Available online at www.sciencedirect.com
SCIENCE DIRECT®
Brain and Cognition 61 (2006) 78–95
Brain and Cognition
www.elsevier.com/locate/b&c

Finding a face in the crowd: Testing the anger superiority effect in Asperger Syndrome

Chris Ashwin *, Sally Wheelwright, Simon Baron-Cohen

Autism Research Centre, Department of Psychiatry, University of Cambridge, Douglas House, 18b Trumpington Road, Cambridge CB2 2AH, UK

Accepted 9 December 2005
Available online 7 February 2006

Abstract

Social threat captures attention and is processed rapidly and efficiently, with many lines of research showing involvement of the amygdala. Visual search paradigms looking at social threat have shown angry faces 'pop-out' in a crowd, compared to happy faces. Autism and Asperger Syndrome (AS) are neurodevelopmental conditions characterised by social deficits, abnormal face processing, and amygdala dysfunction. We tested adults with high-functioning autism (HFA) and AS using a facial visual search paradigm with schematic neutral and emotional faces. We found, contrary to predictions, that people with HFA/AS performed similarly to controls in many conditions. However, the effect was reduced in the HFA/AS group when using widely varying crowd sizes and when faces were inverted, suggesting a difference in face-processing style may be evident even with simple schematic faces. We conclude there are intact threat detection mechanisms in AS, under simple and predictable conditions, but that like other face-perception tasks, the visual search of threat faces task reveals atypical face-processing in HFA/AS.

Keywords: Asperger Syndrome; Autism; Face-processing; Visual search; Emotions; Amygdala

1. Introduction

Faces are one of the most important visual stimuli and are potent facilitators for social interaction and communication. Facial expressions of emotion convey critical signals for inferences about the intentions and motivations of others (Blair, 2003; Darwin, 1872/1965). Although faces provide a wealth of information, people are generally able to extract important information rapidly and efficiently and to produce appropriate responses. Humans are so adept at various aspects of face processing it is suggested we may have evolved special face processing modules (Ekman, 2003; Young, 1998).

However, not all humans are proficient at face processing. Autism and Asperger Syndrome (AS) are neurodevelopmental conditions characterised by severe social and communication difficulties, as well as restricted behaviours and interests (APA, 1994; ICD-10, 1994). From the earliest descriptions of these disorders, striking abnormalities were noted in social-emotional behaviour including difficulties with face processing and social interactions (Asperger, 1944; Kanner, 1943). Face-processing deficits are likely to relate to the social difficulties, in that people with autism spectrum conditions (ASC) have not developed the same expertise with faces as typical controls (Grelotti et al., 2005). Various differences have been reported about how people with ASC process faces. For example, while typically developing people normally use a more holistic style when processing faces and emotional expressions (Tanaka & Farah, 1993; Yin, 1969), people with autism rely on a more feature-based style of processing faces (Hobson, Ouston, & Lee, 1988; Langdell, 1978; Weeks & Hobson, 1987). People with ASC also focus their attention more on the mouth region when processing faces, while typical controls rely on the eye region that provides more information about the

* Corresponding author. Fax: +44 01223 746033.
E-mail address: ca235@cam.ac.uk (C. Ashwin).
URL: http://www.autismresearchcentre.com (C. Ashwin).

0278-2626/$ - see front matter
doi:10.1016/j.bandc.2005.12.008

emotional states of others (Baron-Cohen, Wheelwright, & Jolliffe, 1997; Joseph & Tanaka, 2003; Weeks & Hobson, 1987).

Results concerning emotional expression processing in ASC have been less consistent and suggest an uneven profile. People with ASC show difficulties on tasks with complex mental states and emotions (Baron-Cohen, Spitz, & Cross, 1993; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen et al., 1997), whereas their accuracy in recognising basic emotions may be intact, particularly when high-functioning participants are studied (Adolphs, Sears, & Piven, 2000; Baron-Cohen et al., 1997; Golan, Baron-Cohen, & Hill, in press; Grossman, Klin, Carter, & Volkmar, 2000; Volkmar, Sparrow, Rende, & Cohen, 1989). However, other studies have reported deficits by people with autism in processing basic emotions (Bolte & Poustka, 2003; Celani, Battacchi, & Arcidiacono, 1999; Howard et al., 2000), somewhat confusing the current understanding of emotion recognition in autism (Frith, 2003). Research involving the more automatic and implicit emotional processing mechanisms in people with ASC has been lacking. When task variables and procedures are kept simple and predictable, people with autism show evidence of normal configural face-processing strategies (Joseph & Tanaka, 2003; Teunisse & de Gelder, 2003). These findings suggest that the ability to process faces using configural or holistic processing styles may not be completely absent in ASC, rather that people with these conditions are just more likely to process information using a 'cognitive style' characterised by enhanced local feature detection over holistic processing (Frith, 2003; Happe, 1999).

Facial expressions of emotion are important for nonverbal communication, and facial threat is a particularly potent social signal. The emotional expression of anger is a typical example and is a very potent facial warning signal. Threatening facial expressions have considerable power to recruit attention and are processed rapidly and efficiently (Vuilleumier & Schwartz, 2001). Neuroimaging experiments have shown that angry and fearful expression faces activate the amygdala (Breiter et al., 1996; Morris et al., 1996; Phillips et al., 1998), a brain area important for detecting threat and producing appropriate responses (Aggleton, 2000; LeDoux, 1996). The amygdala activation occurs even when threatening faces are masked and below the level of awareness (Morris, Ohman, & Dolan, 1998; Whalen et al., 1998), demonstrating a quick and direct subcortical route to the amygdala for automatic processing of threat (Morris, Ohman, & Dolan, 1999).

These findings are consistent with investigations of humans with amygdala damage, who show deficits in perceiving fearful expressions (Adolphs, Tranel, Damasio, & Damasio, 1995; Adolphs et al., 1999; Calder et al., 1996). Amygdala patients also judge people rated negatively by typical controls as being more trustworthy and approachable (Adolphs, Tranel, & Damasio, 1998), and do not show the enhanced perception of emotionally significant stimuli normally seen in control participants (Anderson & Phelps, 2001). The face-processing deficits seen in amygdala patients are similar in some ways to emotion processing deficits seen in people with ASC, including reports that the deficits may involve complex emotions more than basic emotions (Adolphs, Baron-Cohen, & Tranel, 2002; Adolphs et al., 2000; Baron-Cohen et al., 1997; Golan et al., in press). Neuroimaging studies of people with ASC have shown decreased amygdala activation while processing faces, including threatening expressions (Ashwin, Baron-Cohen, Wheelwright, O'Riordan, & Bullmore, in press; Baron-Cohen et al., 1999; Critchley et al., 2000; Pierce, Muller, Ambrose, Allen, & Courchesne, 2001).

A simple task developed to investigate the attention capturing abilities of threat is the 'face-in-the-crowd' visual search paradigm. A pioneering study by Hansen and Hansen (1988) found that an angry face was detected more quickly and accurately than a happy face in a crowd of distracter faces. They further found this 'anger superiority' effect was unaffected by the number of distracter faces in the display, supporting the notion that facial threat detection may elicit pre-attentive processing involving 'pop-out.' The pop-out effect shows reaction times (RT's) that do not vary greatly with increasing size of the distracters, as shown by a search slope (the increase in RT divided by the increase in number of distracters) in the range of 5–6 ms/item (Hershler & Hochstein, 2005; Treisman & Souther, 1985).

However, further studies with similar stimuli did not replicate these findings and criticisms were raised about the results involving visual confounds and lack of a condition with neutral face crowds (Nothdurft, 1993; White, 1995). To address these problems and further test the face-in-the-crowd effect, researchers have developed schematic faces for visual search experiments. By using schematic faces it is possible to eliminate many low-level perceptual variations found in emotional expression photographs and to allow for greater control over experimental variables. The features of angry and happy schematic faces can be matched very closely and easily manipulated to test a variety of factors in a consistent way. Naturally, this greater control comes at the cost of a lack in ecological validity.

Several studies have shown schematic threatening faces are found more quickly and accurately than schematic friendly faces, strengthening the idea that social threat captures attention (Eastwood, Smilek, & Merikle, 2001; Fox, Russo, Bowles, Pichler, & Dutton, 2000; Ohman, Lundqvist, & Esteves, 2001). Another intriguing effect is longer response latencies for non-target displays containing all-angry faces compared to all-happy displays, which is thought to reflect that each angry face captures attention to a greater degree than each happy face (Fox et al., 2000; Vuilleumier & Schwartz, 2001; White, 1995). However, other studies have failed to replicate the findings of 'pop-out' for schematic threatening faces (Ohman et al., 2001) and for longer dwell times for all-angry displays (Ohman et al., 2001), suggesting further replication studies of this type are needed.

For facial threat to elicit the rapid and efficient extraction of information and adaptive responses, there have to be clear and prototypical features (Darwin, 1872/1965; Lundqvist, Esteves, & Ohman, 1999; Ohman & Soares, 1993). Lundqvist et al. (1999, 2004) have investigated the role of individual schematic facial features and configurations of schematic features in their ability to convey threat. Results showed that V-shaped eyebrows are the most salient individual feature for conveying threat, followed by down-turned mouths (Lundqvist et al., 1999). In addition, they found individual features do not convey the same degree of threat as configurations of facial features, particularly compared to the most negatively rated configuration of V-shaped eyebrows and down-turned mouths together. From their findings Lundqvist et al. (2004) illustrated different levels of face-processing including single features, feature configurations, and holistic shapes, and the importance of configurations of features for conveying highly effective threat. These ideas of different levels of information extraction from faces is consistent with a prominent model of face-processing (Bruce & Young, 1986) that posits face recognition involves different modules extracting various aspects of facial information in parallel.

Results from visual search studies with schematic faces show the anger superiority effect does not emerge from single feature detection, as the effect is not seen when threatening features are presented in isolation. Fox et al. (2000) found no difference in RT's to detect angry (down-turned) versus friendly (up-turned) mouths when they were presented in isolation. Similarly, others have found that people are no quicker to detect threatening (V-shaped) eyebrows than friendly eyebrows when presented in isolation (Tipples, Atkinson, & Young, 2002). Therefore, V-shaped eyebrows need a configuration containing other internal facial features in order to produce a facilitated detection effect. Consistent with this, Eastwood, Smilek, and Merikle (2003) found the detection of threatening schematic faces was actually associated with a *disruption* in feature-processing and longer latencies, and a *facilitation* in the configural processing of faces. Therefore, it appears the anger superiority effect involves some degree of configural and/or holistic level of face-processing (Fox et al., 2000; Lundqvist et al., 2004; Ohman et al., 2001; Tipples, Young, Quinlan, Broks, & Ellis, 2002).

Research with visual search tasks have also reported normal or even *superior* ability by people with ASC compared to controls in non-social paradigms (O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998a, Plaisted, O'Riordan, & Baron-Cohen, 1998b). Visual search studies have typically found children and adults with ASC are better able to detect target stimuli among distracters. This is important as it reflects a paradigm where people with ASC are known to perform at levels comparable to controls, probably because it is a simple and predictable task with limited requirements of language ability or executive function. These factors may confound other studies of social-emotional functioning in ASC (Teunisse & de Gelder, 2003). However, to date no published research has reported findings of visual search paradigms with social-emotional stimuli in autism.

This gap in the evidence is filled by the experiments reported here. This is important because it allows us to test 4 questions: (a) Are the rapid, evolved aspects of threat detection intact in HFA/AS? (b) Is basic emotion discrimination intact in HFA/AS? (c) Do the savant skills in visual search extend to detecting odd-one-out faces? And finally (d); Is there any evidence of a difference in cognitive style in HFA/AS (e.g., under conditions of face-inversion)?

1.1. Aims and hypotheses

The present study investigated the effects of the following variables on RT and accuracy to detect threatening and happy faces in crowds of distracter faces: the size of the matrix, time of presentation, and inverted presentation. The experiments had the following aims: (1) To replicate previous studies reporting facilitated detection of threatening faces over friendly faces; (2) to test if previous findings of longer search times for displays containing all angry faces would replicate; (3) to investigate the pop-out effect for angry faces; and (4) to determine if people with HFA/AS show the same attention biases for the detection of threatening faces compared to control participants.

We predicted the typical control group would be quicker and more accurate in the detection of the threatening faces compared with the friendly faces, and would take longer and be less accurate to detect non-target displays comprised of all angry faces, consistent with previous studies. If the evolutionary model of threat detection is true, we expected to find evidence for pre-attentive processing of the threatening faces consistent with a pop-out effect. We were open to how the group with HFA/AS would perform, given previous evidence from some studies that basic emotion processing is intact (Adolphs et al., 2000; Baron-Cohen et al., 1993; Baron-Cohen et al., 1997; Golan et al., in press). If people with ASC are processing faces using only single features, we would not expect them to show evidence of the anger superiority effect. However, if they are extracting facial information using a configural and/or holistic level of processing, then we would expect to see evidence of an angry face superiority. Further, if people with ASC are extracting facial information using a lower level of processing than controls (e.g., feature configural versus holistic), we would predict they will show less evidence of the anger superiority effect than the control group. We expected differences in processing style would be most evident in the face inversion condition, consistent with previous findings of face orientation (Langdell, 1978).

2. Experiment 1

Previous research has shown that threatening faces are detected faster and more accurately than friendly faces

(Hansen & Hansen, 1988; Ohman et al., 2001), and that all-angry displays are detected slower and less accurately than all-happy displays (Fox et al., 2000; White, 1995). In Experiment 1, the effect of exposure time on threat detection was investigated by setting the display time of the matrices to be either short (1 s) or long duration (2 s). People with autism have difficulty making social judgments, which may be more evident under shorter time constraints. We tested (1) whether the control group would show faster and more accurate detection of threatening compared to friendly faces, (2) if there would be longer dwell times for all-angry displays, and (3) if the HFA/AS group would show the same behavioural effects as the control group.

2.1. Methods

2.1.1. Participants

For the study, we recruited 18 adult male participants with HFA/AS (1 HFA/17 AS: mean age ± *SD*, 25.9 ± 7.7; full-scale IQ, 115.2 ± 19.8) from people who had previously participated in research with our laboratory. All participants with HFA/AS were diagnosed according to internationally accepted criteria (APA, 1994; ICD-10, 1994), and completed the Autism Spectrum Quotient (AQ) (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). We also recruited 18 adult male participants (mean age ± *SD*, 27.3 ± 6.4; full-scale IQ, 117.2 ± 15.4) with no history of any psychiatric condition from the community as a control group. All participants apart from one in each group completed measures of intelligence (Wechsler, 1999), and both groups were matched on handedness and sex.

Independent samples t tests showed the groups did not differ in age, $t(34) = 0.57$, $p = .57$ *ns*, or in IQ, $t(32) = 0.34$, $p = .74$ *ns*. Due to time limitations, some of the participants were not able to complete all 4 experiments, and since we randomised the order of experiments it resulted in different participant numbers across the experiments. We compared the groups on age and IQ for each experiment and found no significant differences for any ($p > .33$ for all comparisons). The results of the AQ scores for the participants with AS ($N = 18$, mean AQ score = 34.8, $SD = 7.6$, 82.4% scoring 32+) were very similar to the findings from previously published studies ($N = 58$, mean AQ score = 35.8, SD = 6.5, 80% scoring 32+) (Baron-Cohen, Wheelwright & Skinner et al., 2001). The AQ measures for the HFA/AS group differed very little across all the experiments.

2.1.2. Stimuli

The faces were drawn in black against a white background. The outline of the faces and the nose were drawn with 1-pixel lines, and the eyebrows, eyes, and mouth were drawn with lines of 2 pixels. The individual faces were 84 by 98 pixels (Fig. 1A).

All the pictures consisted of matrices of nine individual schematic faces arranged in 3 by 3 matrices (Fig. 1B). Half of the pictures were shown for 1 s before the display disappeared from the screen. In the other half of the pictures, the display was presented for 2 s before it disappeared from the screen. Half the matrices for each time were composed of faces all showing the same emotional expression. The other half of the matrices had one face that was a target and had a different emotional expression from the other background distracter faces. All three distracter expressions were combined with each target expression, making six different combinations of target–distracters. The target could occur at any of the nine positions in the matrix for each target–distracter combination, creating a total of 54 different matrices containing a target (target-present displays). These were repeated twice in the experiment, in two separate blocks. Trials were randomised within each of the two blocks. There were three different distracter matrices without targets (non-target displays) for each condition, which were each repeated 36 times so that the number of non-target displays matched the number of target-present displays. This led to 216 trials for Experiment 1, plus dummy trials after errors for which data were not recorded.

2.1.3. Procedure for Experiment 1

Visual stimuli were presented on a 20-in. (50.80 cm) screen of a monitor connected to a DELL Inspiron 7500 laptop computer and DMDX experiment software (Forster & Forster, 2003) was used to initiate trials and record responses. The participants pressed two keys on a response box made and designed for use with the DELL laptop and the DMDX program. Participants were tested individually in a quiet dimly lit room and were seated approximately 1 m from the computer screen with their eyes positioned at the centre of the screen. Each individual schematic face had a size on the screen of approximately 3° by 3.5°, and the outline of the matrix on the screen gave visual angles of approximately 10° by 11.5°. Participants were first given written instructions about the nature of the task, which was then explained verbally to ensure they understood everything. Instructions also appeared on the computer screen before and during the task as a reminder. The instructions explained the task was to detect a discrepant face in a matrix of faces. The participants started with a practice session to familiarise themselves with the task. When they could perform the task with ease, the experiment was begun.

Each trial consisted of a presentation of a fixation cross on an otherwise blank screen for 500 ms, followed by the matrix display and the initiation of timing. The participants had 10 s to make a response, and if a response was not made by 10 s the words "You were too slow" appeared on the screen. If an incorrect response was made, a tone was sounded as an indication of the error. An incorrect trial was always followed by a dummy trial, and the response to this trial was not recorded. This procedure allowed the participant to recover from an error. This meant people who made greater errors performed more trials. However, results showed that general performance on the task was very high in both groups, and no significant differences between the groups were found for accuracy.

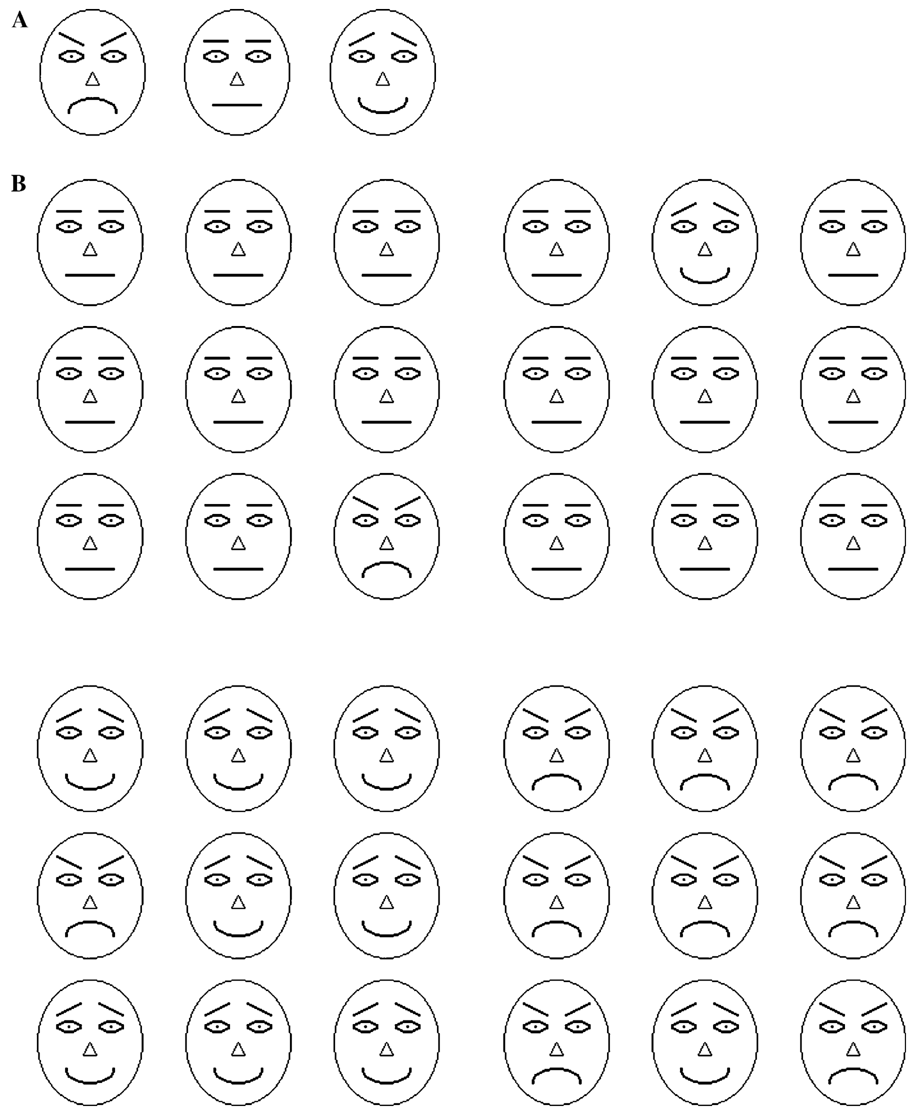

Fig. 1. Examples of (A) angry, neutral, and happy schematic faces used in the study, and (B) 3 × 3 matrices used in Experiment 1.

2.2. Results of Experiment 1

All trials on which incorrect responses were made were excluded from the main RT analyses. The RTs and accuracy scores for the target present and target absent conditions are given in Fig. 2.

2.2.1. Target-present trials

A general linear model (GLM) ANOVA with repeated measures was performed on the RT data with Target (threatening face vs. non-threatening face), Distracter (neutral vs. emotional), and Time (one second vs. two seconds) as the within-subject factors, and Group (controls vs. HFA/AS) as the between-subject factor. Statistics showed there was no main effect for group, $F(1,26) = 0.25$, $p = .63$ *ns,*and no significant interactions involving group ($p > .05$ for all). As seen in Figs. 2A and B, it appears both groups found the angry faces more quickly and accurately than the happy faces in the crowd of neutral faces. Statistics showed there was a main effect of target, $F(1,26) = 17.80$, $p < .001$, with participants in both groups detecting angry faces quicker than the happy faces (Fig. 2A). There was a main effect of distracter, $F(1,26) = 169.04$, $p < .001$, with participants searching longer when distracter faces were emotional compared to when they were neutral (Fig. 2A). There was also a main effect of time, $F(1,26) = 6.61$, $p < .02$, with participants in both groups responding more quickly when display times were one second, than when they were two seconds (Fig. 2A).

Statistics on the accuracy data also did not reveal a main effect for group, $F(1,26) = 1.40$, $p = .25$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a significant main effect of target $F(1,26) = 16.22$, $p < .001$, with participants more accurate when searching for angry faces than happy faces. There was a main effect of distracter, $F(1,26) = 18.1$, $p < .001$, with both groups less accurate when the distracters were emotional compared with neutral. There was also a main effect for time $F(1,26) = 11.74$, $p < .02$, with participants more accurate on the two-second trials com-

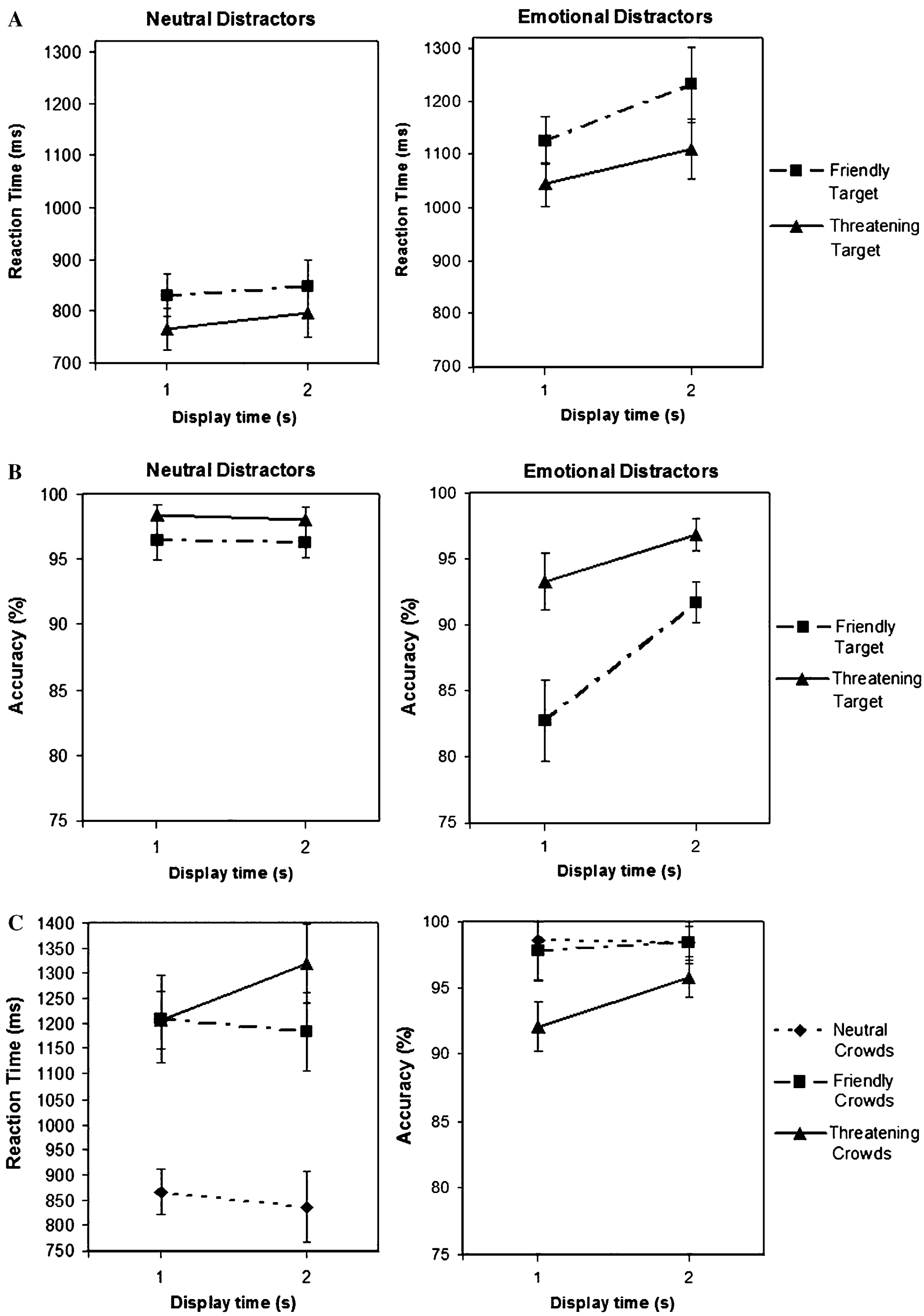

Fig. 2. Reaction times (A) and accuracy (B) for target-present trials and non-target trials (C), to detect angry and happy targets among neutral and emotional distracter crowds across one and two second display times (since there were no group differences, data from both groups are combined).

pared to the one-second trials, and an interaction between target and distracter $F(1,26) = 5.34$, $p < .05$. Paired samples t tests revealed that there was a significant difference in detection accuracy for angry versus happy targets when the distracters were emotional, $t(55) = 3.71$, $p < .001$, but not when they were neutral, $t(55) = 1.79$, *ns* (Fig. 2B). There was also an interaction between distracter and time $F(1,26) = 11.09$, $p < .02$. Paired samples t tests revealed that general target detection accuracy was greater for the two second compared to the one second trials when the distracters were emotional, $t(55) = 3.38$, $p < .001$, but there was no difference in target detection accuracy for one versus two second trials when the distracters were neutral, $t(55) = 0.32$, *ns* (Fig. 2B).

2.2.2. Non-target trials

A general linear model ANOVA with repeated measures on the RT data with Crowd Type (all angry vs. all happy vs. all neutral), and Time (one second vs. two seconds) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor showed no main effect for group, $F(1,26) = 0.48$, $p = .50$ *ns*, and no significant interactions involving group (all $p > .05$). There was a main effect of crowd type, $F(2,25) = 39.8$, $p < .001$, with responses for the all-neutral displays being quicker than the all-angry and all-happy displays. There was an interaction between crowd and time, $F(2,25) = 4.52$, $p < .05$, for non-target RT's. Paired samples t tests showed response times were significantly longer for the all-angry matrices compared to the all-happy matrices when they were displayed for two-seconds, $t(27) = 3.92$, $p < .001$, while there was no difference in RT between the all angry and all happy matrices for the one second displays, $t(27) = 0.05$, *ns* (Fig. 2C).

Statistics on the accuracy data showed no main effect for group, $F(1,26) = 0.05$, $p = .83$ *ns*, and no significant interactions involving group (all $p > .05$). There was a main effect of crowd type, $F(2,25) = 5.76$, $p < .02$, with displays containing all angry faces having lower accuracy than displays with all happy or all neutral faces. There was no difference in accuracy scores for all happy displays compared to the all neutral faces (Fig. 2C).

2.3. Discussion of Experiment 1

The control group showed an advantage for detecting a threatening face in a crowd of faces, which replicates previous findings with real photographs and schematic facial stimuli (Fox et al., 2000; Hansen & Hansen, 1988; Ohman et al., 2001). The anger superiority effect was quite robust, as it appeared across different display times and distracter types. Results also revealed the controls had enhanced dwell times and less accuracy for all-angry displays compared to all-happy displays.

Contrary to some predictions, the HFA/AS group was also faster and more accurate to detect angry faces compared to happy faces, and showed slower and less accurate detection for the all-angry displays. The results from the HFA/AS group are in line with previous research showing that some basic facial emotion processing ability is intact in ASC (Adolphs et al., 2000; Baron-Cohen et al., 1997; Golan et al., in press; Grossman et al., 2000), and suggests intact basic emotional expression processing in HFA/AS may extend to the rapid and efficient detection of social threat, at least under some simple conditions with schematic faces. The findings are consistent with other recent research showing the ability to extract facial information at a configural or holistic level of processing may not be completely absent in ASC (Joseph & Tanaka, 2003; Teunisse & de Gelder, 2003).

3. Experiment 2

Results of Experiment 1 showed the anger superiority effect occurred in both groups across different times and distracter types, and we wondered whether detection times might be affected by the size of the crowd. In Experiment 2, we varied the size of the displays to look at the effect of crowd size on detection of threatening versus friendly faces and also to examine search slopes for the different targets. The search slope is the increase in RT divided by the increase in number of distracters, and a measure less than 6 ms/item is generally considered to represent parallel processing or pop-out (Hershler & Hochstein, 2005; Treisman & Souther, 1985). While some previous research has shown evidence of a pop-out effect for detection of threatening faces (Hansen & Hansen, 1988), others have failed to find this effect (Fox et al., 2000; Ohman et al., 2001). We used only neutral distracter faces in this experiment to include more variation in matrix size within a reasonable amount of trials.

In the control group, we expected to find quicker and more accurate detection for the angry faces compared to the happy faces, and longer and less accurate detection of all-angry displays compared to all-happy displays. While some studies have reported pop-out for threatening faces, others have failed to find this effect. If the evolved mechanisms for threat detection extend to schematic facial stimuli, and schematic faces contain clear and prototypical features of threat, then we expect to see evidence for a pop-out effect.

Based on the findings from Experiment 1, we expected people with autism to also find angry faces faster and more accurately, and longer dwell times for displays of all angry faces. If the HFA/AS group are processing faces in the same way as controls we expect them to also show pop-out for angry faces.

3.1. Methods

3.1.1. Procedure for Experiment 2

The setting, equipment, and general procedure were identical to those used in Experiment 1. In this experiment, the display time was terminated by the participants' response. The experiment examined the participants search for threatening and friendly target faces in different sized crowds of neutral faces. The displays consisted of 2×2, 3×3, 4×4, and 5×5 matrices. The number of distracter faces varied from 3 to 24.

An equal number of non-target all neutral displays were used to match the number of target displays. We used more repetitions of the smaller matrices to roughly equalise the proportion of each different matrix size used in this experiment. For the 2×2 displays each of the two targets could appear in one of four positions, making eight examples. Each of these was repeated twice, producing 32 target trials that were combined with 32 all-neutral trials. Each of the 3×3 matrix combinations was repeated twice, resulting in 36 target matrices that were matched with 36 all-neutral displays for a total of 72 matrices. For the 4×4 displays there was only one presentation of each trial combination type, creating 32 target matrices that were combined with 32 non-target displays for a total of 64 matrices. For the 5×5 matrices, 12 representative examples of both the angry and happy target displays were chosen and were paired with 24 non-target displays for a total of 48 matrices. Two versions of the experiment were created, with each of the target positions being randomised across the two versions, and participants were randomly given one of the two versions of the experiment. There were a total of 248 trials for experiment two, plus dummy trials after errors for which data were not recorded. All the trials were randomised across 4 blocks, with each matrix type being equally probable to occur in any of the blocks.

3.2. Results for Experiment 2

The RTs and accuracy scores for the target-present and target-absent conditions are given in Fig. 3.

3.2.1. Target-present trials

A GLM ANOVA with repeated measures was performed on the RT data with Target (threatening face vs. non-threatening face), and Crowd Size (2×2 vs. 3×3 vs. 4×4 vs. 5×5) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor. There was no main effect for group, $F(1,34) = 1.74$, $p = .20$ *ns*, and none of the interactions involving group reached significance ($p > .05$ for all), except for an interaction between target and group that was barely significant, $F(1,34) = 4.25$, $p < .05$. The interaction showed the anger superiority effect differed between the groups and was larger for the control group than the HFA/AS group. There was a main effect of target, $F(1,34) = 57.0$,

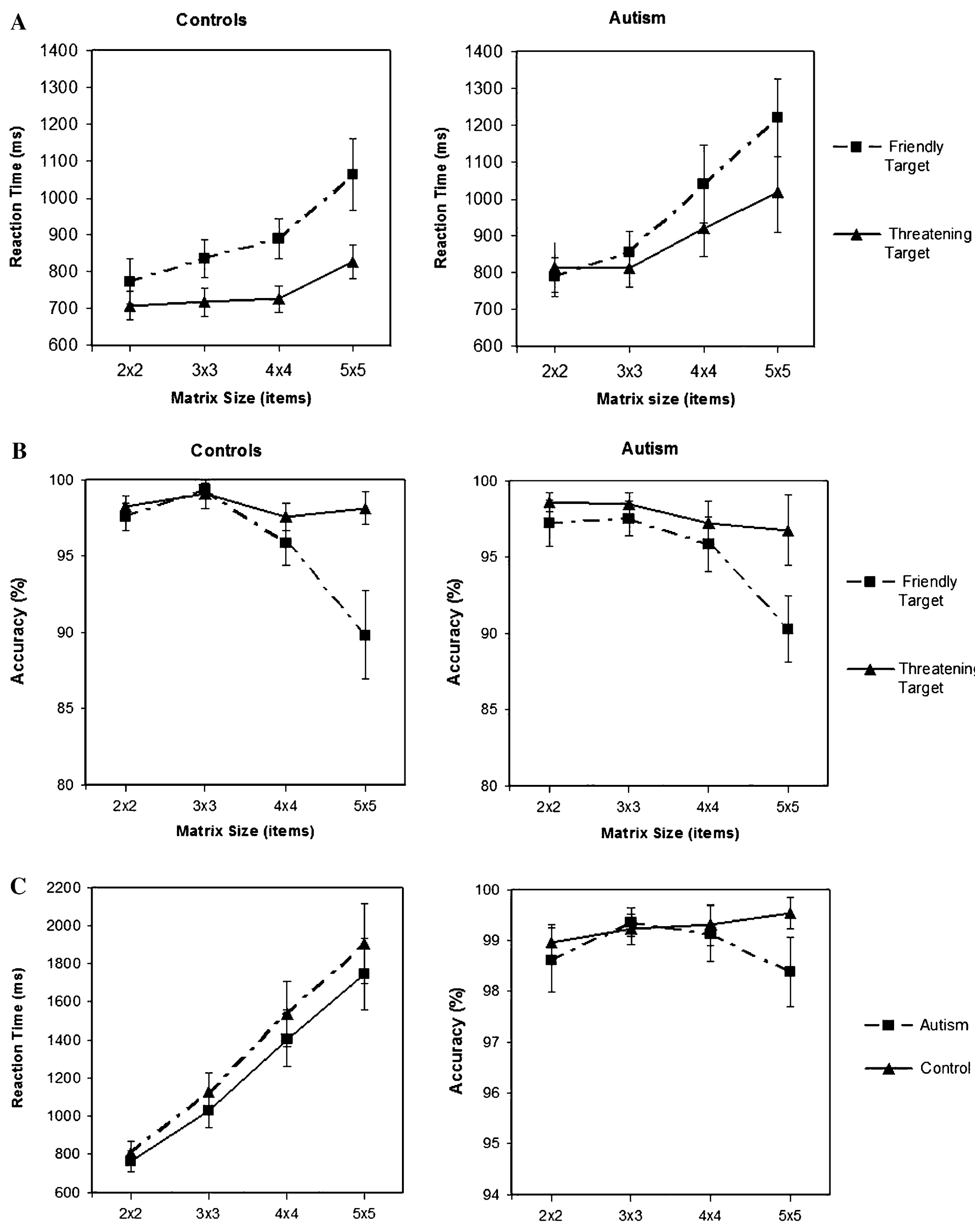

Fig. 3. Reaction times (A) and accuracy (B) for target-present trials and non-target trials (C), for the autism and control groups to detect angry and happy targets among neutral distracter crowds across different matrix sizes.

$p < .001$, revealing that angry faces were detected significantly faster than happy faces by both groups (Fig. 3A). ANOVA's performed on the data for each group alone confirmed both groups were significantly faster to find angry faces than happy face. There was also a main effect of matrix size, $F(3,32) = 14.48$. $p < .001$, with RT's increasing significantly with increasing size. There was an interaction of target and matrix size, $F(3,32) = 9.48$, $p < .001$, with the slope for the happy faces being steeper across increasing matrix sizes compared to the slope for the angry targets (Fig. 3A).

Analysis showed the control group had a search slope of 5.71 ms/item for the angry targets, and 13.76 ms/item for the happy faces. The HFA/AS group showed a search slope of 9.68 ms/item for the angry faces and 20.56 for the happy faces. A search slope of less than 6 ms is generally considered to indicate pop-out, indicating automatic or parallel processing during detection of the target (Hershler & Hochstein, 2005; Treisman & Souther, 1985). Therefore, the controls showed a pop-out effect for the angry faces, but not for the happy faces. The HFA/AS group showed much faster detection and accuracy for angry faces compared to happy faces, but they did not show a pop-out effect for the angry faces.

Statistics on the accuracy data revealed there was no main effect for group, $F(1,34) = 0.12$, $p = .73$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a main effect of target, $F(1,34) = 25.0$, $p < .001$, with accuracy being greater for the angry faces. There was also a main effect for crowd size, $F(3,32) = 4.97$, $p < .02$, revealing that accuracy generally decreased as matrix size increased (Fig. 3B). The accuracy score was markedly decreased for the two highest matrix sizes. There was an interaction between target and size, $F(3,32) = 4.85$, $p < .02$, which was mainly driven by a decreased accuracy for the happy faces as the matrix size increased. The accuracy for the angry faces remained relatively stable across the various matrix sizes.

3.2.2. Target-absent trials

A GLM ANOVA with repeated measures was performed on the RT data with Target (threatening face vs. non-threatening face) and Crowd Size (2×2 vs. 3×3 vs. 4×4 vs. 5×5) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor. There was no main effect for group, $F(1,34) = 0.38$, $p = .54$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). Statistics revealed a main effect of crowd size, $F(1,34) = 56$, $p < .05$, showing that as the size of the crowd increased, the RT's also increased. Each size was significantly different from each other, meaning every increase in size was accompanied by a significant increase in RT (Fig. 3C). Analyses of the accuracy data did not reveal any significant results.

3.3. Discussion of Experiment 2

Once again results showed an advantage for finding threatening faces over friendly faces, although the response latency was smaller for the group with HFA/AS compared to the control group. Despite the group difference in response latency for a threat detection advantage, both groups showed greater accuracy in detecting the angry face. The control group showed pop-out for the angry faces, but not for the happy faces. The HFA/AS group did not show evidence of pop-out for either the angry faces or the happy faces. Therefore, while both groups showed evidence of the angry superiority effect, only the control group showed the pop-out effect for angry faces interpreted as showing parallel processing. In general RTs increased and accuracy decreased with increasing matrix size, with flatter slopes for RT and accuracy of the angry faces compared to the happy faces.

The results replicate previous findings of a threat detection advantage in the control group, and show reduced response latencies (but not reduced accuracy) in the HFA/AS group in Experiment 2. This suggests that when people with autism are processing social-emotional information, group or crowd size may be a greater factor influencing social difficulties than time limitations. The control group also had a pop-out effect for the angry faces, an effect not seen in the HFA/AS group. Results suggest that even though the HFA/AS group shows behavioural responses indicating an anger superiority effect, they may be doing this using a different and less effective cognitive style.

4. Experiment 3

While Experiment 2 always involved crowds of neutral faces, Experiment 3 also included emotional faces as crowds. It is more difficult to detect a threatening or friendly face in a crowd of emotional distracter faces, since the features between the two emotional faces are closer in appearance to each other than they are to the neutral faces. This allowed us to investigate the anger superiority effect across conditions with different levels of difficulty.

Our aims were to test: (1) if controls had faster RT's and greater accuracy to detect angry faces across both distracter types, (2) if controls had longer dwell times and decreased accuracy for the all-angry displays, (3) if the HFA/AS group would show the same effects as the controls, and (4) if either group would show evidence of pop-out across the distracter types including more difficult trials. Consistent with the previous experiments we expected the control group would show faster and more accurate detection of angry face targets, and slower and less accurate detection of all-angry displays. We were interested in whether the ASC group would show the same effects as in Experiment 2 with more difficult trials.

4.1. Methods

4.1.1. Procedure for Experiment 3

The setting, equipment and general procedure were identical to those used in Experiment 2. Three crowd sizes were included, 2×2, 3×3, and 4×4. For the 2×2 matrices there were four target positions across each of the three possible targets (threatening, friendly, and neutral), and two types of distracters for each target. To equate numbers to the larger matrices, each of these were repeated twice, making a total of 48 target present trials and 48 non-target trials. The 3×3 matrices had one presentation of each target position across the various distracters, making a total of 54 target-present trials and 54 non-target trials. For the 4×4 matrices each participant was shown trials with targets at half the positions, with these positions counterbalanced evenly across the participants in both groups. This produced 48 target-present trials and 48 non-target trials, resulting in a total of 300 trials for this experiment, plus dummy trials after errors. All the trials were randomised across 4 blocks, with each matrix type being equally probable to occur in any of the blocks.

4.2. Results for Experiment 3

The RTs and accuracy scores for the target present and target absent conditions are given in Fig. 4.

4.2.1. Target-present trials

A GLM ANOVA with repeated measures was done on the RT data with Target (threatening face vs. non-threatening face), Distracter (neutral vs. emotional), and Matrix

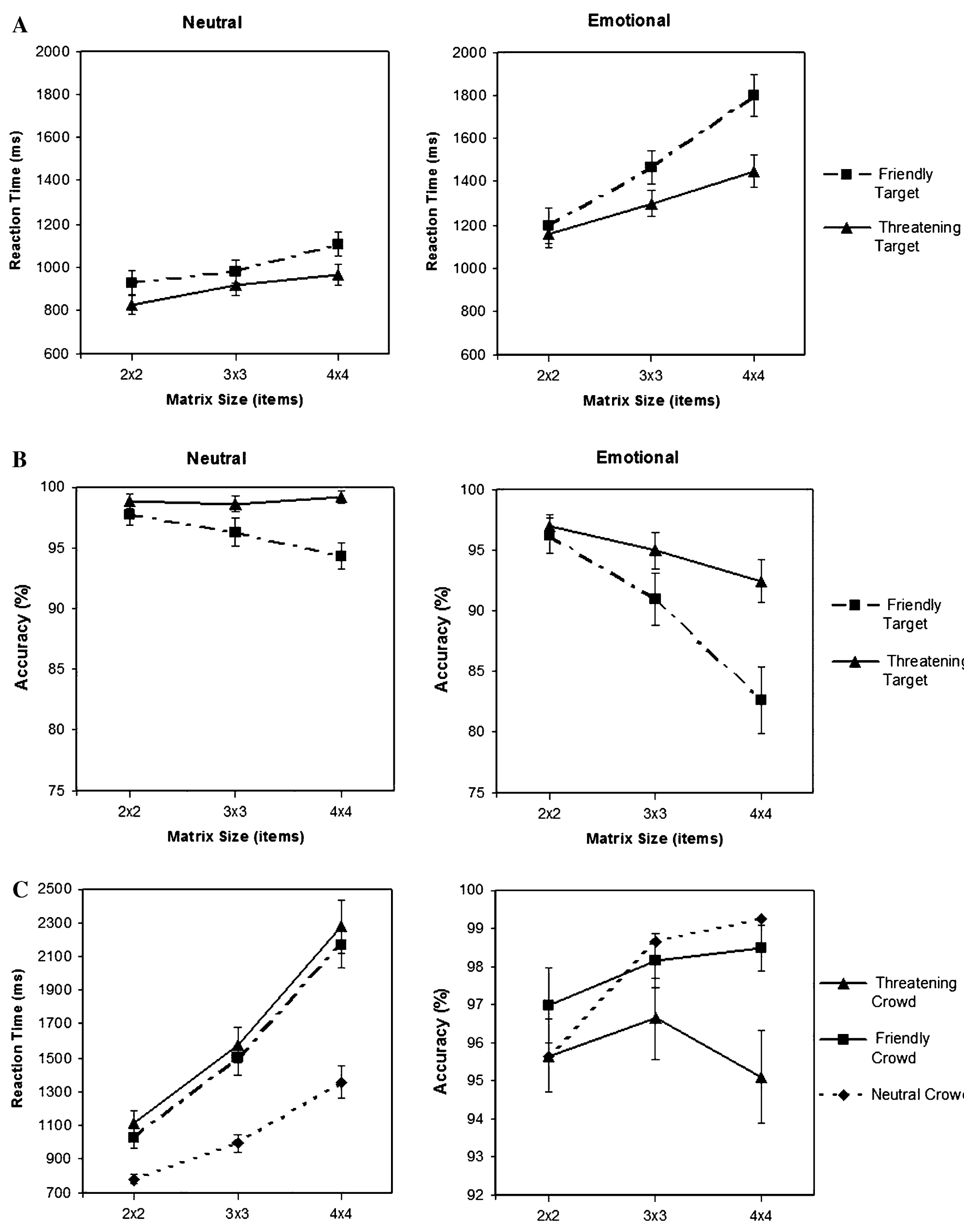

Fig. 4. Reaction times (A) and accuracy (B) for target-present trials to detect angry and happy targets among neutral and emotional distracter crowds and for non-target matrices (C) across different matrix sizes (since there were no group differences, data from both groups are combined).

Size (2×2 vs. 3×3 vs. 4×4) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor. There was no effect for group, $F(1,31) = 3.38$, $p = .08$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a main effect of target, $F(1,31) = 48.34$, $p < .001$, with participants finding the angry faces faster than the happy faces (Fig. 4A). There was also a main effect for distracter, $F(1,31) = 126.33$, $p < .001$, with neutral crowds having quicker search times than emotional crowds. There was a further main effect for matrix size $F(2,30) = 65.44$, $p < .001$, with RT's increasing as the size of the matrix increased. RT's for each matrix size were significantly different from each other, meaning each increase in size was accompanied by a significant increase in RT. There was an interaction between target and distracter $F(1,31) = 8.54$, $p < .02$, with the difference between detecting the angry versus the happy faces being greater with the emotional crowds, compared to neutral crowds (Fig. 4A).

There was also an interaction between target and size $F(2,30) = 14.28$, $p < .001$, with detection times for happy faces showing a larger slope with increasing matrix sizes compared to detection times for angry faces, which were more stable across increasing crowd sizes (Fig. 4A). There was an interaction for distracter and crowd size $F(2,30) = 23.0$, $p < .001$, with emotional crowds having a larger slope across increasing crowd sizes compared to neutral crowds. There was a three-way interaction between target, distracter, and size $F(2,30) = 8.51$, $p < .02$, and inspection of the graphs suggest that the slope to detect friendly faces was steeper across the matrix sizes in the emotional conditions.

Analysis of the search slopes was done for each group for both types of targets across each of the two distracters types (neutral and emotional). The control group had a search slope of 11.49 ms/item for the angry targets with neutral distracters, and 20.63 ms/item for the angry faces with emotional distracters. The controls also showed a search slope of 15.07 ms/item for the happy targets with neutral distracters, and 46.44 ms/item for the happy faces with emotional distracters. The HFA/AS group showed a search slope of 11.98 ms/item for the angry targets with neutral distracters, and 27.90 for the angry targets with emotional distracters. For the happy targets, the HFA/AS group had search slopes of 14.98 with neutral distracters and 54.28 with emotional distracters. Since a search slope of less than 6 ms is our criteria for showing parallel processing, neither of the groups showed evidence of the pop-out effect for detection of angry and happy face targets across both of the distracter types in this experiment.

Statistics on the accuracy data showed there was no effect for group, $F(1,31) = 0.21$, $p = .65$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a main effect of target, $F(1,31) = 19.18$, $p < .001$, with participants in both groups being more accurate when searching for the angry faces compared to happy (Fig. 4B). There was also a main effect of distracter, $F(1,31) = 21.97$, $p < .001$, with participants being more accurate when the crowds were neutral compared to when they were emotional. There was a further main effect of matrix size, $F(2,30) = 16.16$, $p < .001$, with accuracy decreasing as matrix size increased. Pair-wise comparisons showed that each increase in matrix size was accompanied by a significant decrease in accuracy. There was a significant interaction between target and size, $F(2,30) = 6.11$, $p < .02$, showing that the accuracy for the happy faces decreased further than the angry faces across the increasing matrix sizes, while the accuracy for the angry faces was relatively more stable with increasing matrix size (Fig. 4B). There was also an interaction for distracter and size, $F(2,30) = 13.63$, $p < .001$, with accuracy for trials with emotional crowds decreasing more across different matrix sizes than trials with neutral crowds.

4.2.2. Non-target trials

A GLM ANOVA with repeated measures was performed on the RT data with Crowd Type (Angry vs. Happy vs. Neutral) and Crowd Size (2×2 vs. 3×3 vs. 4×4) and as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor. There was no effect for group, $F(1,31) = 0.43$, $p = .52$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a main effect of crowd type $F(2,30) = 47.98$, $p < .001$, with participants taking significantly longer to search when the displays contained all angry faces, and fastest when the displays contained all neutral faces (Fig. 4C). Search times for the all happy displays were significantly longer than the all neutral displays, but significantly quicker than the all angry displays. There was also a main effect for crowd size $F(2,30) = 59.3$, $p < .001$, with each increase in matrix size resulting in a significant increase in RT (Fig. 4C). There was an interaction for crowd type and size $F(4,28) = 30.38$, $p < .001$, with the slope for the RT for the all neutral faces being less steep across the three matrix sizes than the displays having all angry and all happy faces, which had steeper slopes.

Statistics on the accuracy data showed no effect for group, $F(1,31) = 0.01$, $p = .94$ *ns*, and no interactions involving group reached significance ($p > .05$ for all). There was a main effect of crowd type, $F(2,30) = 6.5$, $p < .02$, with participants being significantly less accurate when searching the displays containing all angry faces compared to the displays which had all happy and all neutral faces (Fig. 4C). There was no difference in accuracy for searching displays that were all happy versus ones which were all neutral. There was also a main effect of matrix size, $F(2,30) = 3.46$, $p < .05$, with participants being marginally less accurate with the 2×2 matrix size compared to the other two larger sizes of matrixes, which were not different from each other in accuracy.

4.3. Discussion for Experiment 3

Experiment 3 provided further evidence for the attention bias towards threatening schematic faces in people with and without HFA/AS. Both groups found the angry faces quicker and more accurately than the happy faces, and once again searched longer and were less accurate with the all-angry displays. The facilitated detection of threatening faces compared to the friendly faces was greater when the crowds were emotional rather than neutral. This was mainly due to a steeper decline in the detection of friendly faces compared to less of a decline in performance with angry faces, consistent with previous findings (Ohman et al., 2001). This further supports that threatening faces have a fast and efficient detection that is consistent even under more difficult conditions.

The search slopes for the detection of the friendly faces showed a steeper increase in RT and steeper decrease in accuracy with increasing matrix size, compared to the slope for detection of threatening faces. However, based on a search slope of 6 ms per item that is our criteria for parallel processing, both groups failed to show a pop-out effect for either angry or happy faces across either crowd type. This is probably because participants seemed to find Experiment 3 harder than Experiment 2, according to the RT's.

5. Experiment 4

The previous experiments showed a consistent advantage for the detection of angry faces over happy faces across different sizes, times, and crowd types. The threatening faces were found more quickly and accurately than the friendly faces, both by control participants and, in most cases, those with HFA/AS as well. If the features of the faces are the critical factors mediating the response biases, instead of the conjoining effect of the facial configurations, then inverting the faces should reverse the pattern of responses. Participants should now show facilitated detection for the happy faces over the angry faces, since the happy faces would now have a down-turned mouth and V-shaped eyebrows. This would be consistent with the hypothesis of Aronoff and colleagues, who argued stimuli like mouths and eyebrows shown in isolation may be critical for emotional responses (Aronoff, Barclay, & Stevenson, 1988). We tested this in Experiment 4.

While it is well established that face inversion reduces holistic aspects of face-processing such as identity (Bruce, 1988; Farah, McMullen, & Meyer, 1991; Yin, 1969), the effects of inversion are less clear on emotion recognition. Some studies using visual search paradigms with facial photographs or schematised faces have reported that effects still persist when faces are inverted (Nothdurft, 1993; Ohman et al., 2001; Tong & Nakayama, 1999; White, 1995). Others have found that holistic face-processing effects disappear with inversion in visual search paradigms (Eastwood et al., 2001; Fox et al., 2000).

We tested whether controls would show the anger superiority effect under conditions of face inversion, and whether they would show longer latencies and less accuracy to displays with all angry faces. If people with ASC are performing the task by detecting single features, then we expect to find a reverse pattern of response with an advantage for inverted happy faces, since the features of the happy faces will now have threatening orientations. If the people with ASC are extracting facial information using a different level of processing compared to the controls (e.g., at the feature configure level versus the holistic level), then we expect to see a diminished anger superiority effect.

5.1. Methods

5.1.1. Procedure for Experiment 4

The setting, equipment, and general procedure were identical to those used in the previous experiments. All displays involved 3×3 matrices with 3 possible targets across two distracter types. This resulted in 54 target-present matrices which were repeated twice to produce 108 trials. These were combined with 108 non-target matrices to produce 216 total trials, plus dummy trials after errors for which responses were not recorded. All the trials were randomised across 4 blocks, with each matrix type being equally probable to occur in any of the blocks.

5.2. Results for Experiment 4

The RTs and accuracy scores for the target-present and target-absent conditions are given in Fig. 5.

5.2.1. Target-present trials

A GLM ANOVA with repeated measures on the RT data with Target (threatening face vs. non-threatening face) and Distracter (neutral vs. emotional) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor, revealed no effect for group, $F(1,30)=2.73$, $p=.11$ *ns*. There was a main effect of target, $F(1,30)=31.87$, $p<.001$, with angry faces being found quicker than happy faces (Fig. 5A). However, there was also an interaction involving group and target, $F(1,30)=6.63$, $p<.02$, revealing that the main effect of target was driven mostly by the control group. There was a main effect of distracter, $F(1,30)=146.27$, $p<.001$, showing that participants searched significantly quicker for a target when the crowds were neutral compared to emotional (Fig. 5A). There was an interaction between target and distracter, $F(1,30)=9.09$, $p<.02$, and this was because the slope for the RT's to find the angry faces across the two distracter types was less steep than the slope for the happy face RT's. This meant there was a greater difference between the angry and happy face RT's when the crowds were emotional compared to when they were neutral (Fig. 5A).

Statistics for accuracy revealed no effect for group, $F(1,30)=0.54$, $p=.47$ *ns*, and no interactions involving group reached significance ($p>.05$ for all). There was a main effect of target, $F(1,30)=6.42$, $p<.02$, with the angry faces being found more accurately than the happy faces for both groups (Fig. 5B). Also, there was a main effect of distracter, $F(1,30)=21.87$, $p<.001$, with both groups being more accurate to find a target when the distracter faces were neutral than when they were emotional.

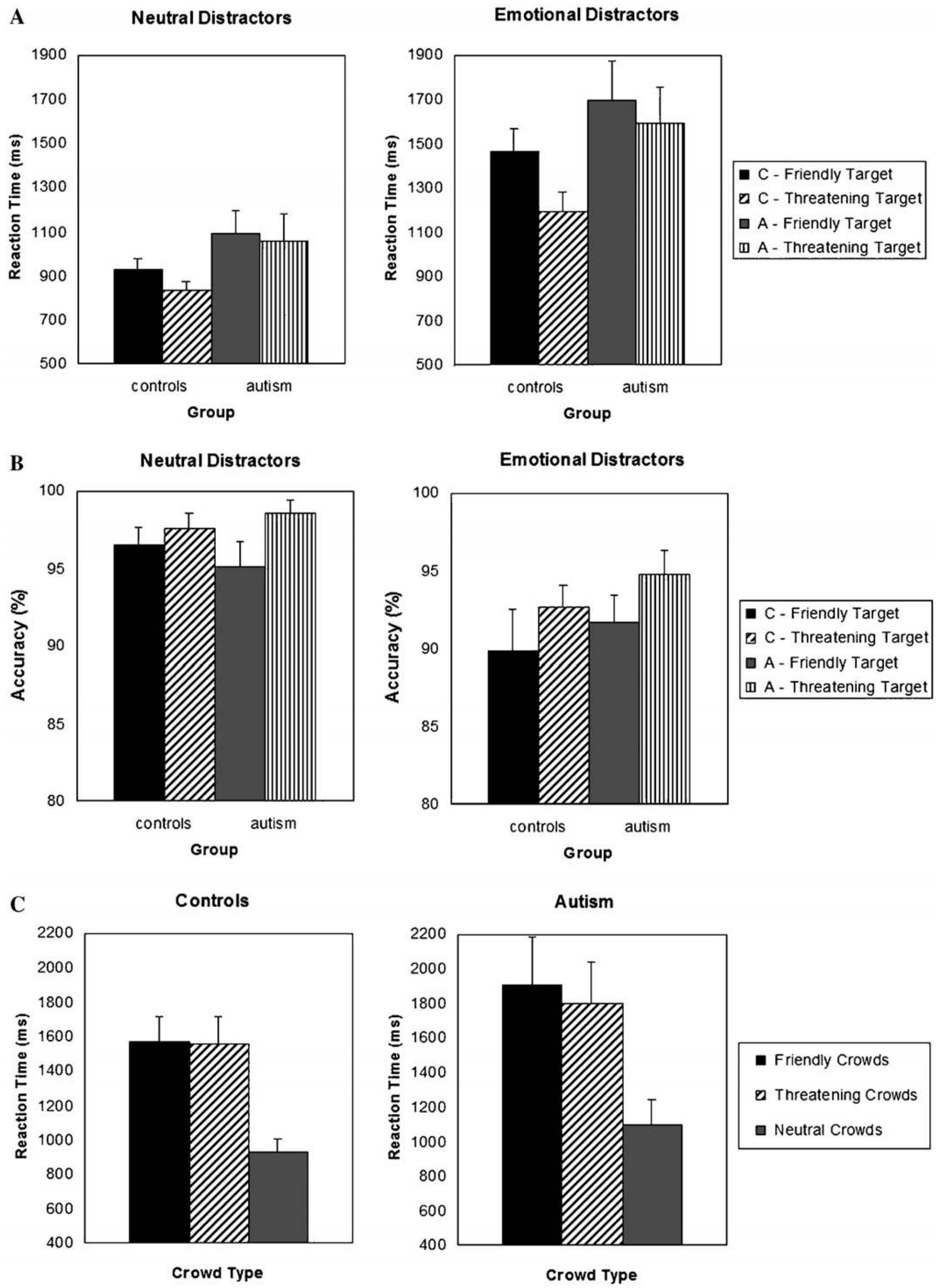

Fig. 5. Reaction times (A) and accuracy (B) for the autism and control groups to detect angry and happy targets among neutral and emotional distracter crowds and for non-target matrices (C) in both upright and inverted conditions.

5.2.2. *Non-target trials*

A GLM ANOVA with repeated measures on the RT data with Crowd Type (threatening vs. non-threatening vs. neutral) as the within-subject factors and Group (controls vs. HFA/AS) as the between-subject factor revealed showed no effect for group, $F(1,30) = 1.00$, $p = .33$ *ns*, and no significant interactions of group ($p > .05$ for all). There was a main effect of crowd type, $F(2,29) = 41.26$, $p < .001$, with participants being quicker when displays had all neutral faces compared to all angry and all happy displays (Fig. 5C). There was no difference in RT for the all angry versus the all happy face displays. Analyses for accuracy did not reveal any significant effects ($p > .05$ for all).

5.3. *Discussion of Experiment 4*

The results of Experiment 4 revealed the control group still found the angry faces more quickly and accurately than the happy faces, even when inverted. The HFA/AS group did not show a difference in response latency in detecting the threatening versus happy faces, although they were still more accurate to detect threatening faces. Therefore, both groups showed evidence of an anger superiority effect when the faces were inverted, however this effect was significantly reduced in the HFA/AS group.

The finding of an anger superiority with inverted faces is consistent with some previous visual search experiments using schematic faces (Nothdurft, 1993; Ohman et al., 2001; White, 1995), but not others (Eastwood et al., 2001; Fox et al., 2000). The anger superiority effect might be so potent that it exerts effects even when stimuli are inverted (Ohman et al., 2001). Eastwood et al. (2003) report that when participants first perceive upright schematic faces it exerts an influence on how the inverted faces are perceived, and there is a carry-over effect of emotional perception. Since all of the participants who took part in Experiment 4 also did experiments with upright presentations, and many likely did an upright condition first, we feel this effect is probably due to a priming or carry-over effect of seeing the stimuli first in an upright position. It was interesting this effect was less evident in the HFA/AS group, indicating they might not be primed as easily or strongly with facial stimuli and so the effect might not carry over to inverted faces. Or they may be using a more feature configural type of processing style compared to the controls, and this might not have as strong a carry-over effect as when faces are processed more holistically.

If the individual features of the face were the critical factors for this visual search task, then it would be expected that inverting the faces would cause detection times to be faster and more accurate for happy faces versus angry faces since the inverted happy faces contain V-shaped eyebrows and a down-turned mouth. However, this was not the case, as control participants still found the angry faces faster and more accurately than the friendly faces. These findings are consistent with previous research showing differences between people with and without HFA/AS in perceiving faces that are inverted versus upright. People with autism may be using different levels of processing during face perception, and these differences become more apparent when faces are inverted.

6. General discussion

The experiments reported here show that threatening schematic faces were detected quicker and more accurately than schematic friendly faces by the control participants, consistent with previous studies (Eastwood et al., 2001; Fox et al., 2000; Hansen & Hansen, 1988; Ohman et al., 2001). In fact the search for angry faces was so effective the controls showed a pop-out effect, indicating pre-attentive parallel processing in one of the experiments. Control participants also had longer dwell times and less accuracy for displays containing all angry faces compared to displays with all happy faces, showing that anger tends to hold attention and results in slower searches through crowds of angry distractors (Fox et al., 2000). Although various studies have reported some of these anger superiority effects, this is the first study with schematised faces to find the various anger superiority effects together in one study, therefore providing further validation of visual search studies involving schematised faces. The findings were very robust, as they were shown across various crowd sizes, display times, with neutral and emotional distracters, and in both upright and inverted displays. The results validate the anger superiority effect and ideas of an evolved adaptive mechanism for the fast and efficient detection of social threat in typical adults (Hansen & Hansen, 1988; Mineka & Ohman, 2002; Ohman et al., 2001; Vuilleumier & Schwartz, 2001).

The surprising finding was the group with HFA/AS also found threatening schematic faces more rapidly and efficiently than friendly schematic faces in most conditions. However, the anger superiority effect was less evident in conditions with widely varying crowd sizes and when faces were inverted, and they did not show evidence of pop-out like the control group. This result reveals that the rapid and automatic processing of social threat may be intact in people with HFA/AS, at least under predictable conditions with simple schematic faces. This is consistent with results from some studies showing evidence that certain basic social and emotional processing abilities may be intact in people with ASC, including preserved basic emotion recognition skills (Adolphs et al., 2000; Baron-Cohen et al., 1997; Golan et al., in press; Grossman et al., 2000), and normal reflexive cueing to the gaze of others (Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003). Those results, together with findings from the present study, suggest that certain basic and automatic social-emotional mechanisms are present in ASC, even if they fail to develop normally at the more complex levels needed to function in the social world.

The detection of threat is thought to be an evolved and adaptive mechanism that is 'hard-wired' in humans to make them biologically prepared (Ohman & Mineka, 2001; Ohman & Soares, 1993). Social threat conveys important waning signals, so an evolved module should be predisposed to direct attention towards facial cues of threat (Ohman et al., 2001). For an evolved module to extract accurate information rapidly and efficiently, there needs be easily perceived prototypical features for rapid and reliable responses (Darwin, 1872/1965; Ohman et al., 2001). Previous research has shown that V-shaped eyebrows and a down-turned mouth are the most salient features for conveying facial threat, and that these features need the configuration of the face to elicit the anger superiority effect seen in visual search paradigms (Eastwood et al., 2003; Fox et al., 2000; Tipples, Atkinson et al., 2002). This evolved mechanism appears to be intact in people with ASC, and may be present from birth. The schematic threat cues used in the present experiment may be simple enough for people with ASC to effectively recognise and respond to. However, this basic ability may not develop further into recognizing more subtle emotional expressions from faces.

From a developmental perspective, autism emerges early in life and involves a lack of social interest and interaction with others. The abnormal behaviours are usually not evident to parents and clinicians until about 18–24 months of age (Baird et al., 2000; Volkmar, Lord, Bailey, Schultz, & Klin, 2004). Sensitivity to different facial expressions normally emerges much earlier than this in development, as infants in the first few months of life are able to discriminate among different emotions like angry and happy (Johnson, 2003), and angry faces in particular grab the attention of infants (Schwartz, Izard, & Ansul, 1985; Serrano, Iglesias, & Loeches, 1992). Thus, the perception and discrimination of fearful and happy expressions emerges early and does not appear to require years of experience to develop (Kotsoni, de Haan, & Johnson, 2001). The physiological effects of threat have been tested in 5 month olds, finding that the blink size of the startle response is increased in response to auditory tones while viewing angry faces, and is decreased in response while viewing happy faces (Balaban, 1995). Since amygdala activation is known to modulate the eyeblink reflex sensitivity (Davis, 1992), this suggests sensitivity to threatening stimuli is present early and involves neural systems including the amygdala.

The amygdala is a key brain structure for the detection of threat and for making an appropriate response (LeDoux, 1996), and many lines of research suggest the amygdala may be dysfunctional in autism (Bachevalier, 2000; Howard et al., 2000; Schultz, 2005). Various models of autism suggest amygdala abnormalities may underlie the social difficulties that characterise ASD, including the amygdala theory of autism (Baron-Cohen et al., 2000). This makes the finding of an anger superiority effect by the ASC group somewhat surprising. However, the amygdala theory of autism and other models do not necessarily suggest the total absence of amygdala function in ASC, but simply that the amygdala may be functioning abnormally or may be wired-up differently to other brain areas (Baron-Cohen et al., 2000; Schultz, 2005, Schultz, Romanski, & Tsatsanis, 2000). Consistent with this, some studies have reported evidence for intact amygdala function in autism, at least under some conditions (Pierce, Haist, Sedaghat, & Courchesne, 2004; Salmond, de Haan, Friston, Gadian, & Vargha-Khadem, 2003). However, other studies have shown the amygdala may respond to objects of obsession like cartoon characters, rather than to faces like typically developing children (Grelotti et al., 2005). Further, there is evidence for differences in connectivity of the amygdala to other brain areas in autism (Welchew et al., 2005). Therefore autism might not involve an absence of amygdala functioning, but instead there may be inappropriate amygdala activity, associations, or neural connectivity of the amygdala with other brain areas. In addition, amygdala activity may be evident only under certain specific conditions, which may include threat detection with simple schematic facial stimuli with visual search paradigms. Further research involving fMRI studies of the anger superiority effect would help to answer some of these questions.

Although our findings reveal an anger superiority effect in ASC, the visual search paradigm and the schematic faces involved lacked ecological validity. Schematic faces were used to avoid many visual confounds found in photographs of emotional expressions and for greater control over experimental and stimulus variables. However, we see real faces in the everyday social world, and children learn emotions mainly from real faces. People with autism are often able to recognise cartoon faces and emotions and to 'learn' explicitly about emotions over time, and may perform normally under experimental conditions in the laboratory (Klin, Jones, Schultz, & Volkmar, 2003). However, this may involve inadequate or inappropriate development of social-emotional abilities required to successfully navigate the social world and for social relationships. People with autism are also able to acquire mental representations about large numbers of 'symbols' (e.g., computer code or gestures like waving), but these symbols do not necessarily have the same meanings for them compared to normally developed individuals (Klin et al., 2003). So although they showed an anger superiority effect in this study with schematic facial stimuli, indicating on some level they differentiated the friendly and threatening schematic faces and responded appropriately, it does not necessarily mean they consciously recognised or identified the faces as angry. The task did not require them to explicitly label the emotions, but simply to detect the 'odd-one-out.' Results may have been different if the task required them to consciously and explicitly label the threatening stimuli. Further research along this line involving more realistic faces and paradigms investigating explicit versus implicit labeling of emotions is warranted.

While the ASC group showed evidence of the anger superiority effect in most conditions, they also had decreased threat detection compared to controls in conditions with widely varying crowd sizes and inverted face orientation. This suggests that even though people with ASC showed anger superiority effects, they may still be processing faces using a different cognitive style or different level of face-processing compared to controls. For example, they may be extracting facial information from 'feature configurations,' rather than using higher level 'holistic' processing. It is unlikely the ASC group was doing the task simply by processing a single feature alone, such as the mouth, as previous visual search studies have shown threatening features shown in isolation do not produce the anger superiority effect (Fox et al., 2000; Tipples, Atkinson et al., 2002). In fact, the detection of threat is associated with a *disruption* in feature processing and longer latencies, and a *facilitation* in configural processing (Eastwood et al., 2001). Individual features are also rated less threatening than configurations of features, and there are differences in ratings amongst the various threatening features (Lundqvist et al., 2004). For example, down-turned mouths are rated less threatening than V-shaped eyebrows. In fact, down-turned mouths are rated even slightly less threatening than 'neutral' straight mouths, making it unlikely for the ASC group to show the anger superiority effect if they were simply focusing on the mouths. The features found in the angry and happy faces were identical to each other, apart from their orientation. If people with ASC were simply using enhanced feature search in this task from physical properties of the stimuli, or focusing on a single feature like the mouth, we would not expect to see any difference in detection bias to detect angry versus happy schematic faces. But this remains to be tested further by using conditions with single features alone.

6.1. Limitations and future directions

The HFA/AS participants in the present study were high-functioning to ensure they could complete the tasks involved, however this subgroup does not reflect the entire spectrum of people with autism. Therefore, future investigations of this type should include lower-functioning people with autism to see if findings extend to lower-functioning people with autism.

Future studies should also include child and female participants to investigate the developmental course of the rapid and automatic processing of facial expressions in autism. If the same findings of intact anger superiority during visual search are found in children, it might be inferred that these mechanisms are innately present in ASC. If these effects are not found in children with ASC, then findings may be due to compensation or 'learned' strategies. Research is under way in our lab, to investigate these groups.

6.2. Conclusion

The results of this study show that controls find angry faces faster and more accurately than happy faces, and that they dwell longer with crowds of all angry faces. The search was so effective they showed pop-out for the angry faces. Surprisingly, the HFA/AS group also showed faster and more accurate detection of angry faces in most conditions. However, they did not find the effect with widely varying crowd sizes and with inverted orientation, and also did not show evidence of pop-out. This suggests that, while they showed the anger superiority effect, they may be processing the faces using a different strategy or style.

References

Adolphs, R., Baron-Cohen, S., & Tranel, D. (2002). Impaired recognition of social emotions following amygdala damage. *Journal of Cognitive Neuroscience, 14*(8), 1264–1274.

Adolphs, R., Sears, L., & Piven, J. (2000). Abnormal processing of social information from faces in autism. *Journal of Cognitive Neuroscience, 13*(2), 232–240.

Adolphs, R., Tranel, D., & Damasio, A. R. (1998). The human amygdala in social judgment. *Nature, 393*(6684), 470–474.

Adolphs, R., Tranel, D., Damasio, H., & Damasio, A. R. (1995). Fear and the human amygdala. *Journal of Neuroscience, 15*(9), 5879–5891.

Adolphs, R., Tranel, D., Hamann, S., Young, A. W., Calder, A. J., Phelps, E. A., et al. (1999). Recognition of facial emotion in nine individuals with bilateral amygdala damage. *Neuropsychologia, 37*(10), 1111–1117.

Aggleton, J. (2000). *The amygdala: A functional analysis* (2nd ed.). New York: Oxford University Press.

Anderson, A. K., & Phelps, E. A. (2001). Lesions of the human amygdala impair enhanced perception of emotionally salient events. *Nature, 411*, 305–309.

APA (1994).*DSM-IV Diagnostic and Statistical Manual of Mental Disorders* (4th ed.). Washington, DC: American Psychiatric Association.

Aronoff, J., Barclay, A. M., & Stevenson, L. A. (1988). The recognition of threatening facial stimuli. *Journal of Personality and Social Psychology, 54*(4), 647–655.

Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., & Bullmore, E. T. (in press). Differential activation of the social brain during fearful face-processing in adults with and without autism.

Asperger, H. (1944). Die "Autistischen Psychopathen" im Kindesalter. *Archiv fur Psychiatrie und Nervenkrankheiten, 117*, 76–136.

Bachevalier, J. (2000). The amygdala, social cognition, and autism. In J. Aggleton (Ed.), *The Amygdala: Neurobiological aspects of emotion, memory and mental dysfunction*. New York: Wiley-Liss.

Baird, G., Charman, T., Baron-Cohen, S., Cox, A., Swettenham, J., Wheelwright, S., et al. (2000). A screening instrument for autism at 18 months of age: A 6-year follow- up study. *J. Am. Acad. Child Adolesc. Psychiatry, 39*(6), 694–702.

Balaban, M. T. (1995). Affective influences on startle in five-month-olds: Reactions to facial expressions of emotion. *Child Development, 66*, 28–36.

Baron-Cohen, S., Ring, H., Wheelwright, S., Bullmore, E., Brammer, M., Simmons, A., et al. (1999). Social intelligence in the normal and autistic brain: An fMRI study. *European Journal of Neuroscience, 11*, 1891–1898.

Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. (2000). The amygdala theory of autism. *Neuroscience and Biobehavioural Reviews, 24*(3), 355–364.

Baron-Cohen, S., Spitz, A., & Cross, P. (1993). Can children with autism recognize surprise? *Cognition and Emotion, 7*, 507–516.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" Test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241–251.

Baron-Cohen, S., Wheelwright, S., & Jolliffe, T. (1997). Is there a "language of the eyes. Evidence from normal adults and adults with autism or Asperger syndrome. *Visual Cognition, 4*, 311–331.

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.

Blair, R. J. (2003). Facial expressions, their communicatory functions and neuro-cognitive substrates. *Philosophical Transactions of the Royal Society of London, B, Biological Sciences, 358*(1431), 561–572.

Bolte, S., & Poustka, F. (2003). The recognition of facial affect in autistic and schizophrenic subjects and their first-degree relatives. *Psychol. Med., 33*(5), 907–915.

Breiter, H. C., Etcoff, N. L., Whalen, P. J., Kennedy, W. A., Rauch, S. L., Buckner, R. L., et al. (1996). Response and habituation of the human amygdala during visual processing of facial expression. *Neuron, 17*(5), 875–887.

Bruce, V. (1988). *Recognizing faces*. London: Lawrence Erlbaum Associates.

Bruce, V., & Young, A. (1986). Understanding face-recognition. *British Journal of Psychology, 77*, 305–327.

Calder, A. J., Young, A. W., Rowland, D., Perrett, D. I., Hodges, J. R., & Etcoff, N. L. (1996). Facial emotion recognition after bilateral amygdala damage: Differentially severe impairment of fear. *Cognitive Neuropsychology, 13*, 699–745.

Celani, G., Battacchi, M. W., & Arcidiacono, L. (1999). The understanding of the emotional meaning of facial expressions in people with autism. *Journal of Autism and Developmental Disorders, 29*(1), 57–66.

Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C., Van Amelsvoort, T., Robertson, D. M., et al. (2000). The functional neuroanatomy of social behaviour: Changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain, 123*(11), 2203–2212.

Darwin, C. (1872/1965). *The expression of emotions in man and animals*. Chicago: University of Chicago Press.
Davis, M. (1992). The role of the amygdala in conditioned fear. In J. Aggleton (Ed.), *The amygdala: Neurobiological aspects of emotion, memory and mental dysfunction* (pp. 255–305). New York: Wiley-Liss.
Eastwood, J. D., Smilek, D., & Merikle, P. M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & Psychophysics, 63*, 1004–1013.
Eastwood, J. D., Smilek, D., & Merikle, P. M. (2003). Negative facial expression captures attention and disrupts performance. *Perception & Psychophysics, 65*(3), 352–358.
Ekman, P. (2003). *Emotions revealed*. London: Weidenfeld & Nicolson.
Farah, M., McMullen, P., & Meyer, M. (1991). Can recognition of living things be selectively impaired? *Neuropsychologia, 29*, 185–193.
Forster, K. L., & Forster, J. C. (2003). DMDX: a windows display program with millisecond accuracy. *Behaviour Research Methods, Instruments, and Computing, 35*(1), 116–124.
Fox, E., Russo, R., Bowles, R. J., Pichler, A., & Dutton, K. (2000). Facial expressions of emotion: are angry faces detected more efficiently? *Cognition and Emotion, 14*(1), 61–92.
Frith, U. (2003). *Autism. Explaining the enigma* (2nd ed.). Oxford: Blackwell.
Golan, O., Baron-Cohen, S., & Hill, J. J. (in press). The Cambridge Mindreading (CAM) Face-Voice Battery: Testing complex emotion recognition in adults with and without Asperger Syndrome. *Journal of Autism and Developmental Disorders*.
Grelotti, D. J., Klin, A. J., Gauthier, I., Skudlarski, P., Cohen, D. J., Gore, J. C., et al. (2005). fMRI activation of the fusiform gyrus and amygdala to cartoon characters but not to faces in a boy with autism. *Neuropsychologia, 43*(3), 373–385.
Grossman, J. B., Klin, A., Carter, A. S., & Volkmar, F. R. (2000). Verbal bias in recognition of facial emotions in children with Asperger syndrome. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 41*, 369–379.
Hansen, P., & Hansen, R. (1988). Finding the face in the crowd: An anger superiority effect. *Journal of Personality and Social Psychology, 54*, 917–924.
Happe, F. (1999). Autism: Cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3*, 216–222.
Hershler, O., & Hochstein, S. (2005). At first sight: A high-level pop out effect for faces. *Vision Research, 45*, 1707–1724.
Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. *British Journal of Developmental Psychology, 79*, 441–453.
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.
ICD-10 (1994). *International classification of diseases* (10th ed.). Geneva, Switzerland: World Health Organisation.
Johnson, M. H. (2003). *Developmental cognitive neuroscience*. Oxford: Blackwell Publishing.
Joseph, R. M., & Tanaka, J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, 44*(4), 529–542.
Kanner, L. (1943). Autistic disturbance of affective contact. *Nervous Child, 2*, 217–250.
Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: Lessons from autism. *Philosophical Transactions of the Royal Society of London, B, Biological Sciences, 358*(1430), 345–360.
Kotsoni, E., de Haan, M., & Johnson, M. H. (2001). Categorical perception of facial expressions by 7-month-old infants. *Perception, 30*, 1115–1125.
Langdell, T. (1978). Recognition of faces: An approach to the study of autism. *Journal of Child Psychology and Psychiatry, 19*, 225–238.
LeDoux, J. E. (1996). *The emotional brain: The mysterious underpinnings of emotional life*. New York: Simon and Schuster.
Lundqvist, D., Esteves, F., & Ohman, A. (1999). The face of wrath: Critical features for conveying social threat. *Cognition and Emotion, 13*, 691–711.
Lundqvist, D., Esteves, F., & Ohman, A. (2004). The face of wrath: The role of features and configurations in conveying social threat. *Cognition and Emotion, 18*(2), 161–182.
Mineka, S., & Ohman, A. (2002). Phobias and preparedness: The selective, automatic, and encapsulated nature of fear. *Biological Psychiatry, 52*(10), 927–937.
Morris, J., Frith, C., Perrett, D., Rowland, D., Young, A., Calder, A., et al. (1996). A differential neural response in the human amygdala to fearful and happy facial expressions. *Nature, 383*, 812–815.
Morris, J. S., Ohman, A., & Dolan, R. J. (1998). Conscious and unconscious emotional learning in the human amygdala. *Nature, 393*(6684), 467–470.
Morris, J. S., Ohman, A., & Dolan, R. J. (1999). A subcortical pathway to the right amygdala mediating "unseen" fear. *Proceedings of the National Academy of Sciences of the United States of America, 96*(4), 1680–1685.
Nothdurft, H. C. (1993). Faces and facial expressions do not pop out. *Perception, 22*(11), 1287–1298.
Ohman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal of Personality and Social Psychology, 80*(3), 381–396.
Ohman, A., & Mineka, S. (2001). Fears, phobias, and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review, 108*(3), 483–522.
Ohman, A., & Soares, J. J. (1993). On the automatic nature of phobic fear: Conditioned electrodermal responses to masked fear-relevant stimuli. *Journal of Abnormal Psychology, 102*(1), 121–132.
O'Riordan, M., & Plaisted, K. (2001). Enhanced discrimination in autism. *Quarterly Journal of Experimental Psychology, A, 54*(4), 961–979.
O'Riordan, M. A., Plaisted, K. C., Driver, J., & Baron-Cohen, S. (2001). Superior visual search in autism. *Journal of Experimental Psychology, Human Perception and Performance, 27*(3), 719–730.
Phillips, M. L., Young, A. W., Scott, S. K., Calder, A. J., Andrew, C., Giampietro, V., et al. (1998). Neural responses to facial and vocal expressions of fear and disgust. *Proceedings of the Royal Society of London. Series B. Biological Science, 265*(1408), 1809–1817.
Pierce, K., Haist, F., Sedaghat, F., & Courchesne, E. (2004). The brain response to personally familiar faces in autism: Findings of fusiform activity and beyond. *Brain, 127*, 2703–2716.
Pierce, K., Muller, R. A., Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform 'face area' in autism: Evidence from functional MRI. *Brain, 124*(10), 2059–2073.
Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998a). Enhanced discrimination of novel, highly similar stimuli by adults with autism during a perceptual learning task. *Journal of Child Psychology and Psychiatry, 39*(5), 765–775.
Plaisted, K., O'Riordan, M., & Baron-Cohen, S. (1998b). Enhanced visual search for a conjunctive target in autism: A research note. *Journal of Child Psychology and Psychiatry, 39*(7), 777–783.
Salmond, C. H., de Haan, M., Friston, K. J., Gadian, D. G., & Vargha-Khadem, F. (2003). Investigating individual differences in brain abnormalities in autism. *Philosophical Transactions of the Royal Society of London, B, Biological Sciences, 358*, 405–413.
Schultz, R. T. (2005). Developmental deficits in social perception in autism: the role of the amygdala and fusiform face area. *International Journal of Developmental Neuroscience, 23*(2–3), 125–141.
Schwartz, G., Izard, C., & Ansul, S. (1985). The 5-month-old's ability to discriminate facial expressions of emotions. *Infant Behavior and Development, 8*, 65–77.
Schultz, R., Romanski, L. M., & Tsatsanis, K. D. (2000). Neurofunctional models of autistic disorder and asperger syndrome. In A. Klin, F. R. Volkmar, & S. S. Sparrow (Eds.), *Asperger syndrome* (pp. 172–209). New York: Guildford Press.
Senju, A., Tojo, Y., Dairoku, H., & Hasegawa, T. (2004). Reflexive orienting in response to eye gaze and an arrow in children with and without autism. *Journal of Child Psychology and Psychiatry, 45*(3), 445–458.
Serrano, J. M., Iglesias, J., & Loeches, A. (1992). Visual discrimination and recognition of facial expressions of anger, fear, and surprise in 4- to 6-month-old infants. *Developmental Psychobiology, 25*, 411–425.

Swettenham, J., Condie, S., Campbell, R., Milne, E., & Coleman, M. (2003). Does the perception of moving eyes trigger reflexive visual orienting in autism? *Philosophical Transactions of the Royal Society of London, B, Biological Sciences, 358*(1430), 325–334.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46A*, 225–245.

Teunisse, J. P., & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: the inversion and composite effects. *Brain and Cognition, 52*(3), 285–294.

Tipples, J., Atkinson, A. P., & Young, A. W. (2002). The eyebrow frown: a salient social signal. *Emotion, 2*(3), 288–296.

Tipples, J., Young, A. W., Quinlan, P., Broks, P., & Ellis, A. W. (2002). Searching for threat. *The Quarterly Journal of Experimental Psychology A, 55*(3), 1007–1026.

Tong, F., & Nakayama, K. (1999). Robust representations for faces: Evidence from visual search. *Journal of Experimental Psychology. Human Perception and Performance, 25*(4), 1016–1035.

Treisman, A., & Souther, J. (1985). Search asymmetry: A diagnostic for preattentive processing of separable features. *Journal of Experimental Psychology. General, 114*(3), 285–310.

Volkmar, F., Sparrow, S., Rende, R. D., & Cohen, D. J. (1989). Facial perception in autism. *Journal of Child Psychology and Psychiatry, 30*, 591–598.

Volkmar, F. R., Lord, C., Bailey, A., Schultz, R. T., & Klin, A. (2004). Autism and pervasive developmental disorders. *Journal of Child Psychology and Psychiatry, 45*(1), 135–170.

Vuilleumier, P., & Schwartz, S. (2001). Emotional facial expressions capture attention. *Neurology, 56*(2), 153–158.

Wechsler, D. (1999). *Wechsler abbreviated scale of intelligence*. San Antonio: The Psychological Corporation.

Weeks, S. J., & Hobson, R. P. (1987). The salience of facial expression for autistic children. *Journal of Child Psychology and Psychiatry, 28*, 137–152.

Welchew, D., Ashwin, C., Berkouk, K., Salvador, R., Suckling, J., Baron-Cohen, S., et al. (2005). Functional dysconnectivity of the medial temporal lobe in autism. *Biological Psychiatry, 57*(9), 991–998.

Whalen, P. J., Rauch, S. L., Etcoff, N. L., McInerney, S. C., Lee, M. B., & Jenike, M. A. (1998). Masked presentations of emotional facial expressions modulate amygdala activity without explicit knowledge. *The Journal of Neuroscience, 18*, 411–418.

White, M. (1995). Preattentive analysis of facial expressions of emotion. *Cognition and Emotion, 9*, 439–460.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*, 141–145.

Young, A. W. (1998). *Face and mind*. Oxford: Oxford University Press.