members of individuals with autism, and that autistic behavioral traits are normally distributed in the general population (e.g., Austin 2005; Hoekstra et al. 2007; Hurst et al. 2007). The Autism Spectrum Quotient (AQ; Baron-Cohen et al. 2001) is a self-report scale designed to measure autistic traits in adults with normal intelligence. Several studies have indicated that it is effective at distinguishing individuals with Asperger's Syndrome and high-functioning autism from typically-developing individuals (Baron-Cohen et al. 2001; Hoekstra et al. 2008; Wakabayashi et al. 2006; Woodbury-Smith et al. 2005) and

B. Ingersoll (✉)
Department of Psychology, Michigan State University,
105B Psychology Building, East Lansing, MI 48824, USA
e-mail: ingers19@msu.edu

identifying the broader autism phenotype in parents of individuals with ASD (Bishop et al. 2004). Recently, it has been shown to be effective for identifying subclinical characteristics of autism in the general population (Austin 2005; Baron-Cohen et al. 2001; Hurst et al. 2007; Jobe and White 2007; Kunihiro et al. 2006; Wakabayashi et al. 2006). In the general population, individuals scoring higher on the AQ are more likely to be male, “hard science students,” and have a parent in a scientific occupation (Austin 2005; Baron-Cohen et al. 2001; Hoekstra et al. 2008).

If autistic behavioral traits are indeed distributed normally in the population, then individuals in the general population who score high on measures of the BAP, such as the AQ, should also express deficits, albeit less pronounced, in the same core areas as individuals with autism. Consistent with this idea, several studies have found that individuals in the general population who score higher on the AQ are more likely to show personality traits that are associated with the broader autism phenotype, such as high neuroticism and low extroversion (Austin 2005; Wakabayashi et al. 2006), as well as increased depression and anxiety (Kunihiro et al. 2006). There is also evidence that the ASD characteristics in the general population are associated with interpersonal deficits. Jobe and Williams White (2007) found that a non-clinical sample of college students who scored higher on the AQ were more likely to report feeling lonely and have fewer and shorter duration friendships.

Two recent studies have examined the relationship between measures of the BAP and cognitive characteristics associated with autism (e.g., Rajendran and Mitchell 2007). In the first study, Kunihiro et al. (2006) examined whether there was an association between AQ scores of university students and autism-related cognitive characteristics. Although they found that AQ scores were associated with personality profiles thought to characterize the BAP, they were not associated with cognitive deficits in theory of mind, executive functioning, or central coherence. In the second study, Best et al. (2008), examined the association between scores on the Social Communication Questionnaire (Berument et al. 1999), a parent report measure of autistic symptomatology, and the same set of cognitive deficits in a sample of 13- to 22-year-old adolescents and young adults with learning difficulties. Best et al. found that performance on tests of theory of mind, executive functioning, and central coherence all added to the prediction of SCQ score. One possible reason for the disparate findings is that the Kunihiro et al. sample included only typically-developing individuals, while all of the participants in Best et al.’s sample had learning difficulties, with slightly over half scoring above the cut-off on the SCQ for probable Pervasive Developmental Disorder. Thus, although Best et al.’s findings suggest that cognitive characteristics of ASD extend beyond the boundaries of an autism diagnosis, Kunihiro et al.’s findings call

into question whether this cognitive phenotype extends well into the general population.

It is possible that the association between the BAP and cognitive deficits associated with autism is present only in those individuals expressing a significant number of autistic traits (Best et al. 2008). If so, this would question the validity of the BAP in the general population. Thus, it is important to establish that individuals who exhibit a higher number of ASD traits also exhibit deficits, albeit subtle, in other areas of functioning associated with autism. One such area is nonverbal sensitivity. Nonverbal sensitivity is the ability to interpret and use the nonverbal aspects of communication such as eye gaze, facial expressions, gestures, body language/postures, and prosody. This ability is important for initiating and maintaining social interactions, developing relationships, and managing impressions (Hall and Bernieri 2001; Riggio 2006). There is substantial evidence that individuals with autism exhibit specific deficits in these nonverbal aspects of communication (for review, see Carter et al. 2005). In fact, a marked deficit in nonverbal behavior used to regulate social interaction is one of the diagnostic criteria for autism (American Psychiatric Association 2000). Further, research has found that there are significant individual differences in nonverbal sensitivity in the general population that do not appear to be related to overall cognitive ability (Nowicki and Duke 1994, 2001; Rosip and Hall 2004).

Thus, a next step in validating the BAP in the general population would be to establish that scores on a measure of the BAP, such as the AQ, are associated with performance on measures of nonverbal sensitivity. We use the Test of Nonverbal Cue Knowledge (TONCK; Rosip and Hall 2004), an omnibus test of knowledge of nonverbal cues during interpersonal interactions, and three subtests of the Diagnostic Analysis of Nonverbal Accuracy 2 (DANVA2; Nowicki and Duke 1994, 2001), a performance-based measure of the ability to correctly identify emotions associated with facial expressions, prosody/paralanguage, and body postures. These assessments were chosen because they have been shown to tap related, but non-overlapping skills related to nonverbal sensitivity (Hall and Bernieri 2001). We hypothesize that participants who score higher on the AQ will perform more poorly on measures of nonverbal sensitivity.

Method

Participants

One hundred and six undergraduate students at a large, Midwestern university were recruited through a departmental subject pool and participated for course credit. Four

participants were excluded due to excessively high error rates (see “Results”), yielding a final sample of 102 participants. The final sample was 59% female ($n = 61$) and ranged in age from 18 to 25 years ($M = 19.47$, $SD = 1.39$). Participants’ reported ethnicity was 78% White, 8% Black, 8% Asian/Pacific Islander, 3% Hispanic, 1% Native American, and 2% Bi/Multiracial.

After obtaining informed consent, participants were administered the AQ (Baron-Cohen et al. 2001), TONCK (Rosip and Hall 2004), and three subtests of the DANVA2 (Nowicki and Duke 1994, 2001) on a computer. Demographic information on the participants was also collected. The order of administration of the assessments was counter-balanced across participants.

Measures

Autism Spectrum Quotient (AQ; Baron-Cohen et al. 2001)

The AQ is a 50-item self-report scale that measures characteristics of autism in the general population. Each item is rated on a 4-point scale, “definitely agree”, “slightly agree”, “slightly disagree”, and “definitely disagree.” Items are scored dichotomously as “0” or “1”, with “1” representing answers in the direction of autism (Baron-Cohen et al.). Higher scores indicate a greater expression of the broader autism phenotype. The AQ has been found to have high internal consistency (.82) and test–retest reliability (.70) in college populations. The AQ contains five subscales which represent domains of autistic behavior. Two subsequent studies have demonstrated that the factor structure of the AQ is better represented by three factors comprised of 26-items of the original 50-item AQ: (Poor) social skills ($\alpha = .85$), attention to details/patterns ($\alpha = .70$), and (poor) communication/mindreading ($\alpha = .66$; Austin 2005; Hurst et al. 2007). Thus, the subscales proposed by Austin (2005), in addition to the overall AQ, were used in the current analyses. See Table 1 for sample items from the AQ.

Test of Nonverbal Cue Knowledge: (TONCK; Rosip and Hall 2004)

The TONCK is an 81-item true/false test that measures the participant’s explicit knowledge of a diverse set of

nonverbal cues used to regulate social interactions, with higher scores indicating a greater number of correct responses. This assessment has been found to have high internal consistency (.82) and test–retest reliability (.88) in college populations. It has also been shown to be correlated with performance-based measures of nonverbal sensitivity, including the adult faces and adult paralinguistic subtests of the DANVA2 (Nowicki and Duke 1994) and the Profile of Nonverbal Sensitivity (Rosenthal et al. 1979). See Table 1 for sample items from the TONCK.

Diagnostic Analysis of Nonverbal Accuracy 2 (DANVA2; Nowicki and Duke 1994, 2001)

The three subtests of the DANVA2 that use adult stimuli [adult faces (AF), adult paralinguistic (AP), and postures (POS)] were administered to assess the participants’ ability to decode non-verbal cues. The child faces and child paralinguistic subtests were not used given their conceptual overlap with the adult stimuli. In the DANVA2-AF task, the participant viewed 24 pictures of male and female actors posing a facial expression of emotion for 2 s and rated the emotion expressed. In the DANVA2-AP task, the participant listened to 24 trials of a male and female voice actor reading a standard sentence (“I’m going out of the room now and I’ll be back later”) depicting four different emotions and rated the emotion expressed in the voice. On the DANVA2-POS task, the participant viewed 24 pictures of male and female adults standing or sitting and rated the emotion expressed in the posture. Each scale includes an equal number of each emotion (Happy, Sad, Angry, or Fearful) as well as high and low intensity items. Responses are scored for accuracy against correct answers. Higher scores indicate a greater number of errors. The DANVA2-AF subtest has a reported internal consistency of .77 and test–retest reliability of .84 in college students (Nowicki and Carton 1993). The DANVA2-AP subtest has a reported internal consistency of .78 and test–retest reliability of .83 in college students (Nowicki 1995). The DANVA2-POS subtest has a reported internal consistency of .68 and a test–retest reliability of .85 in college students (Pitterman and Nowicki 2004).

Table 1 Sample items from the autism spectrum quotient and test of nonverbal cue knowledge

Autism spectrum quotient ^a	Test of nonverbal cue knowledge
Other people frequently tell me that what I’ve said is impolite, even though I think it is polite. (Definitely Agree or Slightly Agree)	You maintain greater interaction distances with unknown adults than with familiar adults. (True)
I find myself drawn more strongly to people than to things. (Slightly Disagree or Definitely Disagree)	Hand gestures are not used to regulate the flow of an interaction. (False)

^a Responses in the direction of autism are depicted above

Results

The data were inspected for outliers. If a participant's error rate on any of the tests of nonverbal sensitivity was greater than three standard deviations above the mean, his or her data was excluded from further analysis. This procedure was conducted to control for random responding by participants. This criterion resulted in an exclusion of 4 of 106 participants' data.

Total AQ scores ranged from 7 to 30, with a mean of 16.81 and a standard deviation of 5.10. The average AQ score was consistent with Baron-Cohen et al. (2001) report in the general college population ($M = 17.6$, $SD = 6.4$). Unlike most previous research on the AQ (e.g., Austin 2005; Baron-Cohen et al.), males in our sample ($M = 17.68$, $SD = 6.09$) did not score significantly higher than females ($M = 16.23$, $SD = 4.26$) on the overall AQ, $t(100) = 1.42$, *n.s.*, although the scores were in the expected direction. However, a significantly greater proportion of males (37%) scored above the intermediate point on the scale (20+) than females (16%), $X^2(1, N = 102) = 4.30$, $p < .05$, which is highly consistent with Baron-Cohen et al.'s original finding on the AQ. Thus, our failure to find a significant difference in mean AQ scores is likely due to the fact that our sample was smaller than previous studies. Consistent with previous research using Austin's (2005) subscales, males ($M = 2.68$, $SD = 2.70$) scored higher than females ($M = 1.51$, $SD = 1.72$) on the (poor) social skills subscale of the AQ, $t(100) = 2.67$, $p < .01$, but showed no difference on the other two subscales. None of the participants scored above the cut-off for probable autism spectrum disorder (32). See Fig. 1 for the distribution of AQ scores.¹

The average TONCK score was 59.64 ($SD = 6.57$), which was highly consistent with Rosip and Hall's (2004) report in a similar sample ($M = 59.70$, $SD = 10.20$). The average total scores for the DANVA2 subtests were 4.52 ($SD = 2.29$) for adult faces, 5.99 ($SD = 2.27$) for adult paralanguage, and 6.01 ($SD = 2.19$) for postures. Within subject comparisons using paired t-tests with a bonferroni correction (.05/3) suggested that faces were easier to identify than paralanguage, $t(101) = -5.60$, $p < .001$, and postures, $t(101) = -5.43$, $p < .001$, but paralanguage and postures did not differ, $t(101) = -.07$, *n.s.* These scores were consistent with the norms for college-aged individuals (AF: $M = 4.2$, $SD = 2.4$; AP: $M = 5.5$, $SD = 2.2$;

¹ Unlike previous reports suggesting a normal distribution of AQ scores in the general population (Hoekstra et al. 2008; Hurst et al. 2007), scores on the AQ in our sample were slightly positively skewed. This may be due to sampling error given our smaller sample size (102 participants compared to >900 participants in previous reports).

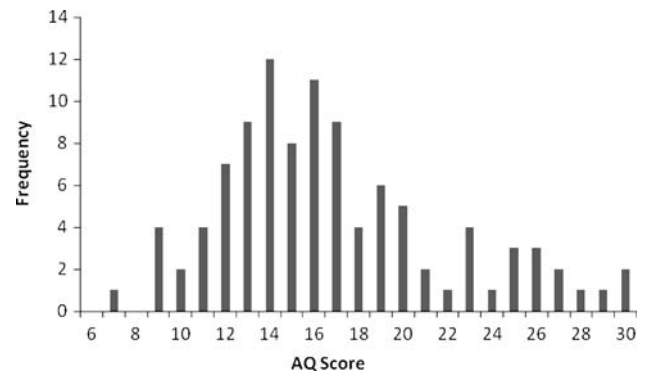


Fig. 1 Distribution of AQ scores

POS: $M = 7.9$, $SD = 2.4$) reported in the DANVA2 manual (Nowicki 2006).

Correlations Between Measures of Nonverbal Sensitivity

There was a significant negative correlation between TONCK performance and error rate on the adult faces ($r = -.34$, $p < .001$) and adult paralanguage ($r = -.21$, $p < .05$) subtests of the DANVA2. The TONCK was not correlated with the postures subtests ($r = -.01$, *n.s.*). These findings are consistent with Rosip and Hall's (2004) findings suggesting only a modest correlation between the TONCK and tests of nonverbal cue decoding, such as the DANVA2 (see Table 2).

There was a small correlation between the participants' performance on the individual subtests of the DANVA2. Error rate on the DANVA2-AF was positively correlated with error rate on the DANVA2-AP ($r = .32$, $p < .001$) and the DANVA2-POS ($r = .23$, $p < .05$) subtests. However, the DANVA2-AP and DANVA2-POS subtests were not correlated ($r = .06$, *n.s.*).

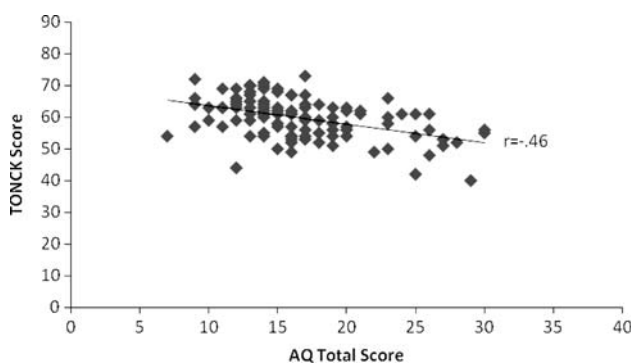
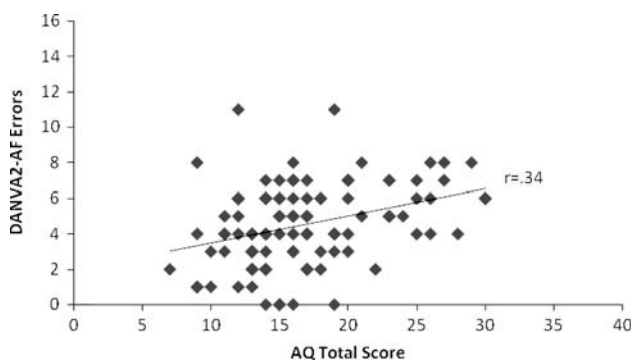
Correlations Between BAP Characteristics and Nonverbal Sensitivity

The goal of this study was to examine the relationship between the characteristics associated with the BAP and sensitivity to nonverbal cues. Overall AQ score was significantly and negatively associated with performance on the TONCK ($r = -.46$, $p < .001$), see Fig. 2. Thus, as predicted, individuals who exhibited a higher number of autistic characteristics showed less explicit knowledge of others' nonverbal cues. The individual subscales of the AQ were examined in relationship to the TONCK. Social skills ($r = -.36$, $p < .001$) and communication/mindreading ($r = -.28$, $p < .01$) were both related to TONCK performance; however, details/patterns was not ($r = -.10$, *n.s.*).

Table 2 Correlations between measures of BAP and nonverbal sensitivity

	TONCK	DANVA2 adult faces	DANVA2 adult paralanguage	DANVA2 postures
AQ total	-.46**	.34**	.02	.09
Social skills	-.36**	.32**	.02	.03
Communication/mindreading	-.28*	.16	-.08	.04
Details/switching attention	-.10	.22*	.05	.10
TONCK	–	-.34**	-.21*	-.01
DANVA2 adult faces		–	.32**	.23*
DANVA2 adult paralanguage			–	.06
DANVA2 postures				–

** $p < .001$, * $p < .05$

**Fig. 2** Correlation between AQ total and TONCK scores**Fig. 3** Correlation between AQ total scores and DANVA2 adult faces errors

Overall AQ score was also significantly and positively correlated with number of errors on the adult faces subtest of the DANVA2 ($r = .34$, $p < .001$), indicating that individuals with a greater number of autistic traits make more errors when identifying facial expressions of emotion, see Fig. 3. When the individual subscales of the AQ were examined separately, social skills ($r = .32$, $p < .001$) and details/patterns ($r = .22$, $p < .05$) were both related to number of errors on the DANVA2-AF. Neither overall AQ score nor any of the AQ subscales were associated with

performance on the adult paralanguage or postures subtests of the DANVA2 (all r 's $< .09$, $n.s.$).

To examine which of the AQ subscales was most predictive of performance on the TONCK and DANVA2-AF, the three AQ subscales were used to predict TONCK and DANVA2-AF in two separate step-wise multiple regression analyses. A regression analysis of the TONCK with the AQ subscales ($F(1,100) = 15.16$, $p < .001$) indicated that the social skills subscale of the AQ predicted TONCK performance ($\beta = -.36$, $p < .001$). The other two subscales did not add to the prediction above and beyond social skills. On the DANVA2-AF ($F(2,99) = 8.24$, $p < .001$), both social skills ($\beta = .32$, $p = .001$) and details/patterns ($\beta = .21$, $p < .05$) explained a unique portion of the variance.

Given the positive association between overall AQ score and error rate on the DANVA2-AF, a follow-up analysis was conducted to determine whether AQ score was related to the number of errors made in response to specific facial expressions of emotion (happiness, sadness, anger, and fear). This analysis indicated that AQ score was positively correlated with numbers of errors in identifying sad ($r = .26$, $p < .01$) and angry ($r = .30$, $p < .01$) faces, but not happy ($r = .09$, $n.s.$) or fearful ($r = .08$, $n.s.$) faces. This finding indicates that individuals who exhibit a greater number of autistic characteristics are more likely to make errors when identifying negative facial expressions of emotion.

Discussion

The results of this study support the idea that characteristics of the BAP in the general population are associated with differences in interpreting nonverbal aspects of social communication. General knowledge of nonverbal cues was associated with a lower number of autistic characteristics,

with those individuals scoring lower on the AQ performing better on the TONCK. In addition, difficulty with identification of facial expressions of emotion on the DANVA2-AF was also related to number of autistic characteristics. These findings are consistent with research with individuals with ASD and indicate that subclinical symptoms of autism are associated with deficits in nonverbal sensitivity as well.

When the individual subscales of the AQ were examined separately, it was found that social skills were predictive of performance on both the TONCK and DANVA2-AF subtest. This finding is consistent with research indicating the importance of nonverbal cues in regulating social interaction (Argyle 1988). It is also consistent with research on the DANVA2 indicating higher error rates in individuals with a range of social deficits (Maxim and Nowicki 2003; McClure and Nowicki 2004; Shean et al. 2007). Interestingly, the details/patterns subscale also predicted a unique amount of variance in performance on the DANVA2-AF. This finding suggests that performance on the DANVA2-AF is related to subclinical manifestation of behaviors that comprise both the social interaction and restricted and repetitive behavior domains of ASD. As the items on the details/patterns subscale would not be expected to be related to weak social skills (e.g., “I am fascinated by numbers”; “I notice patterns in things all the time”), we believe that this finding provides convincing evidence that characteristics of the BAP in the general population co-occur with deficits in nonverbal sensitivity.

The finding that high AQ scores were related to difficulty with recognizing facial expressions of emotion is consistent with previous findings in parents of children with severe autism (Palermo et al. 2006). Further, Palermo et al. found that parents of individuals with autism were impaired in their recognition of facial expressions of emotion when compared to controls, but only for negative facial displays (disgust and sadness). This finding is consistent with our findings that AQ score was associated with number of errors identifying sad and angry faces, but not happy or fearful faces and suggests that individuals in the general population who score high on the AQ show a similar pattern of response as first degree relatives of individuals with ASD, providing additional support for the validity of the BAP in the general population.

Previous research has found that high-functioning individuals with autism have specific deficits in recognizing negative facial expressions (Ashwin et al. 2006), which has been taken as evidence for the amygdale theory of autism (e.g., Ashwin et al.). This may suggest that the amygdale plays a role in the expression of broader autism phenotype. However, individuals with autism, as well as individuals with amygdale damage, also have difficulty with the recognition of fear (Adolphs et al. 1999; Ashwin et al.), whereas we did not find an association between AQ score

and deficits in fear recognition. It is possible that we did not find this association because our face stimuli were different from those used in previous studies. Thus, additional research is necessary to determine if the pattern we observed holds true with different stimuli. If so, it would be important to examine specific brain mechanisms that could explain this pattern of deficits in the recognition of emotional expressions in faces.

Interestingly, AQ scores were correlated with difficulty identifying emotions expressed in faces but not paralanguage or postures. Previous reports have suggested that the ability to decode nonverbal communication skills across different subdomains (e.g., faces, voices, postures) may be somewhat independent (Hall 2001; Nowicki and Duke 2001). Previous research has found that adult males with high-functioning autism have more difficulty recognizing emotions from faces than voices (Golan et al. 2006). Thus, it may be that a specific marker for autism and the broader spectrum is difficulty with recognizing emotions in faces. However, in our sample, faces were significantly easier to identify (fewer errors) than paralanguage or postures. Thus, it is also possible that subtle differences in emotion processing across multiple channels are only evident when the task is easy for most participants. Additional research that examines different mechanisms underlying the ability to recognize emotions expressed through different channels of communication in individuals who exhibit a greater number of ASD characteristics may further clarify this finding.

Previous research and the current findings suggest only a modest correlation between the TONCK and DANVA2 (Rosip and Hall 2004). This finding is likely due to the fact that TONCK's content is broad and diverse and requires explicit knowledge, whereas the DANVA2's content is more specific and may involve a relatively automatic or implicit process (Rosip and Hall). Thus, our findings suggest that autistic characteristics in the general population are associated with deficits in both explicit knowledge of nonverbal cues, as well as implicit perception of simple emotions in faces. It is unclear how these deficits relate to each other or contribute to each other over time. One possibility is that an initial lack of skill in identifying facial expressions of emotion leads to lower quality social interactions. Lower quality social opportunities may disrupt the development of more explicit knowledge of interpersonal behavior.

These findings are consistent with Jobe and White's (2007) finding of poorer interpersonal functioning in individuals scoring higher on the AQ (but not in the clinical range), as measured by greater reported feelings of loneliness and shorter duration of friendship. In fact, this study may suggest a mechanism by which individuals who exhibit a greater number of autistic characteristics may experience poorer interpersonal functioning. It is possible

that individuals who have difficulty interpreting the nonverbal behavior of others are more likely to have difficulty making and maintaining friendships, which may lead to a greater experience of loneliness (Pitterman and Nowicki 2004). Research that can demonstrate that knowledge of nonverbal cues mediates the relationship between autistic characteristics, friendship, and loneliness would further support this position.

The original work on the existence of the BAP in family members has relied on extensive interviews, involving direct clinical assessments, informant reports, and consensus ratings by trained raters. Using this approach, the BAP has been defined categorically as the presence of one or more deficits in each of the core areas associated with ASD (communication, social interaction, restricted and repetitive interests). In contrast, the AQ is a dimensional measure that does not have a recommended cut-off score for the BAP. Higher scores on the AQ in non-clinical samples have been interpreted as representing the broader autism phenotype (e.g., Austin 2005; Hurst et al. 2007; Jobe and Williams White 2007). Thus, although several studies have suggested that the AQ is valid for identifying the BAP in parents (Bishop et al. 2004) and the general population (Austin 2005; Hurst et al. 2007), it is not clear how well it performs in measuring the BAP as originally described in literature. Thus, future research in this area should consider more valid measures of the BAP. To this end, a new self-report measure, the *Broader Autism Phenotype Questionnaire* shows promise as an abbreviated assessment that can identify the BAP as originally conceptualized (Hurley et al. 2007).

The two measures of nonverbal behavior that were used in this study involved general knowledge and judgments of static images. Although previous research has suggested these measures provide a valid index of understanding of nonverbal cues, they do not provide a measurement of how individuals interpret nonverbal cues during real world interactions. Further, they do not provide a measure of how individuals use nonverbal behavior to regulate their interactions with others. Thus, future research examining the relationship between characteristics associated with ASD in the general population and the understanding and use of nonverbal behavior in real world contexts would be important in this regard.

An additional limitation to this study is that we did not evaluate family history of autism in the participants. Thus, it is possible that some of our participants who scored high on the AQ had a family member with autism. If this were the case, it would question the extent to which autistic characteristics are distributed in the general population. Unfortunately, we did not collect these data. However, we do not regard this possibility as a likely alternative explanation for our findings. First, it is unlikely that more than a

few of our participants would have had a first or second degree relative with an ASD. Indeed, in a previous study involving college students, Baron-Cohen et al. (1998) found that only 7 of 1,293 participants in their sample (.5%) reported a first, second, or third-degree family member with autism. Even with current prevalence estimates for ASD as high as 1:150, the number of potential family member in our sample would be very small. Further, this explanation predicts that the effects we report would be driven by a small number of family members with extremely high scores on the AQ who form a cluster of outliers. An examination of the distribution of scores on the measures of interest fails to find such a cluster of outliers.² However, additional research which considers family history of autism is clearly needed. One final limitation is that we did not screen our participants for the presence of other psychiatric conditions; thus it is possible that some of the participants in our non-clinical sample may have been exhibiting some psychiatric problems.

In sum, this study adds to the literature by further validating the BAP in the general population by showing an association between subclinical symptoms of ASD and deficits in nonverbal sensitivity. These findings, in combination with previous work, suggest that the AQ is an appropriate measure for identifying milder expressions of the genetic liability for autism in the general population and may be useful in behavioral and molecular genetics studies aimed at identifying the genetic basis of autistic symptoms (Hoekstra et al. 2007; Hurley et al. 2007). Future research which can examine other aspects of nonverbal social-communication behaviors, as well as potential consequences of subtle nonverbal deficits (e.g., difficulty making friends) in relation to autistic characteristics would be informative.

Acknowledgments This study was supported by a grant from Autism Speaks to the author. I would like to thank Carley Jewell and Steve Welsh for their assistance in data collection and Chris Hopwood and Mark Becker for their helpful comments on an earlier draft.

References

- Adolphs, R., Tranel, D., Hamann, S., Young, A. W., Calder, A. J., Phelps, E. A., et al. (1999). Recognition of facial emotion in nine individuals with bilateral amygdala damage. *Neuropsychologia*, *37*, 1111–1117.
- Argyle, M. (1988). *Bodily communication* (2nd ed.). New York, NY: Methuen & Co.

² Even if we throw out all 12 participants who scored more than 1.5 SD above the mean on the AQ (>24), our main findings remain significant. The likelihood that more than this number of high scoring participants had a first degree relative with autism is very small.

- Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of negative basic emotions in autism: a test of the amygdala theory. *Social Neuroscience*, *1*(3–4), 349–363.
- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, text revision* (4th ed.). Washington, DC: American Psychiatric Association.
- Austin, E. J. (2005). Personality correlates of the broader autism phenotype as assessed by the Autism Spectrum Quotient (AQ). *Personality and Individual Differences*, *38*(2), 451–460.
- Baron-Cohen, S., Bolton, P., Wheelwright, S., Schill, V., Short, L., Mead, G., et al. (1998). Autism occurs more often in families of physicists, engineers, and mathematicians. *Autism*, *2*, 296–301.
- 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*(1), 5–17.
- Berument, S. K., Rutter, M., Lord, C., et al. (1999). Autism screening questionnaire: Diagnostic validity. *British Journal of Psychiatry*, *175*, 444–451.
- Best, C. S., Moffat, V. J., Power, M. J., Owens, D. G. C., & Johnstone, E. C. (2008). The Boundaries of the Cognitive phenotype of autism: Theory of mind, central coherence and ambiguous figure perception in young people with autistic traits. *Journal of Autism and Developmental Disorders*, *38*, 840–847.
- Bishop, D. V. M., 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.
- Bolton, P., Macdonald, H., Pickles, A., Rios, P., Goode, S., Crowson, M., et al. (1994). A case-control family history study of autism. *Journal of Child Psychology and Psychiatry*, *35*, 877–900.
- Carter, A. S., Orstein Davis, N., Klin, A., & Volkmar, F. R. (2005). Social development in autism. In F. Volkmar, A. Klin, R. Paul, & D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, volume 1: Diagnosis, development, neurobiology, and behavior* (pp. 312–334). New York, NY: Wiley.
- Golan, O., Baron-Cohen, S., & Hill, J. (2006). The Cambridge Mindreading (CAM) Face-Voice Battery: Testing complex emotion recognition in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*, *36*(2), 169–183.
- Hall, J. A. (2001). The PONS test and the psychometric approach to measuring interpersonal sensitivity. In J. A. Hall & F. J. Bernieri (Eds.), *Interpersonal sensitivity: Theory and measurement* (pp. 143–160). Hillsdale, NJ: Erlbaum.
- Hall, J. A., & Bernieri, F. J. (2001). *Interpersonal sensitivity: Theory and measurement*. Hillsdale, NJ: Erlbaum.
- Happé, F., Frith, U., & Briskman, J. (2001). Exploring the cognitive phenotype of autism: Weak “central coherence” in parents and siblings of children with autism: I. Experimental tests. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *42*(03), 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. H. J., & Boomsma, D. I. (2007). Heritability of autistic traits in the general population. *Archives of Pediatric and Adolescent Medicine*, *161*, 372–377.
- Hughes, C., Leboyer, M., & Bouvard, M. (1997). Executive function in parents of children with autism. *Psychological Medicine*, *27*(1), 209–220.
- Hurley, R. S. E., Losh, M., Parlier, M., Reznick, J. S., & Piven, J. (2007). The broad autism phenotype questionnaire. *Journal of Autism and Developmental Disorders*, *37*, 1679–1690.
- Hurst, R. M., Mitchell, J. T., Kimbrel, N. A., Kwapil, T. K., & Nelson-Gray, R. O. (2007). Examination of the reliability and factor structure of the Autism Spectrum Quotient (AQ) in a non-clinical sample. *Personality and Individual Differences*, *43*(7), 1938–1949.
- Jobe, L. E., & Williams, W. S. (2007). Loneliness, social relationships, and a broader autism phenotype in college students. *Personality and Individual Differences*, *42*(8), 1479–1489.
- Kunihira, Y., Senju, A., Dairoku, H., Wakabayashi, A., & Hasegawa, T. (2006). ‘Autistic’ traits in non-autistic Japanese populations: Relationships with personality traits and cognitive ability. *Journal of Autism and Developmental Disorders*, *36*(4), 553–566.
- 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.
- Maxim, L. A., & Nowicki, S. J. (2003). Developmental associations between nonverbal ability and social competence. *Facta universitatis-series: Philosophy, Sociology & Psychology*, *2*(10), 745–758.
- McClure, E. B., & Nowicki, S., Jr. (2004). Associations between social anxiety and nonverbal processing skill in preadolescent boys and girls. *Journal of Nonverbal Behavior*, *25*, 3–9.
- Murphy, M., Bolton, P., Pickles, A., Fombonne, E., Piven, J., & Rutter, M. (2000). Personality traits of the relatives of autistic probands. *Psychological Medicine*, *30*(6), 1411–1424.
- Nowicki, S., Jr. (1995). A study of the DANVA-AP in college students. Unpublished manuscript. Department of Psychology, Emory University, Atlanta, GA.
- Nowicki, S., Jr., & Carton, J. (1993). The measurement of emotional intensity from facial expressions: The DANVA FACES 2. *Journal of Social Psychology*, *133*, 749–750.
- Nowicki, S., Jr., & Duke, M. P. (1994). Individual differences in the nonverbal communication of affect: The diagnostic analysis of nonverbal accuracy scale. *Journal of Nonverbal Behavior*, *18*(1), 9–35.
- Nowicki, S., Jr., & Duke, M. P. (2001). Nonverbal receptivity: The Diagnostic Analysis of Nonverbal Accuracy (DANVA). In J. Hall & F. Bernieri (Eds.), *Interpersonal Sensitivity: Theory and Measurement* (pp. 183–198). Mahwah, NJ: Lawrence Erlbaum Associates.
- Nowicki, S., Jr. (2006). Manual for the receptive tests of the Diagnostic Analysis of Nonverbal Accuracy 2 (DANVA2).
- Ozonoff, S., Rogers, S. J., Farnham, J. M., & Pennington, B. F. (1993). Can standard measures identify subclinical markers of autism? *Journal of Autism and Developmental Disorders*, *23*(3), 429–441.
- Palermo, M. T., Pasqualetti, P., Barbati, G., Intelligente, F., & Rossini, P. M. (2006). Recognition of schematic facial displays of emotion in parents of children with autism. *Autism*, *10*(4), 353–364.
- Pitterman, H., & Nowicki, S., Jr. (2004). A test of the ability to identify emotion in human standing and sitting postures: The Diagnostic Analysis of Nonverbal Accuracy-2 Posture Test (DANVA2-POS). *Genetic, Social, and General Psychology Monographs*, *130*(2), 146–162.
- Piven, J., Palmer, P., Jacobi, D., Childress, D., & Arndt, S. (1997). Broader Autism Phenotype: Evidence from a family history study of multiple-incidence autism families. *American Journal of Psychiatry*, *154*, 185–190.
- Rajendran, G., & Mitchell, P. (2007). Cognitive theories of autism. *Developmental Review*, *27*(2), 224–260.

- Riggio, R. E. (2006). Nonverbal skills and abilities. In V. Manusov & M. L. Patterson (Eds.), *The SAGE handbook of nonverbal communication* (pp. 79–95). Thousand Oaks, CA: Sage.
- Rosenthal, R., Hall, J. A., DiMatteo, M. R., Rogers, P. L., & Archer, D. (1979). *Sensitivity to nonverbal communication: The PONS Test*. Baltimore, MD: Johns Hopkins University Press.
- Rosip, J. C., & Hall, J. A. (2004). Knowledge of nonverbal cues, gender, and nonverbal decoding accuracy. *Journal of Nonverbal Behavior, 28*(4), 267–286.
- Santangelo, S. L., & Folstein, S. E. (1995). Social deficits in the families of autistic probands. *American Journal of Human Genetics, 57*, 89.
- Shean, G., Bell, E., & Camerson, C. D. (2007). Recognition of nonverbal affect and schizotypy. *The Journal of Psychology, 14*, 281–291.
- Skuse, D. H., Mandy, W. P. L., & Scourfield, J. (2005). Measuring autistic traits: Heritability, reliability and validity of the Social and Communication Disorders Checklist. *The British Journal of Psychiatry, 187*(6), 568–572.
- Wakabayashi, A., Baron-Cohen, S., & Wheelwright, S. (2006). Are autistic traits an independent personality dimension? A study of the Autism-Spectrum Quotient (AQ) and the NEO-PI-R. *Personality and Individual Differences, 41*(5), 873–883.
- Woodbury-Smith, M. R., Robinson, J., Wheelwright, S., & Baron-Cohen, S. (2005). Screening adults for Asperger syndrome using the AQ: A preliminary study of its diagnostic validity in clinical practice. *Journal of Autism and Developmental Disorders, 35*(3), 331–335.