Autistic traits are linked to reduced adaptive coding of face identity and selectively poorer face recognition in men but not women

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A B S T R A C T

Our ability to discriminate and recognize thousands of faces despite their similarity as visual patterns relies on adaptive, norm-based, coding mechanisms that are continuously updated by experience. Reduced adaptive coding of face identity has been proposed as a neurocognitive endophenotype for autism, because it is found in autism and in relatives of individuals with autism. Autistic traits can also extend continuously into the general population, raising the possibility that reduced adaptive coding of face identity may be more generally associated with autistic traits. In the present study, we investigated whether adaptive coding of face identity decreases as autistic traits increase in an undergraduate population. Adaptive coding was measured using face identity aftereffects, and autistic traits were measured using the Autism-Spectrum Quotient (AQ) and its subscales. We also measured face and car recognition ability to determine whether autistic traits are selectively related to face recognition difficulties. We found that men who scored higher on levels of autistic traits related to social interaction had reduced adaptive coding of face identity. This result is consistent with the idea that atypical adaptive face-coding mechanisms are an endophenotype for autism. Autistic traits were also linked with face-selective recognition difficulties in men. However, there were some unexpected sex differences. In women, autistic traits were linked positively, rather than negatively, with adaptive coding of identity, and were unrelated to face-selective recognition difficulties. These sex differences indicate that autistic traits can have different neurocognitive correlates in men and women and raise the intriguing possibility that endophenotypes of autism can differ in males and females.

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1. Introduction

Autism is a developmental disorder characterized by deficits in social communication, social interaction and restricted and repetitive behaviors. Milder expression of autistic traits can also occur in relatives of individuals with autism, in the “Broader Autism Phenotype” (Losh & Piven, 2007; Piven, Palmer, Jacobi, Childress, & Arndt, 1997; Ronald & Hoekstra, 2011; Sucksmith, Roth, & Hoekstra, 2011). There is also evidence for continuous, quantitative variation in autistic traits in the general population (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Constantino & Todd, 2003; Hoekstra, Bartels, Cath, & Boomsma, 2008). As a result, the concept of a broader autism phenotype can be extended to encompass this variation.

Autism is a highly heritable disorder, but its genetic basis remains poorly understood (Geschwind, 2011; Rutter, 2000; Skuse, 2007). Interest in the broader phenotype has been fueled by a search for endophenotypes that may have a simpler genetic basis than the disorder itself (but see Flint & Munafò, 2007). Endophenotypes are heritable (internal) features or processes that are related to, but simpler than, the entire disorder (Flint & Munafò, 2007; Geschwind, 2011; Gottesman & Gould, 2003). They indicate genetic susceptibility to autism and so should occur more often in family members than the general population. They should also co-vary with levels of autistic traits in the general population.

People with autism can experience a range of face processing difficulties and atypicalities (for reviews, see Dawson, Webb, & McPartland, 2005; Golarai, Grill-Spector, & Reiss, 2006; Sasson, 2006; Webb, Faja, & Dawson, 2011; Weigelt, Koldewyn, & Kanwisher, 2011). Subtle face processing difficulties have also been reported in relatives of individuals with autism (for recent reviews, see Fiorentini, Gray, Rhodes, Jeffery, & Pellicano, 2012; Sucksmith et al., 2011) although these are not always found (Wilson, Freeman, Brock, Burton, & Palermo, 2010). These findings raise the possibility that atypical face-processing mechanisms could be an endophenotype for autism.

One potential mechanism underlying these difficulties is reduced adaptive coding of faces. The adaptive nature of face-coding
mechanisms is highlighted by face aftereffects, in which exposure (adaptation) to a face alters our perception of a subsequently presented face (for reviews see Rhodes & Leopold, 2011; Webster & MacLeod, 2011). For example, exposure to a face biases us to see an identity with opposite features (Leopold, O’Toole, Vetter, & Blanz, 2001; Rhodes & Jeffery, 2006; Tsao, Freiwald, Tootell, & Livingstone, 2006). This bias to see an identity that is opposite (relative to the average) the adapting face in face-space (Fig. 1), suggests that the average face functions as a perceptual norm for coding identity. The use of norms and their calibration by experience likely contributes to our ability to discriminate and recognize thousands of faces despite their similarity as visual patterns (Rhodes & Leopold, 2011; Webster & MacLeod, 2011). Indeed recent studies have linked individual differences in face recognition ability with differences in adaptive coding (Dennett, McKone, Edwards, & Susilo, 2012; Rhodes, Jeffery, Taylor, Hayward, & Ewing, submitted for publication).

Importantly, the size of face identity aftereffects is reduced in children with autism (Pellicano, Jeffery, Burr, & Rhodes, 2007) and in relatives of children with autism (Fiorentini et al., 2012). These findings support the hypothesis that reduced adaptive coding of face identity is an endophenotype for autism. In the present study we test this hypothesis further by examining whether adaptive coding of identity is negatively associated with levels of autistic traits in the general population. If reduced adaptive coding is an endophenotype for autism, as hypothesized, then higher levels of autistic traits should be associated with smaller face identity aftereffects.

We also examined whether face recognition ability is reduced in individuals with higher levels of autistic traits. If higher levels of autistic traits are associated with smaller face identity aftereffects, as hypothesized, then they might also be associated with poorer face recognition, because adaptive coding helps us recognize faces (Dennett et al., 2012; Rhodes et al., submitted for publication; Rhodes & Leopold, 2011; Webster & MacLeod, 2011). Although face recognition is impaired in autism, little is known about face recognition in the broader phenotype (Sucksmith et al., 2011). Only one study has assessed face recognition in family members (Wilson et al., 2010). It found impaired face recognition for fathers, but not mothers, of individuals with autism. Two studies have examined the association between face recognition and autistic traits in undergraduate samples, but results were weak and mixed (Hedley, Brewer, & Young, 2011; Sasson, Nowlin, & Pinkham, 2012). Hedley et al. (2011) found a small, non-significant, negative correlation between the Cambridge Face Memory Test (CFMT) and AQ scores. Sasson et al. (2012) found marginally significant, negative correlations of Benton Facial Recognition Test scores with total Broad Autism Phenotype Questionnaire (BAPQ) scores and with BAPQ social/pragmatic language subscale scores, but a significant positive correlation with observed social skill. These studies provide very limited evidence that face recognition difficulties are part of the broader autism phenotype.

We measured autistic traits using the AQ and its subscales (Baron-Cohen et al., 2001) in a large sample of undergraduates. We measured face and non-face (car) recognition ability using the Cambridge Face Memory Test (CFMT) and the Cambridge Car Memory Test (CCMT), respectively. By including a measure of non-face recognition ability, we could assess whether autistic traits are linked selectively to face recognition ability. We measured adaptive coding of identity using face identity aftereffects. Reliable measurement of these aftereffects requires a lengthy psychophysical testing procedure, which was completed by just over half of our participants. To summarize, we reasoned that if reduced adaptive coding is an endophenotype for autism, as hypothesized, then higher levels of autistic traits should be associated with smaller face identity aftereffects and poorer face recognition in our undergraduate sample.

2. Method

2.1. Participants

Two-hundred and forty Caucasian, Introductory Psychology students participated for course credit (177 females, M = 19.2 years, SD = 4.4, range = 17–46; 63 males, M = 19.4 years, SD = 3.3, range = 17–38). In addition to general recruiting via the experimental participation pool, we invited students who scored in the highest and lowest 25% on the Autism-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001), which had been administered to the entire class together with other questionnaires at the beginning of the semester. A substantial minority of participants (about 20%) were recruited in this way in an attempt to increase the range of scores, and the AQ distributions should be interpreted accordingly. No information was available on psychiatric conditions.

2.2. Tasks and measures

2.2.1. The Autism-Spectrum Quotient (AQ)

This is a widely used self-report measure of autistic traits in adults with normal intelligence (Baron-Cohen et al., 2001). It has good inter-rater and test–retest reliability and yields significantly higher scores for individuals with Asperger Syndrome or high-functioning autism than controls. It contains 10 items in each of 5 domains: communi-

Fig. 1. A hypothetical two-dimensional face-space with two identities, Dan and Jim (plus reduced-identity-strength versions), together with anti-faces that have oppo-

nication, social interaction, imagination, local details and attention switching, for a total of 50 items. For each item, participants respond on a 4-point scale (definitely agree, slightly disagree, definitely disagree). Scoring was originally binary (0–1) for each item, but we followed the more recent practice of using a 4-point scoring system (e.g., Hoekstra et al., 2008; Manara, Del Giudice, Grandi, & Colle, 2011). We calculated a total score, AQ_Total, plus scores for two factors identified by a large scale psychometric study (Hoekstra et al., 2008): an attention to details factor (from local details items), AQ_Atten-to-Detail, and a social interaction factor (from items in the other four domains), AQ_Social. Both factors have acceptable internal and test–retest reliability (Hoekstra et al., 2008). Finally, we calculated a second total AQ score using the binary method, to check whether any participants exceeded the recommended clinical cut-off of 32 (Baron-Cohen et al., 2001).

2.2.2. Face identity aftereffect task

This task has been widely used to measure adaptive, norm-based coding of identity. We used a version adapted from previous studies (Jeffery et al., 2011; Rhodes et al., 2011) (for full details see Rhodes et al., submitted for publication). Briefly, on each trial participants viewed an adapting anti-face followed by a target face presented at low identity strength (15%), which they had to identify (Fig. 1). Adapt and test faces were different sizes to minimize the contribution of low-level,
tasks unrelated to the present study. The CFMT and CCMT were completed in the two sessions, one week apart. Each session lasted up to 40 min and included other

Descriptive statistics.

Identity Aftereffect task (Dennett et al., 2011). It has good reliability (Cronbach’s alpha \(\geq .83\), Dennett et al., 2011).

2.2.4. Cambridge Car Memory Test (CCMT)
The CCMT is analogous to the CFMT, but uses cars instead of faces (for details see Dennett et al., 2011). It has good reliability (Cronbach’s alpha \(\geq .83\), Dennett et al., 2011).

2.3. Procedure
All participants completed the AQ and the CFMT. A subset completed the Face Identity Aftereffect task \((N=129)\) and/or the CCMT \((N=65)\). Participants completed two sessions, one week apart. Each session lasted up to 40 min and included other tasks unrelated to the present study. The CFMT and CCMT were completed in the first session, except for a small group of participants \((N=33)\) who completed the CFMT in the second session. The FIAE task consisted of two identical blocks, one administered in each session. The AQ was administered last.

3. Results

3.1. Distributions and descriptive statistics

Distributions were normal (or very close to normal), except for CFMT scores, but skew and kurtosis were within acceptable limits for parametric analysis (Table 1) (Stuart & Kendall, 1958). One univariate CFMT outlier (low score), identified by SPSS, was replaced by a score 2 SDs below the mean (a common cut-off for potential impairment). There were no multivariate outliers, according to Mahalanobis distances. Descriptive statistics for the final distributions are shown in Table 1. Despite our attempt to increase the representation of high and low scores, distributions of AQ scores (Fig. 2) were very similar to those reported previously (Hoekstra et al., 2008; Stewart & Austin, 2009).

3.2. Sex differences

As expected from Baron-Cohen et al. (2001), men scored higher than women, for AQ_Total, \(t(238)=1.90, p=.029\), one-tailed, Cohen’s \(d=.25\), and AQ_Social, \(t(238)=1.83, p=.034\), one-tailed, Cohen’s \(d=.24\) (Table 1). As in Baron-Cohen et al. (2001), there was no significant sex difference in AQ_Attention-to-Detail scores (Table 1), \(t(238)=-.98, p=.34\) (two-tailed), Cohen’s \(d=.13\). Regression analyses with sex and sex \(\times\) AQ_Total as predictors, yielded significant interaction effects for all three face processing measures (CFMT beta \(-1.076, p=.018\); face-selective CFMT beta \(-1.402, p=.027\); face identity aftereffect beta \(-1.802, p=.003\)). We therefore report our results below separately for men and women. When considered separately by sex, all AQ distributions were normal, except for male AQ_Attention-to-Detail scores, which deviated slightly from normality. However, skew and kurtosis scores were acceptable for parametric analysis (Table 1). Three women and one man scored above the recommended clinical cut-off of 32 in the binary scoring system (women scoring 34, 35, 35; man scoring 35). Although these individuals could potentially meet diagnostic criterion for autism, they were retained for analysis because they form part of the expected continuous distribution of AQ scores.

There were no significant sex differences in age (log transformed to reduce positive skew), CFMT scores, or face identity aftereffects, all \(t s < .54, ps > .58\), Cohen’s \(ds < .07\). Men performed significantly better \((M=58.7, SD=6.9)\) than women \((M=49.0, SD=7.4)\) on the CCMT, \(t(110)=6.22, p < .0001, Cohen’s d=1.19\), as found previously (Dennett et al., 2011). This difference likely reflects men’s greater interest in and experience with cars.
3.3. Men

3.3.1. AQ and face identity aftereffects

Men’s total AQ scores were moderately and significantly negatively correlated with face identity aftereffects (Table 2, Fig. 3). This association was driven by variation on the social interaction factor. Face aftereffects correlated significantly with AQ_Social (Table 2, Fig. 3), but not AQ_Attention-to-Detail, scores (Table 2), and the correlation of aftereffects with AQ_Total scores was close to zero when AQ_Social scores were controlled, partial r=.03, df=32, p=.867. These results indicate that men with higher levels of autistic traits related to social interaction have poorer adaptive coding of identity. They support the hypothesis that reduced adaptive coding of identity is an endophenotype of autism.

3.3.2. AQ and face recognition

Total AQ scores showed a weak and non-significant correlation with face recognition (CFMT) scores (Table 2). However, there was a clear link with face-selective recognition performance, measured as residuals from a regression predicting face recognition (CFMT) scores, and Face Identity AE (Aftereffect). Correlations (with p-values and Ns in rows below) are shown separately for men and women.

Table 2

<table>
<thead>
<tr>
<th></th>
<th>CFMT</th>
<th>CCMT</th>
<th>Face-Selective CFMT</th>
<th>Face Identity AE</th>
</tr>
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<tbody>
<tr>
<td><strong>Men</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AQ_Total</td>
<td>−.131</td>
<td>−.118</td>
<td>−.385*</td>
<td>−.365*</td>
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<tr>
<td></td>
<td>.307</td>
<td>.535</td>
<td>.036</td>
<td>.031</td>
</tr>
<tr>
<td></td>
<td>.63</td>
<td>30</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>AQAttention Detail</td>
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<td>.016</td>
<td>−.113</td>
<td>−.059</td>
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<tr>
<td></td>
<td>.540</td>
<td>.932</td>
<td>.552</td>
<td>.738</td>
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<tr>
<td></td>
<td>.63</td>
<td>30</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td>AQ_Social</td>
<td>−.184</td>
<td>−.145</td>
<td>−.412*</td>
<td>−.393*</td>
</tr>
<tr>
<td></td>
<td>.149</td>
<td>.446</td>
<td>.024</td>
<td>.019</td>
</tr>
<tr>
<td></td>
<td>.63</td>
<td>30</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td><strong>Women</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AQ_Total</td>
<td>.207**</td>
<td>.067</td>
<td>.094</td>
<td>.207*</td>
</tr>
<tr>
<td></td>
<td>.006</td>
<td>.552</td>
<td>.403</td>
<td>.045</td>
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<td></td>
<td>.177</td>
<td>82</td>
<td>82</td>
<td>94</td>
</tr>
<tr>
<td>AQAttention Detail</td>
<td>.272**</td>
<td>.341**</td>
<td>.205</td>
<td>.009</td>
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<td></td>
<td>.000</td>
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<td>.065</td>
<td>.931</td>
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<td></td>
<td>.177</td>
<td>82</td>
<td>82</td>
<td>94</td>
</tr>
<tr>
<td>AQ_Social</td>
<td>.126</td>
<td>.074</td>
<td>.017</td>
<td>.239*</td>
</tr>
<tr>
<td></td>
<td>.095</td>
<td>.511</td>
<td>.880</td>
<td>.02</td>
</tr>
<tr>
<td></td>
<td>.177</td>
<td>82</td>
<td>82</td>
<td>94</td>
</tr>
</tbody>
</table>

* p < .05.

** p < .01.

Fig. 3. Scatterplots showing the negative association between men’s AQ scores and face identity aftereffects. N=35.

3.3.3. Age

Over 95% of our sample was aged between 17 and 25 years, making age effects unlikely (but see Germain, Duchaine, & Nakayama, 2011). Age (log transformed) did not correlate significantly with face recognition (CFMT), r=.11, p=.39, N=63, face-selective recognition (Face-selective CFMT), r=.00, p=1.00, N=30, or face identity aftereffects, r=−.17, p=.32, N=35. It did correlate significantly with car recognition (CCMT), r=.38, p<.04, N=30, possibly because car experience increases with age. Age did not correlate significantly with any AQ measure: AQ_Total, r=−.06, p=.658; AQ_Social, r=−.02, p=.882; AQAttention-to-Detail, r=−.21, p=.092, all Ns=63.

3.4. Women

3.4.1. AQ and face identity aftereffects

In contrast to men, women showed a significant positive (rather than negative) correlation between AQ scores and face identity aftereffects (Table 2, Fig. 5). Again, this association was driven by variation on the social factor. Face identity aftereffects correlated significantly with AQ_Social scores (Table 2, Fig. 5), but not AQ_Attention-to-Detail scores (Table 2), and their correlation with total AQ scores was close to zero when AQ_Social scores were controlled, partial r=−.02, df=91, p=.823. Therefore, unlike men, women with higher levels of autistic traits related to social interaction showed more, rather than less, adaptive coding of face identity. This sex difference was confirmed by a regression using AQ_Social scores, Sex, and the Sex × AQ_Social interaction term to predict face identity aftereffects. It yielded significant effects for all three predictors (AQ_Social beta=.243, p=.020; Sex beta=1.706, p=.001; Sex × AQ_Social beta=−1.763, p=.001).

3.4.2. AQ and face recognition

In contrast to men, women showed a positive, rather than negative, correlation between total AQ scores and face recognition (CFMT) scores (Table 2, Fig. 6). This association also differed from car recognition (CCMT) scores (Table 2, Fig. 4). Total AQ scores were significantly negatively correlated with this measure of face-selective recognition. This association was driven by variation on the social AQ factor. Face-selective recognition performance correlated significantly with AQ_Social scores, but not with AQAttention-to-Detail scores (Table 2, Fig. 4), and the correlation with AQ_Total scores was close to zero when AQ_Social scores were controlled, partial r=.04, df=27, p=.849. No AQ measure correlated with car recognition. These results suggest that men with high levels of autistic traits related to social interaction have face-selective difficulties in recognition that do not extend to non-face (car) recognition.
that seen in men in two further ways. First, it was driven by variation on Attention-to-Detail, rather than Social, factor scores. CFMT scores correlated significantly with AQ_Attention-to-Detail scores (Table 2, Fig. 6), but not AQ_Social scores (Table 2), and their correlation with total AQ scores was close to zero when AQ_Attention-to-Detail scores were controlled, partial $r = 0.07, df = 174, p = 0.387$. Second, AQ_Attention-to-Detail scores correlated moderately and significantly with car recognition, as well as face recognition, scores and no AQ measure correlated significantly with face-selective recognition performance (Table 2). Overall, these results indicate that women with higher levels of autistic traits related to attention to detail score better on tests of visual recognition generally.

3.4.3. Age

Age (log transformed) did not correlate with face recognition (CFMT), $r = 0.12, p = 0.12, N = 177$, face-selective recognition (face-selective CFMT), $r = 0.11, p = 0.33, N = 82$, or car recognition (CCMT), $r = 0.11, p < 0.34, N = 82$. There was a marginally significant correlation with face identity aftereffects, $r = 0.19, p = 0.07, N = 94$, but this was driven by a single 45 year-old outlier, and dropping this person eliminated the effect, $r = 0.11, p = 0.30, N = 93$. Age did not correlate significantly with any AQ measure: AQ_Total, $r = 0.08, p = 0.309$; AQ_Social, $r = 0.06, p = 0.466$; AQ_Attention-to-Detail, $r = 0.08, p = 0.277$ (all $N's = 177$).

4. Discussion

Men with higher levels of autistic traits had reduced adaptive coding of face identity. Adaptive coding of identity is also reduced in some relatives of individuals with autism (Fiorentini et al., 2012) and in boys with autism (Pellicano et al., 2007). Taken together, these findings suggest that atypical adaptive coding of faces may be an endophenotype for autism in males.
Men with higher levels of autistic traits also had selectively poorer recognition of faces. This finding demonstrates that face-selective recognition difficulties extend beyond male relatives (fathers) of individuals with autism (Wilson et al., 2010) to men with high levels of autistic traits in the general population. It also indicates that face-processing difficulties in the broader phenotype extend beyond problems in processing expression and gaze, which have received relatively more attention (for a recent review see Sucksmith et al., 2011), to problems in identity recognition. More generally, it suggests that face recognition problems may be an endophenotype for autism in males.

Our results for women were quite different and unexpected. Women's AQ scores were positively, rather than negatively, related to adaptive coding of identity. Adaptive coding was related to AQ_Social scores, as it was for men, but whereas men with higher scores showed smaller identity aftereffects, women with higher scores showed larger identity aftereffects. Larger aftereffects in women with more autistic traits is surprising given that reduced aftereffects are found in relatives of individuals with autism, and in children with autism, regardless of sex (Fiorentini et al., 2012). However, power to detect sex differences would have been low.

Another sex difference was that autistic traits in women, unlike those in men, were unrelated to face-selective recognition performance. Instead women's AQ_Attention-to-Detail scores were linked with general (i.e., non-face-selective) visual recognition performance. This recognition advantage in more detail-focused women might possibly result from closer attention to visual details in study images. Given that face recognition normally relies on holistic coding, such a detail-focused strategy would indicate a face-processing atypicality. Alternatively, attention to detail might just be a useful strategy in memory tasks, although it is not clear why this should only be so for women.

Although surprising, the sex differences found here are not easily dismissed given the large sample of women. Rather they may indicate a genuine sex difference in the broader phenotype. They are broadly consistent with other evidence for sex differences in the broader phenotype from studies of relatives of individuals with autism. For example, male, but not female, relatives are reported to show poor face recognition (Wilson et al., 2010), low empathy (Sucksmith, Allison, Baron-Cohen, Chakrabarti, & Hoekstra, 2013), and more detail-focused processing (Happé, Briskman, & Frith, 2001).

Given the strongly biased sex ratio in autism, most of what we know about face processing in autism is based on male performance, with little attention given to the possibility of sex differences. Indeed none of the recent reviews of face perception in autism even mention sex differences (Dawson et al., 2005; Golarai et al., 2006; Sasson, 2006; Webb et al., 2011; Weigelt et al., 2011). The present results raise the possibility of sex differences in face processing in autism. If found, these would add to the growing evidence for sex differences in autistic neurobiology, symptomatology and associated difficulties (Lai et al., 2011; Lai et al., 2013; Mandy et al., 2012; Rivet & Matson, 2011).

Our findings also broaden our understanding of genetically-based individual differences in face-selective recognition ability (McKone & Paeremo, 2010; Wilmer et al., 2010; Zhu et al., 2010). These have been linked to individual differences in both adaptive (Dennett et al., 2012; Rhodes et al., submitted for publication) and holistic (DeGutis, Wilmer, Mercado, & Cohan, 2012; Richler, Cheung, & Gauthier, 2011; Wang, Li, Fang, Tian, & Liu, 2012) face-coding mechanisms. Our results indicate that they are also linked to autistic traits in men. Interestingly, this association is only apparent when face-selective recognition ability is isolated. Two previous studies that failed to find a clear link between face recognition ability and autistic traits did not isolate face-selective recognition ability (Hedley et al., 2011; Sasson et al., 2012).

Our study has several possible limitations. First, we used a student sample that was relatively young and likely above-average in intelligence. We suggest that such factors are unlikely to affect our results, because AQ distributions do not differ between general population samples and student samples (Baron-Cohen et al., 2001). However, we cannot rule out the possibility that different associations would be found between AQ and behavior in different populations. The sex differences in these associations, observed here, cannot be attributed to any sex difference in age. Nor are they likely to be due to a sex difference in IQ, if one were to exist (we did not measure), because IQ is not related to AQ scores (Baron-Cohen et al., 2001) or to face recognition ability (Zhu et al., 2010).

A second limitation is that men were under-represented in our sample, which was recruited from an Introductory Psychology course. Nevertheless, men showed the predicted relationships between autistic traits and face processing atypicalities, and it was women whose results were surprising and more difficult to interpret.

A third limitation is that for ethical reasons we did not screen our participants for psychiatric diagnoses. It is possible, therefore, that our sample contained some individuals with psychiatric conditions that could impair face processing (e.g., autism, prosopagnosia, schizophrenia). However, inspection of our scatterplots shows that our correlations were not driven by a few individuals with extreme scores, suggesting that the presence of any such individuals had little, if any, impact on our results.

A more general limitation is that inferences about endophenotypes for autism based on data from individuals who do not meet diagnostic criteria for autism, are necessarily indirect. Our suggestion that atypical coding of faces may be an endophenotype for autism in males is supported by evidence from boys with a diagnosis (Pellicano et al., 2007) and family members (some male) of individuals with autism (Fiorentini et al., 2012). However, the possibility, raised by our results, that this endophenotype does not extend to females with autism, has not been tested. A logical extension to this study, therefore, would be to determine whether the sex differences reported here, also occur individuals with autism.

Cermine and colleagues (2011) have reported that face recognition (CMFT performance) improves throughout early adulthood. We found small, non-significant, positive associations for both men ($r = .11$) and women ($r = .12$). They reported a correlation of .06 for the 20–30 year age range that is closest to our range, which was statistically significant due to the extremely high power in their study (inspection of their age distributions suggests an $N$ of many thousands in this age range). In terms of effect size, therefore, our results seem reasonably consistent with theirs.

In recent years there has been increasing interest in the idea that autistic traits are continuously distributed in the general population. In the present study, we found that men with higher levels of autistic traits had reduced adaptive coding of identity and poorer face-selective recognition. These results support the hypothesis that reduced adaptive coding of identity is an endophenotype for autism. However, we also found some unexpected sex differences, which suggest that autistic traits may have different neurocognitive correlates, and therefore different endophenotypes, in males and females.

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