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ORIGINAL PAPER

Recognition of Emotions in Autism: A Formal Meta-Analysis

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Abstract Determining the integrity of emotion recognition in autistic spectrum disorder is important to our theoretical understanding of autism and to teaching social skills. Previous studies have reported both positive and negative results. Here, we take a formal meta-analytic approach, bringing together data from 48 papers testing over 980 participants with autism. Results show there is an emotion recognition difficulty in autism, with a mean effect size of 0.80 which reduces to 0.41 when a correction for publication bias is applied. Recognition of happiness was only marginally impaired in autism, but recognition of fear was marginally worse than recognition of happiness. This meta-analysis provides an opportunity to survey the state of emotion recognition research in autism and to outline potential future directions.

Keywords Autism · Emotion · Face · Meta-analysis · Social

Introduction

In Kanner's original (1943) description of autism, he considered this condition to be an ''example of inborn autistic disturbances of affective contact''. Over 60 years later, the role of emotion in autism is still debated. Current ICD-10 and DSM-IV criteria for diagnosis of autistic spectrum condition (ASC) list marked impairments in the use of facial expression, body postures, and gestures to regulate social interaction; the lack of mutual sharing of emotions, impaired or deviant response to other people's emotions and the lack of spontaneous seeking to share enjoyment, among other symptoms. These difficulties in using, sharing and responding to emotions correspond roughly to two of the three components of emotion processing (as defined by Begeer et al. 2008; Herba and Phillips 2004; Phillips et al. 2003), namely production of an emotional state and regulation of that state. Diagnostic criteria for autism do not require a difficulty in the first of Philips's components; the identification of emotional cues. Nevertheless, it is commonly assumed that emotion recognition difficulties are present in individuals with ASC.

In typical children, recognition of emotional facial expressions is an early developing social skill. Walker-Andrews (1998) found that 4-month-old infants were able to discriminate between expressions of anger, fear, sadness, happiness and surprise when those expressions were presented in a familiar context and that their reactions were specific for particular emotional expressions. Also, between 8 and 10 months infants begin to use emotional expressions for social referencing (Camras and Shutter 2010). Emotional expressions are a basic source of information about the sender's current emotional state (Ekman 1992), intentions (Adams et al. 2006) and about important objects and events in the environment (Moses et al. 2001; Olsson et al. 2007).

Failure of these fundamental early emotion recognition skills would have profound consequences for a child's social development, cutting the child off from learning

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about other people's feelings and responses. Thus, it has been suggested that emotion reading might be a primary difficulty in autism (Hobson 1986a, b). Some interventions for autism specifically teach emotion recognition skills (Golan et al. 2010; Hopkins et al. 2011). However, despite numerous studies, there is not yet any consensus whether if basic emotion recognition is a fundamental and universal difficulty for individuals with ASC or not. The following brief review provides a summary of some of the research conducted (see Harms et al. 2010 for a more detailed approach).

Early work on emotion matching suggested that participants with autism have difficulty matching emotional facial expressions to emotional body actions, contexts or line drawings (Hobson 1986a, b; Hobson et al. 1988; Weeks and Hobson 1987; Braverman et al. 1989). However, a detailed study with well-matched participant groups did not find any evidence for basic emotion recognition difficulties (Ozonoff et al. 1990). Research turned to the idea that participants with autism might have difficulties in the recognition of just some of the six basic emotions rather than a generalised deficit. Baron-Cohen et al. (1993) suggested that theory of mind difficulties in autism could cause selective difficulties in recognizing surprise, and found some evidence in favour. However, other studies have failed to replicate this finding (Baron-Cohen et al. 1997; Castelli 2005; Spezio et al. 2007). Other studies suggest fear recognition is most difficult for individuals with autism (Ashwin et al. 2006; Corden et al. 2008; Howard et al. 2000; Humphreys et al. 2007; Pelphrey et al. 2002; Wallace et al. 2008). Difficulties have also been reported in other negative emotions (anger: Ashwin et al. 2006; disgust: Wallace et al. 2008; Humphreys et al. 2007; Ashwin et al. 2006; sadness: Boraston et al. 2007; Corden et al. 2008; Wallace et al. 2008). However, there are also published studies that did not find impairments in the recognition of fear and other negative emotions (Lacroix et al. 2009; Piggot et al. 2004) or found deficits in the recognition of positive emotions as well (Humphreys et al. 2007).

Research on generalised emotion recognition difficulties in ASC has also continued, with very mixed results. Published studies have found generalised deficits on various emotion reading tasks (Corbett et al. 2009; Davies et al. 1994; Loveland et al. 2008; Tantam et al. 1989). However, there are also a significant number of papers reporting no differences between typical and autistic participants (Baron-Cohen et al. 1997; Castelli 2005; Da Fonseca et al. 2009; Jones et al. 2011; Lacroix et al. 2009; Neumann et al. 2006; Ozonoff et al. 1990; Piggot et al. 2004; Spezio et al. 2007). These include some of the studies with the closest match between participant groups (Ozonoff et al. 1990) and studies with large sample sizes (Jones et al. 2011; Loveland et al. 2008).

Thus, the overall picture of emotion reading in autism is very mixed. The interpretation is further complicated by the large variability between studies in sample size, task, participant characteristics and group matching. Published studies have sample sizes ranging from only 5 participants up to 97, and it is possible that many studies are underpowered. Different tasks have also been used, but positive and negative results have been found in both emotion labelling tasks which might rely on verbal skills and in emotion matching tasks which are non-verbal. Some have suggested that subtle or difficult tasks are required to reveal emotion reading difficulties (Clark et al. 2008; Humphreys et al. 2007; Law Smith et al. 2010). Again, other studies show good performance by autistic children even in subtle tasks (Castelli 2005; Tracy et al. 2011). Finally, it has been suggested that deficits in emotion recognition are only evident when the autistic group is not carefully matched with the control group (Ozonoff et al. 1990). However, although this fact might explain findings on some earlier studies (Tantam et al. 1989), more recent research has addressed this issue more carefully (Humphreys et al. 2007; Wallace et al. 2008).

This brief narrative review demonstrates that there are currently no straightforward answers in research on emotion recognition in autism. It is not clear if individuals with autism spectrum disorder are impaired in their ability to read basic emotional expressions. Furthermore, if such impairment does exist, it is not clear if all emotions are equally affected or whether reading of certain emotions might be spared or impaired to a lesser extent. Ozonoff et al. (1990) suggested that for the emotion reading impairment to be considered a fundamental deficit in autism, impairments should be apparent across studies, paradigms and control groups. One way to test this is to conduct a formal meta-analysis.

Meta-analysis uses a strict set of search criteria to enable identification of all possible and relevant research studies published on the subject of interest. Inclusion and exclusion criteria are clearly stated and this together with comprehensive search minimizes the risk of bias. Statistical analysis of effect sizes for each study weighted by the sample size of the study provides numerical estimates of overall effect size, as well as the impact of moderator variables and the possibility of publication bias. By analyzing large collections of data from individual studies, meta-analysis can overcome the problem of heterogeneity in results due to small sample size and heterogeneity in study characteristics (Egger 1997a; Green 2005; Van den Noortgate and Onghena 2006). The present paper uses a formal meta-analytic approach to examine the question of emotion recognition in autism based on the existing literature. This approach allows us to systematically summarise and integrate the findings of multiple studies, and thus assess the general question of emotion reading in autism. We focus on emotion reading from visual stimuli because these are most studied, and aim to determine if deficits in reading visual emotions are present across age, IQ and task in autism, and if such difficulties are equivalent in magnitude across different emotions.

Methods

Literature Search

In order to find eligible studies, we searched Web of Science, PsychINFO and PubMed using combinations of the following terms: autism, Asperger syndrome, pervasive developmental disorders, emotion recognition, emotion perception, facial expression, facial affect, face, body. Additional searches of relevant journals (Journal of Autism and Developmental Disorders, Autism, The Journal of Child Psychology and Psychiatry, Journal of Child Psychology and Psychiatry, Developmental Psychopathology) were performed. Also we searched the reference list of review articles and lists of publications of researchers working in this field. Studies published after December 2011 were not included.

Inclusion Criteria

We included studies published in English comparing a group of participants formally diagnosed with ASC and a group of typically developed subjects. Master and doctoral theses and conference presentations were not included. We limited our analysis to studies examining recognition of emotions presented in the visual modality. Information regarding the accuracy on behavioural tasks had to be available in order for study to be included. We included all studies examining more than one of the six standard emotions: fear, surprise, anger, disgust, happiness and surprise expressed by face and body (Ekman and Friesen 1976; Prinz 2004). Complex or social emotions and recognition of emotional hand gestures were excluded. Neuroimaging, electroencephalograhic, eye-tracking and physiological studies were also included if they employed behavioural tasks that met above mentioned criteria. Figure 1 provides an overview of the selection process, and Table 3 of supplementary information lists the 59 articles which were excluded with details of why.

Coding and Analysis

Each study was initially coded by the first author and coding was then checked by the second author. Studies were coded for the following variables:

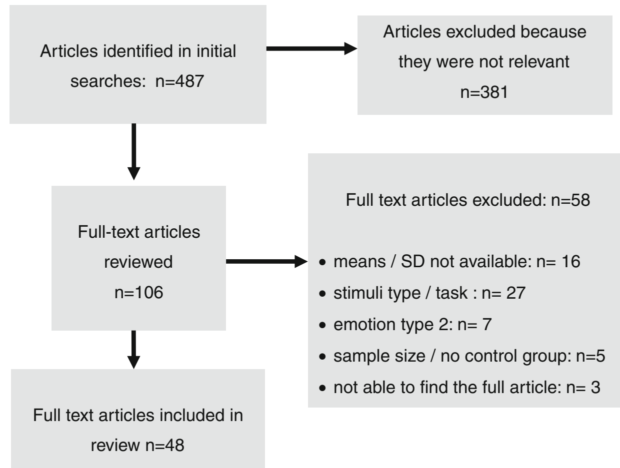

Fig. 1 Selection process. This *chart* indicates how papers were selected for inclusion in the meta-analysis. Articles were excluded if they were not relevant (e.g. did not examine participants with autism, did not examine recognition of emotion, were review articles, were not published in English)

1. Number/gender of participants in autistic and control groups;
2. Diagnosis and tools used for diagnosis;
3. Mean age and standard deviation of participants in autistic and control groups;
4. Level of function of participants—this included mental age (verbal and non verbal) intelligence (full scale, verbal and performance) and instruments used;
5. Type of task: we classified tasks as emotion labelling (EL) which could be forced choice or free choice, emotion matching (EM) or a different task (detailed in Table 1 of supplementary information).
6. Stimuli: whether stimuli showed faces or bodies, and whether they were static or dynamic. For face stimuli, the source and style of stimuli was noted.
7. Emotions: we focused on ''the big six'' (Ekman and Friesen 1976; Prinz 2004): happiness, anger, fear, disgust, sadness, surprise and not on the emotions later included in this category (amusement, embarrassment, excitement, pride, pride, shame, relief …).

We coded the results of each study in terms of the mean correct performance of each group and the standard deviation of correct performance, rather than reaction time or neurophysiological measures. Reaction time data was not coded because many studies did not collect this data, but this does limit the sensitivity of our analysis. Where performance measures had been recorded but full data was not present in the paper (e.g. data was plotted but not listed as numbers), we contacted the authors to obtain the groups means and standard deviations. We are grateful to all authors who responded to our requests. Using the mean and SD data, we calculated Hedge's d, a measure of effect size that is equivalent to Cohen's d but includes a correction for small sample sizes (Hedges 1981). Studies that did not report means and standard deviations of behavioural performance for each group could not be included, but are listed in Table 3 of supplementary information. Where studies reported performance data for individual emotions separately, we recorded this data (Table 2 of supplementary information) to enable an analysis of differences in recognition performance for different emotions. Again, data was summarised in terms of Hedge's d and the variance of d. Supplementary data 4 lists the full references of all studies in the meta-analysis.

Some studies reported more than one analysis of the same ASC participant group. For example, the same participants might have completed an emotion-matching and an emotion-labelling task or might be matched to one typical group on verbal mental age and to another typical group on non-verbal mental age. Each of these results is listed as a separate row in Table 1 of supplementary information. However, it would not be appropriate to include data from exactly the same autism sample several times in the meta-analysis, so we had to select only one result from each study for further consideration. The comparisons which were included are marked with a star in Table 1 of supplementary information. Where studies tested the same group of participants on multiple tasks, we included the Emotion Labelling task (EL) in preference to others, and Static stimuli in preference to dynamic. This selection was made because these were the most common tasks/stimuli, and we wanted to reduce heterogeneity in our results. Analysis using the less common task/stimuli where possible did not change our results substantially. Where multiple comparison groups were present in a study, we included the group matched for verbal abilities in preference to a non-verbal match.

We conducted three analyses on the effect size data. First, analysis of effect size and assessment of the role of moderator variables (participant age and IQ) was conducted using MetaWin 2.0 (Rosenberg et al. 2007). This allows us to answer the general question of whether participants with autism do show emotion recognition difficulties and to obtain confidence limits on this answer. Second, analysis of possible publication bias and the implementation of the trim-and-fill method for ameliorating publication bias (Duval and Tweedie 2000) was implemented using the Meta package in R (Schwarzer 2007; http://cran.r-project.org/web/packages/meta/index.html). This allows an initial assessment of whether unpublished data on emotion recognition (likely to have null results) is an important issue in this area. Finally, we examined effect sizes in the 16 studies which reported data from individual emotions. Here we used conventional ANOVA and *t* tests in SPSS to determine if there were difference in effect size between different emotions.

Results

48 papers published from 1989 to 2011, which tested 932 participants with autism met our criteria (see Fig. 1 for the description of selection process and Table 3 of supplementary information for the list of excluded studies). Table 1 of supplementary information presents a list of the studies that were included in our analysis. Twenty eight comparisons used the Ekman facial affect set of stimuli and 46 used different stimuli. 65 comparisons used static faces and 10 used dynamic stimuli. 38 comparisons used an emotion labelling task (32 forced and 6 free labelling task), 23 used an emotional face matching task and the remaining 12 used other tasks. 63 comparisons examined recognition of facial emotions, while 7 comparisons used body emotion and 8 used emotional context tasks. Sample sizes ranged from 5 (Pelphrey et al. 2002) to 97 (Jones et al. 2011). Mean age of participant's ranged from 6 to 41 years, and mean FSIQs ranged from 40 to 130. Thus, our meta-analysis covers the full range of ages, IQs and emotion recognition tasks which are encountered in the research literature.

General Emotion-Recognition Difficulties in ASC

For this analysis, we included 50 comparisons that examined emotion recognition without overlap in the participant groups. From a random effects analysis of overall effect size, we found a mean effect size of −0.800, with 95 % confidence limits from −0.57 to −0.99. Negative effect sizes indicate worse performance by the autism group. This is a large effect size (Cohen 1988) and indicates that overall, individuals with autism do have difficulties in emotion recognition. The studies also had substantial heterogeneity (Q total = 77.83, $df = 49$, $p = 0.0054$), indicating that effect sizes were not uniform across studies (Gurevitch and Hedges 1999).

We considered the impact of two moderator variables on emotion recognition—the mean age of the autism sample and the mean IQ of the autism sample. Two outlier studies with very large negative effect sizes which were more than 2 standard deviations from the mean effect size (visible on the left of Fig. 2; Da Fonseca et al. 2009; Gepner et al. 1996) were excluded from this analysis. There were no significant effects of age (slope = −0.01, $p = 0.24$) or of IQ (slope = −0.004, $p = 0.27$) on effect size.

To examine effects of task, we compared 34 studies which used an emotion-labelling task to 13 studies which used an emotion matching task. Again, the two outlier studies were excluded. Effect size was −0.68 for emotion-matching and −0.70 for emotion labelling, with no difference between tasks (Q = 0.007, $df = 1{,}46$, $p = 0.93$). Thus, there was no evidence for systematic effects of task.

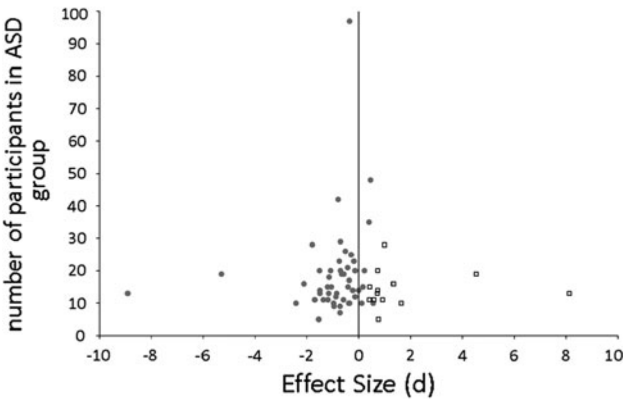

Fig. 2 Funnel Plot. Effect size for each study (Cohen's d) is plotted against the number of participants with autism in that study. *Filled circles* indicate studies in the meta-analysis. *Open squares* indicate studies inferred in the trim-and-fill analysis

The Impact of Publication Bias

Publication bias, arising when studies with null findings are not published, is an important issue to consider in any meta-analysis. As an initial tests of publication bias, we plotted effect sizes against the number of autistic participants in a funnel plot (Egger et al. 1997b) (Fig. 2, solid circles). The clear asymmetry in the funnel plot, with the majority of studies to the left of the plot, suggests that publication bias may be an issue. Thus, we implemented Duval & Tweedie's trim-and-fill method, which estimated an additional 13 'missing studies' (open squares in Fig. 2). Repeating our standard random effects analysis with these filled studies gave an estimated effect size of −0.414, with 95 % confident limits from −0.646 to −0.182 and a *p* value of 0.0005. Thus even after trim-and-fill, the overall effect size for the recognition of emotions by participants with autism is negative with confidence limits that do not span zero. It is important to note that the magnitude of the effect after trim-and-fill is substantially smaller than the raw estimate. Figure 1 also illustrates how the majority of published studies have small participant groups, with only 13 studies out of 45 testing 20 or more participants, and that the largest study reports an effect size close to zero.

Differences Between Individual Emotions

16 studies were available with data on the recognition of different emotions in individuals with autism (see Table 2 of supplementary information). These tested 379 participants with autism and most examined adults. Three of these studies used more than one task on the same participant sample, so all results are listed but only one comparison from each study was included in the meta-analysis. All six individual emotions showed negative effect sizes. For five emotions (sadness, anger, surprise, fear, disgust), the 95 % confidence intervals were entirely in the negative range, suggesting that adults with ASC have difficulty with recognition of each of these individual emotions. However, the 95 % confidence intervals for happiness spanned zero, demonstrating no reliable difficulty in the recognition of happiness across these studies (Fig. 2). As the confidence limits came close to zero, it is possible that there is a marginal difficulty in the recognition of happiness which would be revealed with more subtle measures such as reaction time.

Comparison between different emotions was complicated by the fact that only eight of these studies tested all six emotions (Table 2 of supplementary information). An ANOVA across the effect sizes found in these eight studies revealed no significant effects of emotion ($F = 1.89$; $df = 5,35$; $p = 0.12$). This is congruent with Fig. 3 which shows overlapping confidence intervals between all emotions. To allow all the original data to be considered, we decided to compare each emotion to Happiness as a baseline emotion. Unfortunately, there was not enough data on recognition of neutral faces (the more traditional baseline) to use this option. Happiness makes a suitable baseline because no theoretical accounts suggest a specific impairment in happiness, and because all studies tested this item. We performed paired-sample *t* tests comparing the effect size for each other emotion to the effect size for happiness. Results revealed no difference for sadness ($p = 0.36$, $df = 15$, $t = 0.94$), surprise ($p = 0.14$, $df = 10$, $t = 1.6$), disgust ($p = 0.32$, $df = 9$, $t = 1.06$) or anger ($p = 0.069$, $df = 14$, $t = 1.97$). Recognition of fear ($p = 0.044$, $df = 12$, $t = 2.248$) was significantly worse than recognition of happiness, but as this result would not survive Bonferroni correction for 5 comparisons ($p < 0.01$), it must be considered marginal.

Discussion

This paper used formal meta-analysis to examine whether individuals with autism spectrum disorders show general emotion recognition deficits. We examined 48 studies testing over 930 participants with autism, and found evidence of a large negative effect size (−0.80) indicating that there is indeed a general impairment in emotion recognition in individuals with ASC. This effect size was substantially reduced (to −0.41) but still significantly different from zero when a correction for publication bias was included. Participant age, IQ and task had no impact on performance. There was marginal evidence for differences between emotions, with confidence limits for recognition of happiness spanning zero, and marginally worse recognition of fear than happiness. Based on these results, we discuss general methodological issues in emotion research

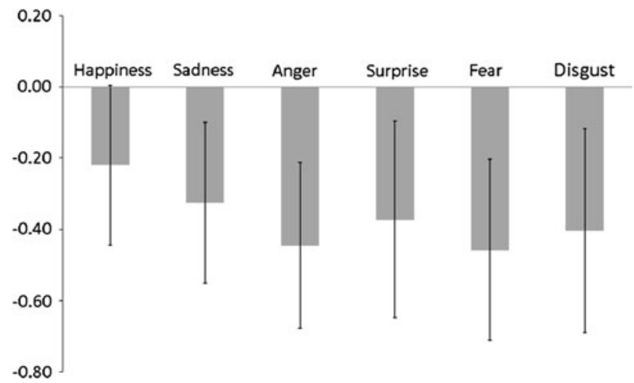

Fig. 3 Effect size for different emotions. Mean effect size (±95 % confidence limits) are plotted for each of the six basic emotions. Data are from Table 2 of supplementary information

and then consider the impact of age, IQ, task and the different emotions tested on performance by participants with autism. Finally, we highlight useful directions for further research.

Methodological Issues

The question of how best to examine atypical development of cognitive abilities is not an easy one to answer (Charman et al. 1998; Johnson et al. 2002; Thomas et al. 2009) and our overview of the literature raises several important points. First, the issue of publication bias (Dickersin 1990) is likely to be important in autism-emotion research. Publication of null effects tends to be harder than publication of positive results, and it is plausible that studies with small groups and null findings (or better performance in the autism group) remain hidden in university filing cabinets around the world. Even in cases where results are published, statistical tests that did not yield significant results (at $p < 0.05$) are sometimes not reported in detail. Of the 58 comparisons in Table 3 of supplementary information (which did not provide detailed results), 22 reported either no differences, mixed results or subtle differences between typical and autistic groups. In contrast, the studies in Table 1 of supplementary information (which did provide detailed results) reported significant findings in the vast majority of cases. This suggests a bias in reporting statistics even within published papers, and motivates us to strongly encourage researchers to report in full the results of the statistical tests they conducted, even when not significant.

Second, of the 48 studies in Table 1 of supplementary information, only 31 % (15 studies) tested groups with 20 or more participants. However, a straightforward power analysis suggests that detection of a large group difference (effect size = 0.8) between two independent populations with a power of 0.95 requires 35 participants in each group. This suggests that the vast majority of studies examining emotion recognition in autism are underpowered. This is where a meta-analysis of the form conducted here can add substantially to the existing literature. Notably, the two largest studies in our sample (Jones et al. 2011; Loveland et al. 2008), which examined 97 and 80 autistic participants, respectively, both found no evidence of group differences in emotion recognition.

We used Duval & Tweedie's trim-and-fill method to attempt to correct for publication bias, and this analysis 'filled in' an additional 13 results. After filling-in, the overall effect size for the emotion recognition deficit in autism remained significantly different from zero but was small (0.40). Power analysis suggests that groups of over 135 participants would be needed to reliably detect such an effect in a simple comparison of typical and autistic participants, but no researchers have yet attempted such an ambitious task. However, we note a trend for larger sample sizes in more recent studies and hope this continues.

Age, IQ and Task Factors

Our meta-analysis shows that the question of emotion recognition in autism is an active one which continues to attract research 25 years after the first studies on the topic. With over 100 articles published on the topic of emotion processing in autism, it might seem surprising that this question still remains unresolved. One possible explanation for this might be the heterogeneity of tasks and participant groups involved in different research studies. Our studies covered a wide age range but did not reveal any effects of age or IQ on emotion recognition performance. This suggests that emotion recognition difficulties are not specific to any particular subgroup of individuals with autism (e.g. lower functioning individuals), and that there were no substantial changes in recognition performance with age. This does not mean that individuals cannot improve as they grow older, but rather that the population as a whole does not improve. We also note that this lack of an IQ effect does not mean that there is no relationship between IQ and emotion processing. Many studies in the meta-analysis match participant groups on the basis of their IQ, so these studies can at best show participants with ASC performing at the level expects for their mental age, not at the same level as individuals with the same chronological age. Second, several studies in the meta-analysis provide only very limited IQ information. Thus, further research would be needed to define how intellectual capacity relates to emotion processing.

Another important issue in considering the role of IQ and level of functioning in emotion processing is the possibility of subgroups within the autism spectrum having different capabilities. The autism spectrum can be divided into classical autism, high-functioning autism, Asperger's syndrome and pervasive developmental disorder not otherwise specified (PDD-NOS) though the meaning of these categories is under debate (Lord and Jones 2012; Mandy et al. 2012). It is possible that emotion processing is abnormal in just some of these groups but not others. Unfortunately, the papers reviewed in this meta-analysis used a variety of diagnostic tools and few distinguish between these different subgroups of autism. Thus, it was not feasible to examine emotion recognition within specific subgroups. This would be an interesting topic for future studies.

Differences in the tasks used to assess emotion recognition could also contribute to the heterogeneity of results. In the studies we examined, 38 comparisons used an emotion labelling while 23 used an emotion matching task and 12 used other tasks. In a typical matching task, participants are asked to match pictures with a target picture where correct choice expresses the same emotion as the target but differs in other features such as identity or angle of view. In emotion labelling tasks participants are shown images or videos of emotional displays and are asked to either choose an item from a short, pre-specified list (forced choice format) or to come up with an emotion term (free labelling format) for what is portrayed on the picture.

While it is often assumed that both labelling and matching tasks tap the same core emotion recognition systems, there are important differences between them (Hariri et al. 2000; Herba and Phillips 2004; Phan et al. 2002). Matching tasks could be completed based on surface characteristics of the stimuli without a full understanding of the emotion. Thus, these tasks might lack sensitivity and allow individuals with autism to use compensatory strategies (Celani et al. 1999; Fein et al. 1992; Klin et al. 2002; Teunisse and de Gelder 2001). Labelling tasks require good verbal skills, especially in free-labelling conditions, but forced choice labelling may allow participants to guess a correct answer (Russell et al. 2003). Our meta-analysis did not find any evidence for overall differences in performance between emotion labelling and emotion matching tasks. This suggests that the difficulties experienced by ASC participants in these tasks are due to emotion processing and not to the linguistic or perceptual demands of these different tasks.

Role of Different Emotions

We analysed recognition of individual emotions in 16 studies that provided sufficient data and found that ASC individuals had difficulties in the recognition of five basic emotions but did not have difficulties in recognition of happiness (there may be a marginal difficulty here because confidence limits only just span zero). There was tentative evidence for worse recognition of fear than of happiness, but no differences between happiness and sadness, surprise or disgust. One limitation of these results is that there was not enough data on the recognition of neutral faces for this category to contribute to our analysis. This means that we lack the ideal baseline, and had to use happiness as a 'baseline' emotion because this was the only emotion tested in all the studies examined. With these caveats, there are two important implications to these results. First, if recognition of happiness is not impaired in autism, this argues against the idea that poor emotion recognition is universal and primary in autism. Second, if recognition of fear is worse than recognition of happiness, this favours theories that link autism to poor eye contact and poor fear processing in the amygdala. We consider each of these in turn.

The finding that recognition of happiness is only borderline-impaired in autism might seem contrary to the global meta-analysis which found an overall recognition deficit. Mean effect size for happiness recognition was negative and the confidence limits only just spanned zero, suggesting there might be a marginal difference. Thus, it might be tempting to argue that more studies would reveal a true happiness recognition deficit. However, if publication bias is a factor, and our analysis above suggests this is likely, then studies reporting group differences in emotion recognition are more likely to be published than those which do not. This means that current estimates of effect size may be inflated, and future studies might decrease our estimate of effect size in happiness recognition and solidify the conclusion that recognition of this emotion is intact in autism. This is an important result because it suggests we should rule out theories that claim a global emotion recognition difficulty is primary and universal in autism. Rather, difficulties with emotion processing must be specific to particular emotions or stimuli.

A hint of specific difficulties was seen in the comparison of happiness recognition to fear recognition, where a marginally significant difference was found. Several theories link predict poor fear processing in autism, drawing on neurological or behavioural explanations. In neurological terms, it has been suggested that the amygdala has a specific role in the processing of fear (Adolphs 2008) and negative emotions in general (Adolphs et al. 1999; Anderson et al. 2000). Dysfunction of the amygdala in autism could cause poor recognition of fear and other negative emotions (Ashwin et al. 2006; Baron-Cohen et al. 2000; Howard et al. 2000), which is compatible with our data. Dysfunction of the amygdala in autism might lead to a lack of orienting to social stimuli, in particular to the eyes in a face (Neumann et al. 2006; Spezio et al. 2007). For example, several studies have found reduced attention to the eyes (Boraston et al. 2007; Dalton et al. 2005; Klin et al. 2002; Pelphrey et al. 2002) and increased attention to the mouth region (Joseph and Tanaka 2003) in ASC, though contradictory results have been reported (Lopez et al. 2004; Van Der Geest et al. 2002). Processing of the eye region is particularly relevant to the recognition of fear, which requires attention to eyes and eye-brows (Dimberg and Petterson 2000; Dimberg and Thunberg 1998; Ekman 2004; Smith et al. 2005). In contrast, processing of the mouth region could be sufficient to judge happiness, which seems easier for participants with autism. Thus, amygdala dysfunction in autism could lead to reduced fixation on the eyes and to a difficulty in fear and anger recognition (Adolphs et al. 2005) together with better happiness recognition.

While this explanation is appealing, it is complicated by some results which suggest no difference between typical and autistic amygdala activity during emotion labelling and matching tasks (Piggot et al. 2004). There is also evidence that the amygdala is does not respond only to fear, but functions as a 'motivational relevance detector' (Whalen 2007), which responds to positive and ambiguous stimuli as well (Phan et al. 2002; Whalen 2007). Thus, the status of an amygdala explanation of poor fear recognition in autism remains unclear.

Finally, our data provide evidence against one particular emotion-specific account of autism. At least some formulations of the Theory of Mind hypothesis predict a specific deficit in recognition of surprise in autism (Baron-Cohen et al. 1993). Of the six basic emotions, surprise is the only one that requires assessment of another person's mental state (he expected something different, he is surprised). This means that if mental state judgements are impaired in autism and are required for processing of surprised facial expressions, then recognition of surprise might be specifically impaired. However, our results did not provide any evidence that surprise recognition is more difficult than recognition of any other emotions.

Future Directions

Ozonoff et al. (1990) suggested that for the emotion recognition difficulties to be considered a fundamental deficit in autism, impairments should be apparent across studies, paradigms and control groups. The data reviewed here do not strongly support a global emotion recognition impairment, because recognition of happiness was (just) intact across the studies we sampled. However, even a meta-analysis of this scale is fundamentally limited by the quality of the input data. Thus, issues such as sample size, group matching and the tasks used are critical (Burack et al. 2004; Harms et al. 2010; Jarrold and Brock 2004; Mervis and Klein-Tasman 2004). Based on the studies reviewed, we would encourage researchers in the field to use larger sample sizes in order to increase the reliability and replicability of data. We would also strongly encourage full reporting of results (in tables, not just graphs) and of all statistical tests, even those which were not formally significant. Lack of full data substantially reduced the sample of published papers which could contribute to this meta-analysis (Table 3 of supplementary information).

Despite over 20 years of research, the status of emotion recognition in autism remains uncertain and the present meta-analysis highlights some possibilities. One important question is the role of timing in emotion recognition—individuals with autism might be slower to recognise emotions, or might have more difficulty with dynamically moving faces which have higher ecological validity than static photos. Examining emotion recognition in dynamic, time constrained and realistic contexts will be an important focus of future research. A second key area to focus on is potential differences in the recognition of different emotions, which has both theoretical and practical implications. Our results provide tentative evidence for poorer recognition of negative emotion, but further work testing different emotions in large participant groups and in combination with neuroimaging and eye tracking methods would be valuable. In particular, it is critical to determine the contribution of specific brain regions and abnormal eye scanning patterns to differences in recognition of different emotions. Addressing these questions will require more ambitious and large scale studies than cognitive scientists are accustomed to, but will provide critical insights into the origins of poor social cognition in autism, and the relationship between brain, development and social information processing.

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