Neuropsychologia 51 (2013) 98–105

Contents lists available at SciVerse ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Empathy and emotion recognition in people with autism, first-degree relatives, and controls

E. Sucksmith [a,*], C. Allison [b], S. Baron-Cohen [b], B. Chakrabarti [b,c,1], R.A. Hoekstra [a]

[a] Department of Life, Health and Chemical Sciences, The Open University, Milton Keynes MK7 6AA, UK
[b] Department of Psychiatry, Autism Research Centre, University of Cambridge, Cambridge, UK
[c] School of Psychology and Clinical Language Sciences, Centre for Integrative Neuroscience and Neurodynamics, University of Reading, Reading, UK

ARTICLE INFO

Article history:
Received 20 August 2012
Received in revised form
19 October 2012
Accepted 11 November 2012
Available online 19 November 2012

Keywords:
Autism
Empathy
Emotion
Broader autism phenotype
Endophenotype

ABSTRACT

Empathy is the lens through which we view others' emotion expressions, and respond to them. In this study, empathy and facial emotion recognition were investigated in adults with autism spectrum conditions (ASC; $N=314$), parents of a child with ASC ($N=297$) and IQ-matched controls ($N=184$). Participants completed a self-report measure of empathy (the Empathy Quotient [EQ]) and a modified version of the Karolinska Directed Emotional Faces Task (KDEF) using an online test interface. Results showed that mean scores on the EQ were significantly lower in fathers ($p<0.05$) but not mothers ($p>0.05$) of children with ASC compared to controls, whilst both males and females with ASC obtained significantly lower EQ scores ($p<0.001$) than controls. On the KDEF, statistical analyses revealed poorer overall performance by adults with ASC ($p<0.001$) compared to the control group. When the 6 distinct basic emotions were analysed separately, the ASC group showed impaired performance across five out of six expressions (happy, sad, angry, afraid and disgusted). Parents of a child with ASC were not significantly worse than controls at recognising any of the basic emotions, after controlling for age and non-verbal IQ (all $p>0.05$). Finally, results indicated significant differences between males and females with ASC for emotion recognition performance ($p<0.05$) but not for self-reported empathy ($p>0.05$). These findings suggest that self-reported empathy deficits in fathers of autistic probands are part of the 'broader autism phenotype'. This study also reports new findings of sex differences amongst people with ASC in emotion recognition, as well as replicating previous work demonstrating empathy difficulties in adults with ASC. The use of empathy measures as quantitative endophenotypes for ASC is discussed.

1. Introduction

Autism spectrum conditions (ASC) are neurodevelopmental in origin, and are characterized by difficulties with social interaction and communication, together with unusually restricted, repetitive behaviours and interests (APA, 2000; WHO, 1993). ASC involve a large number of behavioural manifestations that vary considerably across individuals and development. It is therefore important to test neurocognitive models that reduce these behavioural symptoms to a small number of underlying processes.

One of the earliest and most influential neurocognitive models for ASC is the theory of mind (ToM)/'mind-blindness' hypothesis. This states that the behaviour observed in ASC is due to difficulties representing the contents of one's own and other people's minds (Baron-Cohen, 1995). Successful social interaction requires the ability to attribute mental states to others in order to explain and predict their behaviour. Early studies assessing ToM in ASC and typically developing children primarily focused on the application and understanding of beliefs (Baron-Cohen, Leslie, & Frith, 1985; Leslie & Frith, 1988; Perner, Frith, Leslie, & Leekam, 1989), intentions (Phillips, Baron-Cohen, & Rutter, 1998) and pretence (Baron-Cohen, 1987; Leslie, 1987; Scott & Baron-Cohen, 1996). The ToM hypothesis can explain the social features of ASC but never set out to explain its non-social features. The hypothesis can also only explain the earliest symptoms of ASC by reference to simpler precursors of ToM, such as joint-attention and pretence (Pellicano, 2011). More recently, empathy has been proposed as a broader neurocognitive construct underlying the social and communicative difficulties observed in people with ASC (Baron-Cohen, 2002). Empathy extends the ToM hypothesis by not only focusing on the attribution of another person's mental state but also on the capacity to respond to another's mental states with an appropriate emotion (Baron-Cohen, 2002). It

* Corresponding author. Tel.: +44 0 7964 744170.
E-mail address: E.Sucksmith@open.ac.uk (E. Sucksmith).
[1] B. Chakrabarti and R.A. Hoekstra are joint senior authors.

0028-3932/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.neuropsychologia.2012.11.013

Participants also completed a modified version of the Karolinska directed emotional faces task (KDEF; Lundqvist, Flykt, & Ohman, 1998) using the online test interface. Participants were shown 140 photographs of people's faces expressing one of six 'basic' emotions (happy, sad, angry, afraid, disgusted and surprised) as well as a neutral expression (see Fig. 1). There were 20 photographs in total for each expression. For each photograph, participants were asked to select which of the seven words described the emotion being expressed. Participants were told they had 20 s to respond to each photograph and they must answer as quickly and accurately as possible. Results provide an accuracy score and response time (for correct trials only) for each facial expression of emotion. The stimuli used in the KDEF have been validated on emotional content, intensity and arousal and have good test–retest reliability (Goeleven, De Raedt, Leyman, & Verschuere, 2008). Furthermore, the KDEF stimuli set have good ecological validity, unlike schematic or computerized faces (see Supplementary material for the stimuli ID codes selected for this task).

All data were rigorously checked prior to the data analyses. Twenty-two data points were identified as outliers (> 3 standard deviations from the group mean) and so were removed from the data set, resulting in the final sample size of 314 adults with ASC, 297 parents and 184 control participants.

Finally, participants used the online test interface to complete an online adaptation of the RPM, a measure of non-verbal intelligence (Raven et al., 1996). The RPM consists of 60 items displaying geometric designs of varying complexity that contain a missing piece. Participants had to choose from a selection of designs to complete the pattern. Performance on the online RPM was used so that groups could be matched on non-verbal IQ; this ensures that the relationship between group status and the empathy/emotion recognition measures is undistorted by non-verbal IQ and that any significant differences found reflect selective difficulties in behaviour/cognition. RPM accuracy score was also used as a covariate in data analyses to remove any covariance from the outcome measures that could be attributed to variation in non-verbal cognitive ability.

2.3. Statistical analyses

Adults with ASC, parents of children with ASC and the control group were compared on mean EQ scores using a univariate analysis of covariance (ANCOVA) with non-verbal IQ and age used as covariates. Previous studies have reported sex-specific expression of the BAP (Constantino et al., 2006; Happé, Briskman, & Frith, 2001) and sex differences on measures of empathy (Baron-Cohen & Wheelwright, 2004), so sex was also used as a between-subjects factor in the data analyses.

Fig. 1. Example of Stimuli used in the KDEF (Lundqvist et al., 1998). KDEF; Karolinska directed emotional faces task. KDEF stimulus ID: happy af28.

For the KDEF, two dependent variables were analysed. First, accuracy was used, in line with previous research on facial emotion recognition in ASC (Ashwin et al., 2006; Bölte & Poustka, 2003). Second, 'accuracy-adjusted response time' was used which is likely to be a more sensitive measure as it controls for a potential speed-accuracy trade-off (see Mevorach, Humphreys, & Shalev, 2006 and Sutherland & Crewther, 2010 for similar approaches). Accuracy scores showed high ceiling effects, with distributions significantly deviating from the normal distribution. Therefore, non-parametric Kruskal–Wallis tests were carried out on accuracy scores for each emotion, with group used as the fixed factor. For emotions that showed significant differences, planned follow-up Mann–Whitney U tests were carried out between ASC parents and controls and between ASC adults and controls.

Accuracy-adjusted response times were calculated for each emotion by dividing the mean response time for correct items by the fraction of items answered correctly. This ratio provides a degree of adjustment for potential speed-accuracy tradeoffs. Adults with ASC, parents of children with ASC and the control group were compared on this dependent variable using a mixed analysis of covariance (ANCOVA). This test was used to compare groups on overall mean accuracy-adjusted response time across all emotions. Follow up ANCOVAs with planned contrasts were then carried out to compare groups on each emotion separately. In these analyses, sex was again included as a fixed factor and non-verbal IQ and age used as covariates.

3. Results

3.1. Self-rated empathy

Table 2 shows the mean EQ scores, standard deviations and available sample sizes for each group, separated by gender. A group × sex ANCOVA with age and non-verbal IQ as the covariates showed that age did not have a significant effect on mean EQ score ($F(1,818)=0.25$, $p>0.05$), whilst non-verbal IQ was significantly related to mean EQ score ($F(1,818)=10.59$, $p<0.01$; Pearson's correlation coefficient $r=0.11$, indicating a small effect size and thus a modest positive association between empathy and non-verbal IQ). Results also revealed a significant main effect of group ($F(2,818)=242.60$, $p<0.001$). Contrast analyses suggested that the mean EQ score was significantly lower in adults with ASC ($p<0.001$, $r=0.51$) compared to the control group. The ANCOVA also revealed a significant main effect of sex ($F(1,818)=57.06$, $p<0.001$, $r=0.30$), with females obtaining higher scores than males. A significant interaction effect between group and sex on mean EQ score ($F(2,818)=14.64$, $p<0.001$) was seen, suggesting that group effects are different for males and females (see Fig. 2). Results from subsequent sex-specific ANCOVAs confirmed that both males and females with ASC reported significantly lower EQ scores on average than controls ($p<0.001$. See Table 2 for mean scores). However, contrasts confirmed that fathers, but not mothers, of children with ASC reported a significantly lower mean EQ score compared to sex-specific controls (fathers: $p<0.05$, $r=0.32$; mothers: $p=0.21$). Results from group-specific ANCOVAs confirmed that there was a non-significant difference

Table 2
Descriptive data for group analysis of the EQ and performance on the KDEF, separated by gender[a].

	Males			Females		
	Control	**ASC parent**	**ASC**	**Control**	**ASC parent**	**ASC**
EQ						
N	93	38	161	94	272	168
Mean score (SD)	37.7 (13.5)	32.2 (13.5)	17.5 (10.5)	48.5 (14.1)	46.6 (17.7)	18.2 (8.9)
KDEF						
N	92	36	164	92	261	150
Mean accuracy per emotion (/20) (SD)	17.49 (1.18)	17.34 (1.38)	16.60 (1.80)	17.80 (1.21)	17.71 (1.03)	16.70 (1.76)
Mean ART (ms) per emotion (SD)	2885.44 (745.14)	3113.44 (794.68)	3577.71 (1091.95)	2637.13 (621.80)	2774.75 (708.09)	3168.45 (1071.96)

[a] EQ; empathy quotient, KDEF; Karolinska directed emotional faces task, ASC; autism spectrum conditions, ART; accuracy-adjusted response time.

emotions and the neutral expression (happy; sad; angry; afraid; disgust; neutral; $p<0.001$). There was also a significant main effect of sex on accuracy-adjusted response time for five emotions (disgust; surprise; $p<0.001$, sad; angry; $p<0.01$, happy; $p<0.05$). The non-verbal IQ covariate had a significant effect on the accuracy-adjusted response time for three facial expressions (afraid; $p<0.001$, angry; disgust; $p<0.05$), whilst the age covariate had a significant effect on the accuracy-adjusted response time for four facial expressions (happy; sad; neutral; $p<0.001$, surprise; $p<0.01$). There were no significant group × sex interactions (all $p>0.05$). Contrast analyses indicated that the accuracy-adjusted response times of adults with ASC were significantly higher than the control group on five emotions and the neutral expression (happy; sad; angry; afraid; disgust; neutral; $p<0.001$). These contrasts also indicated that there were no significant differences between parents of children with ASC and controls on accuracy-adjusted response times for each facial expression (all $p>0.05$).

3.2.3. Correlations with EQ score

Lastly, the correlation between self-reported empathy and emotion recognition was explored in all three groups. Mean EQ scores and mean KDEF accuracy-adjusted response times were negatively correlated (ASC: $r=-0.16$, $p<0.01$, ASC parents: $r=-0.15$, $p<0.01$ and Controls: $r=-0.15$, $p<0.05$). These significant correlations suggest that the EQ and KDEF measure modestly overlapping constructs, such that people with relatively low self-rated empathy score somewhat lower on the performance test for emotion recognition.

4. Discussion

This study investigated empathy and facial emotion recognition in adults with ASC and in first-degree relatives (parents) of children with ASC. The evidence supports a broader autism phenotype (BAP) for self-rated empathy in fathers of children with ASC, but not for basic facial emotion recognition in parents of children with ASC. We also replicated previous studies reporting empathy and emotion recognition difficulties in adults with ASC, and found evidence for a difference between males and females with ASC on emotion perception. Each of these findings is discussed below.

Fathers but not mothers of children with ASC self-reported lower empathy than controls on the empathy quotient (EQ). This suggests that lower self-reported empathy may be a reliable feature of the BAP in fathers only. Further research is needed to assess whether this sex-specific finding generalizes to other relatives, e.g., to brothers but not sisters of individuals with ASC. Some previous studies have suggested that certain aspects of the BAP may be especially prevalent in male relatives (Constantino et al., 2006). This study is the first to explore self-reported empathy in parents of a child with ASC. Equally, further research is needed to test if the absence of a self-reported empathy deficit in mothers is because they are over-estimating their true empathy level.

When analyzing facial emotion recognition using a sensitive measure of performance (accuracy-adjusted response time), parents of children with ASC were not significantly poorer than IQ-matched controls at identifying the six basic facial expressions of emotion. These results do not support the notion that there is a BAP for basic emotion recognition, in contrast to some previous studies (Palermo et al., 2006; Smalley & Asarnow, 1990; Wallace et al., 2010). One possible reason for these discrepant findings is that the measure of basic emotion recognition used here was not sensitive enough to detect subtle differences in basic emotion recognition in ASC relatives. Whilst the dependent variable used included a sensitive measure of emotion recognition performance (accuracy-adjusted response time), the KDEF stimuli comprise high intensity, 'full blown' emotions – exaggerated facial expressions – that were relatively easy to identify in non-clinical samples. Making emotional expressions more subtle would have increased task difficulty and may have increased the power to detect subtle differences in emotion recognition ability. Our previous study used the 'Reading the Mind in the Eyes' (Eyes) test that requires emotion recognition from just the eye region of the face and involves emotions beyond the basic ones. On the Eyes test, both mothers and fathers of children with ASC showed deficits (Baron-Cohen & Hammer, 1997). In clinical samples of ASC emotion recognition deficits have also emerged more clearly when using lower intensity stimuli (Law Smith et al., 2010).

A second possible reason for these discrepant findings is that mild difficulties in basic emotion recognition performance may be 'compensated' in parents of children with ASC. Evidence for cognitive compensation has been detected in first-degree relatives using neuroimaging techniques: at a neural level Spencer et al. (2011) found that unaffected siblings of children with ASC, showed reduced neural response (in multiple brain regions including the fusiform face area and superior temporal sulcus) to happy but not fear faces. These neurophysiological differences in siblings were seen despite non-significant differences in performance on the facial emotion recognition task. Understanding what occurs in such examples of 'compensation' will be important in future work.

A third finding from this study relates to adults with ASC. There was a significant sex difference in adults with ASC on the emotion recognition task, females with ASC performing significantly better than males. This contrasts with results on the EQ that did not show significant sex differences in adults with ASC. This suggests that females with ASC may perform better than males with ASC at tests of social cognition, despite having comparably low levels of self-reported empathy.

A number of different interpretations may account for these findings. Females' low self-reported empathy may be more related to difficulties that extend beyond basic emotion recognition which were not analysed here (e.g., more advanced theory of mind). Alternatively, their low self-reported empathy may reflect higher social expectations on females in the real world. If typical females are expected to be better at empathy than males, this may cause females with ASC to report their empathy problems to a greater degree than males. Finally, these results may reflect greater cognitive compensation in females with ASC. Perhaps as a result of greater social expectations and greater motivation to integrate into social groups, females with ASC work harder to compensate for their problems by developing cognitive strategies to improve their social skills. Thus, females with ASC may have a heightened self-awareness of their social difficulties as a result of being more able than males with ASC to read the emotions of others. This interpretation is consistent with previous studies which find that people with ASC who display stronger intellectual and emotional capabilities perceive themselves as less socially competent than people with ASC who possess less emotional understanding (Capps, Sigman, & Yirmiya, 1995).

To date, only a small number of studies have investigated behavioural differences between males and females with ASC. Similar to the findings reported here Lai et al. (2011) found higher levels of autistic traits in females with ASC compared to males on a self-rating scale (the Autism Spectrum Quotient [AQ]; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) but fewer social-communication difficulties on an observational measure (the Autism Diagnostic Observational Schedule [ADOS] (Lord et al., 2000)). Further studies are needed to confirm these findings and to test these different explanations.

for ASC which could help to elucidate the genetic and biological pathways underlying clinical ASC.

Acknowledgements

ES was supported by a PhD studentship from the Open University. SBC was supported by the MRC UK and the Wellcome Trust during the period of this study. BC is supported by the MRC UK. The study was conducted in association with the NIHR CLAHRC for NHS Cambridgeshire and Peterborough Foundation Trust. Preliminary data for this work was presented at the International Meeting for Autism Research, San Diego 2011. We are extremely grateful to all participants that took part.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.neuropsychologia.2012.11.013.

References

Abrahams, B. S., & Geschwind, D. H. (2008). Advances in autism genetics: On the threshold of a new neurobiology. *Nature Reviews Genetics*, *9*(6), 341–355.

Adolphs, R., Sears, L., & Piven, J. (2001). Abnormal processing of social information from faces in autism. *Journal of Cognitive Neuroscience*, *13*(2), 232–240.

Allison, C., Baron-Cohen, S., Wheelwright, S. J., Stone, M. H., & Muncer, S. J. (2011). Psychometric analysis of the empathy quotient (EQ). *Personality and Individual Differences*, *51*, 829–835.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders 4th Edn.—Text revision (DSM-IV-TR)*. Washington, DC: American Psychiatric Association.

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.

Baron-Cohen, S. (1987). Autism and symbolic play. *British Journal of Developmental Psychology*, *5*, 139–148.

Baron-Cohen, S. (1995). *Mindblindess: An essay on autism and theory of mind*. Boston: MIT Press/Bradford Books.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, *6*, 248–254.

Baron-Cohen, S. (2009). Autism: The empathizing–systemizing (E-S) theory. *Year in Cognitive Neuroscience 2009, Annals of the New York Academy of Sciences*, *1156*, 68–80.

Baron-Cohen, S., & Hammer, J. (1997). Parents of children with asperger syndrome: What is the cognitive phenotype? *Journal of Cognitive Neuroscience*, *9*(4), 548–554.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a 'theory of mind'? *Cognition*, *21*, 37–46.

Baron-Cohen, S., & Wheelwright, S. (2004). The Empathy Quotient: An investigation of adults with asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, *34*(2), 163–175.

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.

Bartels, M., Boomsma, D. I., Hudziak, J. J., van Beijsterveldt, T. C. E. M., & van den Oord, E. J. C. G. (2007). Twins and the study of rater (dis)agreement. *Psychological Methods*, *12*(4), 451–466.

Belmonte, M. K., Gomot, M., & Baron-Cohen, S. (2010). Visual attention in autism families: 'Unaffected' sibs share atypical frontal activation. *The Journal of Child Psychology and Psychiatry*, *51*(3), 259–276.

Bölte, S., Duketis, E., Poustka, F., & Holtmann, M. (2011). Sex differences in cognitive domains and their clinical correlates in higher-functioning autism spectrum disorders. *Autism*, *15*(4), 497–511.

Bölte, S., & Poustka, F. (2003). The recognition of facial affect in autistic and schizophrenic subjects and their first-degree relatives. *Psychological Medicine*, 33, 907–915.

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*(5), 877–900.

Brothers, L. (1990). The social brain: A project for integrating primate behaviour and neurophysiology in a new domain. *Concepts in Neuroscience*, *1*, 27–51.

Calder, A. J., Keane, J., Manly, T., Sprengelmeyer, R., Scott, S., Nimmo-Smith, I., et al. (2003). Facial expression recognition across the adult life span. *Neuropsychologia*, *41*, 195–202.

Capps, L., Sigman, M., & Yirmiya, N. (1995). Self-competence and emotional understanding in high-functioning children with autism. *Development and Psychopathology*, *7*, 137–149.

Chakrabarti, B., & Baron-Cohen, S. (2006a). Empathizing: Neurocognitive developmental mechanisms and individual differences. *Progress in Brain Research*, *156*, 403–417.

Chakrabarti, B., Bullmore, E., & Baron-Cohen, S. (2006b). Empathizing with basic emotions: Common and discrete neural substrates. *Social Neuroscience*, *1*(3–4), 364–384.

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.

Darwin, C. (2009). *The expression of the emotions in man and animals*. Harper Collins Publishers (original work published 1872).

Decety, J., & Moriguchi, Y. (2007). The empathic brain and its dysfunction in psychiatric populations: Implications for intervention across different clinical conditions. *BioPsychoSocial Medicine*, *1*, 22.

Ekman, P., & Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, *17*, 124–129.

Field, T. M., Woodson, R., Greenberg, R., & Cohen, D. (1982). Discrimination and imitation of facial expressions by neonates. *Science*, *281*, 179–181.

Freitag, C. M., Staal, W., Klauck, S. M., Duketis, E., & Waltes, R. (2010). Genetics of autistic disorders: Review and clinical implications. *European Child & Adolescent Psychiatry*, *19*(3), 169–178.

Giola, J. V., & Brosgole, L. (1988). Visual and auditory affect recognition in singly diagnosed mentally retarded patients, mentally retarded patients with autism and normal young children. *International Journal of Neuroscience*, *43*, 149–163.

Goeleven, E., De Raedt, R., Leyman, L., & Verschuere, B. (2008). The Karolinska directed emotional faces: A validation study. *Cognition and Emotion*, *22*(6), 1094–1118.

Golan, O., Baron-Cohen, S., & Hill, J. J. (2006). The Cambridge mindreading face-voice battery: Testing complex emotion recognition in adults with and without asperger syndrome. *Journal of Autism and Developmental Disorders*, *36*, 169–183.

Gosling, S. D., Vazire, S., Srivastava, S., & John, O. P. (2004). Should we trust web-based studies? A comparative analysis of six preconceptions about internet questionnaires. *American Psychologist*, *59*(2), 93–104.

Gottesman, I. I., & Gould, T. D. (2003). The endophenotype concept in psychiatry; etymology and strategic intentions. *The American Journal of Psychiatry*, *160*(4), 636–645.

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.

Harms, M., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychology Review*, *20*, 290–322.

Holt, R., & Monaco, A. P. (2011). Links between genetics and pathophysiology in the autism spectrum disorders. *Molecular Medicine*, 3, 438–450.

Howard, M. A., Cowell, P. E., Boucher, J., Broks, P., Mayes, A., Farrant, A., et al. (2000). Convergent neuroanatomical and behavioural evidence of an amygdala hypothesis of autism. *Neuroreport*, *11*(13), 2931–2935.

Isler, J. R., Martien, K. M., Grieve, P. G., Stark, R. I., & Herbert, M. R. (2010). Reduced functional connectivity in visual evoked potentials in children with autism spectrum disorder. *Clinical Neurophysiology*, *121*, 2035–2043.

Lai, M.-C., Lombardo, M. V., Pasco, G., Ruigrok, A. N. V., Wheelwright, S. J., Sadek, S. A., et al. (2011). A behavioral comparison of male and female adults with high functioning autism spectrum conditions. *PLoS One*, *6*(6), e20835, http://dx.doi.org/10.1371/journal.pone.0020835.

Law Smith, M. J., Montagne, B., Perrett, D. I., Gill, M., & Gallagher, L. (2010). Detecting subtle facial emotion recognition deficits in high-functioning autism using dynamic stimuli of varying intensities. *Neuropsychologia*, *48*, 2777–2781.

Lawrence, E. J., Shaw, P., Baker, D., Baron-Cohen, S., & David, A. S. (2004). Measuring empathy: Reliability and validity of the empathy quotient. *Psychological Medicine*, *34*(5), 911–919.

Lee, H., Marvin, A. R., Watson, T., Piggot, J., Law, J. K., & Law, P. A. (2010). Accuracy of phenotyping of autistic children based on internet implemented parent report. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics*, *153B*(6), 1119–1126.

Leslie, A. M. (1987). Pretense and representation: the origins of 'theory of mind'. *Psychological Review*, *94*, 412–426.

Leslie, A. M., & Frith, U. (1988). Autistic children's understanding of seeing, knowing and believing. *British Journal of Developmental Psychology*, *6*, 315–324.

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*(3), 205–223.

Losh, M., Adolphs, R., Poe, M. D., Couture, S., Penn, D., Baranek, G. T., et al. (2009). Neuropsychological profile of autism and the broad autism phenotype. *Archives of General Psychiatry*, *66*(5), 518–526.

Loveland, K. A., TunaliKotoski, B., Chen, Y. R., Ortegon, J., Pearson, D. A., Brelsford, K. A., et al. (1997). Emotion recognition in autism: Verbal and non-verbal information. *Development and Psychopathology*, *9*(3), 579–593.