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Analysis of face gaze in autism using “Bubbles”

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Abstract

One of the components of abnormal social functioning in autism is an impaired ability to direct eye gaze onto other people’s faces in social situations. Here, we investigated the relationship between gaze onto the eye and mouth regions of faces, and the visual information that was present within those regions. We used the “Bubbles” method to vary the facial information available on any given trial by revealing only small parts of the face, and measured the eye movements made as participants viewed these stimuli. Compared to ten IQ- and age-matched healthy controls, eight participants with autism showed less fixation specificity to the eyes and mouth, a greater tendency to saccade away from the eyes when information was present in those regions, and abnormal directionality of saccades. The findings provide novel detail to the abnormal way in which people with autism look at faces, an impairment that likely influences all subsequent face processing.

Keywords: Social cognition; Emotion; Autism; HFA; Eyetracking; Facial information

Autism is a neurodevelopmental disorder strongly characterized by deficits in social interaction and impaired understanding of the mental states of others (Baron-Cohen, 1997; Frith & Frith, 1999; Kanner, 1943; Siegel, Vukicevic, & Spitzer, 1990), a dysfunction that persists even in people with autism who have IQs in the normal range. Because high functioning children and adults with autism show (Baron-Cohen et al., 1999; Buitelaar, van Engeland, de Kogel, de Vries, & van Hooff, 1991; Carpenter, Pennington, & Rogers, 2002; Castelli, Frith, Happe, & Frith, 2002; Loveland, Pearson, Tunali-Kotoski, Ortegon, & Gibbs, 2001; Ozonoff & Miller, 1995; Pedersen, Livoir-Petersen, & Schelde, 1989; Rogers, 2000; Rogers, Hepburn, Stackhouse, & Wehner, 2003) and report (Gilpin, 2002; Grandin, 1996) difficulties in social judgment (e.g., understanding others’ emotions, deciding on appropriate social behaviors, etc.), a main focus of autism research is to understand how people with autism process salient social cues, notably from faces.

There has been a considerable amount of work using static faces (i.e., photographs) to investigate social judgments (Celani, Battacchi, & Arcidiacono, 1999; Critchley et al., 2000; Grelotti, Gauthier, & Schultz, 2002; Trepagnier, Sebrechts, & Peterson, 2002; Volkmar, Sparrow, Rende, & Cohen, 1989; Weeks & Hobson, 1987) and gaze fixation behavior (Pelphrey et al., 2002; Trepagnier et al., 2002; van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002a; van der Geest, Kemner, Verbaten, & van Engeland, 2002b). Weeks and Hobson (1987) showed that children with autism sorted static images of emotional facial expressions using non-emotional characteristics (e.g., type of hat the person was wearing), while control children matched for verbal ability sorted the faces mainly according to emotional expression. The difference in behavior was unlikely to be due to impairments in simple object recognition, since Volkmar et al. (1989) found that children with autism performed normally in assembling puzzles displaying pictures of human faces. Celani et al. (1999) found that children with autism were impaired both at matching facial emotions in static faces and at judging valence from static facial expressions, compared to healthy controls or controls with Down syndrome. Children with autism were not impaired at matching facial identities or at judging valence given a social situation, however, further, Trepagnier et al. (2002) found that high functioning people with autism, while being normal or better than normal at object recognition, were impaired in facial recognition.

Eyetracking studies of children and adults with autism have typically found abnormally infrequent gaze to the eyes and abnormally frequent gaze to the mouth (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b; but see van der Geest et al., 2002a). Pelphrey et al. (2002), in a study of high functioning adults with autism, showed increased gaze to nonfeatural elements of static faces and decreased gaze to facial features (e.g., eyes, nose,

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mouth) compared to controls. Trepagnier et al. (2002) found that high functioning people with autism showed less gaze onto faces overall than controls.

Critchley and co-workers (2000) identified neurobiological abnormalities in high functioning adults with autism during processing of emotional facial images: unlike in healthy brains, the fusiform face area, the left amygdala, and the left cerebellum failed to show significant activations during implicit processing of faces. Ogai et al. (2003) were also able to differentiate high functioning people with autism from controls using neuroimaging during face processing. Although they did not find any behavioral differences in the ability to accurately judge the emotion in a face, they did show reduced activation in the insula elicited by disgust faces and reduced activation in the middle frontal gyrus in response to fear faces.

The literature thus documents impairments in eye gaze, in social judgments, and in brain activation when people with autism process faces. An important open question is whether the impaired face gaze might account for impairments in the other two domains, an issue that requires quantitative, detailed assessment of face gaze behavior. Here, we probed several aspects of face gaze behavior during emotion judgment in autism. Specifically, we focused on the relationship between, on the one hand, fixations to and saccades away from the eyes and mouth, and on the other hand, the visual information present within those regions.

First, we examined whether people with autism would show less specific fixation behavior to the eyes and mouth, such that their fixations to those regions would not be as strongly associated with information in the regions. Given that people with autism are reported to make more fixations to the mouth and less to the eyes (Klin et al., 2002b), compared to controls, one would expect that their fixations to the mouth would be less specific than those of controls. Second, we examined the relationship between saccades away from the eyes and mouth and the information within those regions. Given evidence for direct gaze aversion in autism (Dalton et al., 2005; Hutt & Ounsted, 1966; Richer & Coss, 1976), one would expect that when people with autism make saccades away from the eyes, there would be greater information in the eye areas, compared to when controls make saccades away from the eyes. Controls, of course, would be expected not to make saccades away from the eyes when task-relevant information is present there. Finally, we examined whether people with autism make saccades away from the eyes and mouth in the same general direction as do controls. Given known facial processing deficits in autism, one would expect that people with autism would show abnormal directionality in saccades away from the eyes and mouth, compared to controls.

Our approach, utilizing the "Bubbles" method (Gosselin & Schyns, 2001), combines the ease of static facial stimuli with an approach that allows the visual information in the face on each trial to be varied randomly. During "Bubbles," a given trial shows only randomly revealed areas of the face, determined by the number of "bubbles," or Gaussian holes in a mask covering the underlying, or base, image. This mask is called the "Bubbles" mask. The more bubbles there are, the greater the portion of the face that is revealed to a viewer. Averaging "Bubbles" masks in a parameter-specific manner across all the trials (i.e., across emotions as well) yields an image, called the "diagnostic image," that depicts which areas of the face, on average, were associated most with the parameter under investigation. For example, if people fixated the ears consistently, and not the eyes and mouth, when the ears were revealed by the "Bubbles" method, an analysis driven by fixations to the ears would yield an image prominently showing the ears but missing the eyes and mouth. So what is seen in a "Bubbles" diagnostic image is the information associated with the behavioral parameter under investigation. We combined eyetracking with "Bubbles" in order to answer questions about the facial information associated with detailed aspects of face gaze behavior.

1. Methods

1.1. Research participants

Research methods were conducted with the approval of the Institutional Review Boards at the California Institute of Technology and the University of North Carolina. Eight high functioning male participants with autism (HFA) were recruited through the Subject Registry of the Neurodevelopmental Disorders Research Center (NDRC) at the University of North Carolina, where they were tested. All HFA participants met DSM-IV/ICD-10 diagnostic criteria for autism, and all met the cutoff scores for autism on both the Autism Diagnostic Interview (LeCouteur, Rutter, & Lord, 1989) and the Autism Diagnostic Observation Schedule (Lord et al., 1989). We assessed IQ for all participants using the Wechsler Abbreviated Scale of Intelligence (WASI^{TM}). The HFA group had a mean age of 23 years (20, 22, 21, 26, 20, 20, 18, 40), and mean IQ values of 106 verbal (108, 77, 122, 74, 120, 130, 87, 131), 102 performance (111, 118, 104, 97, 91, 119, 82, 94), and 104 full scale (111, 96, 115, 83, 106, 128, 83, 112).[1] Ten male participants were enrolled as controls (C) and tested at Caltech with the same protocols as were used for the HFA participants. Control participants had no history of neurological or psychiatric disease or pervasive developmental disorder or other evidence of developmental disability, or family history of autism. Controls had a mean age of 28 years (20, 20, 22, 22, 22, 40, 39, 34, 32, 35), and mean IQ values of 101 verbal (83, 76, 81, 123, 104, 109, 121, 105, 95, 117), 111 performance (93, 106, 98, 119, 118, 106, 119, 109, 121, 119), and 106 full scale (86, 88, 88, 125, 111, 109, 124, 108, 108, 118). There was no significant difference between the HFA group and controls in age, or in verbal, performance, or full-scale IQ ($p > 0.1$ for each comparison, Wilcoxon rank-sum test). All participants had normal or corrected-to-normal vision at testing time.

1.2. Procedures

All eyetracking data and button responses were recorded using the Eyelink II head-mounted eyetracking system (SR Research, Osgoode, Ontario). Eyetracking data were recorded either at 250 Hz, when a stable corneal reflection was obtainable for a given participant, or at 500 Hz, when pupil-only recording was used. These two different sampling rates had no effect on the results. New nine-point calibrations and validations were performed prior to the start of each experiment in a participant's session. Accuracy in the validations typically was better than 0.5° of visual angle. Experiments were run under WindowsXP (Microsoft, Inc.) in Matlab (Mathworks, Inc., Natick, MA) using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) and the Eyelink Toolbox (Cornelissen, Peters, & Palmer, 2002).

[1] High functioning autism (HFA) typically is defined as autism occurring with IQ scores >70. Thus, although our HFA sample included two individuals whose verbal IQs were in the 70s, they belong to the HFA population, especially given that their full-scale IQs are >80. Note that three of the individuals in our control sample had full-scale IQs <90, to ensure IQ comparability.

Judgment of facial expressions in the "Bubbles" task used faces with randomly revealed regions as previously described (Gosselin & Schyns, 2001). Briefly, on each trial, a randomly selected base facial image was first decomposed into a six-level Laplacian pyramid using the Simoncelli steerable pyramid toolbox for Matlab (Portilla & Simoncelli, 2000) with a Gaussian filter subtending 1° of visual angle (11 w × 11 h). Levels one through five were then filtered with a number of bubbles whose centers were randomly distributed across the image. These bubbles are collectively described as the "Bubbles" *mask* for a given spatial frequency on a given trial. After filtering, levels one through five were combined with a standard background corresponding to the sixth level, and the resulting image was presented. The number of bubbles was adjusted for each participant on a trial by trial basis in order to maintain performance accuracy of response near 80% correct. Note that bubbles were allowed to overlap, increasing the amount of the face revealed beyond the size of a single bubble. Base stimuli (256 w × 256 h; pixel units) were cropped from four Ekman faces (Ekman & Friesen, 1976), each of a different posing participant (image codes: A1-6, JB1-9, JJ5-13, MF1-27), and balanced for gender and facial expression (2 fearful, 2 happy, 2 male, 2 female). Images were normalized for magnitude across all spatial frequencies and centrally displayed using a monitor resolution of 640 w × 480 h (pixel units) on a 15.9 in. w × 11.9 in. h monitor, at an eye-to-screen distance of approximately 31 in., thus subtending 11.3° of horizontal visual angle.

A given trial lasted the time it took participants to decide whether the face showed fear or happiness (Adolphs et al., 2005), for a maximal decision time of 10 s following image onset. Participants were asked to judge whether the bubbled face they saw was afraid or happy, by pushing a button. All participants completed 512 trials. On every fifth trial, a circular annulus was centrally displayed and participants were given an opportunity to rest. When they decided to continue, they fixated the annulus and simultaneously pressed a key. This advanced the experiment to the next trial and allowed the system to correct for any drift in eyetracking accuracy. Participants were instructed to decide as quickly as possible and to always make a decision, even if it was a best guess.

1.3. Analysis of performance and gaze behavior

Eyetracking data were analyzed for fixations using the Eyelink DataViewer (SR Research, Osgoode, Ontario). Data were collected for both eyes and gaze coordinates for a given datapoint were calculated by taking the average of the coordinates for both eyes. In discriminating fixations, we set saccade velocity, acceleration, and motion thresholds to 30°/s, 9500°/s^2, and 0.15°, respectively. Regions of interest (ROIs) were drawn for each facial image, using the drawing functions within the DataViewer. We used regions of interest defined as the right eye region (including the right eye and the eye socket around it), the left eye region (including the left eye and the eye socket around it), and the mouth. The designations right and left are anatomical, and not from the perspective of the viewer.

1.4. Association between face gaze and facial information in the eyes and mouth

Each trial in the "Bubbles" paradigm reveals to a participant some areas of the face while obscuring others. To determine the extent of group differences in how face gaze to the right eye region, the left eye region, and the mouth associated with facial information revealed in these regions, we first calculated, for each region of interest, a fixation-dependent "Bubbles" mask. A fixation-dependent "Bubbles" mask for a given region was calculated by summing all "Bubbles" masks for trials on which a fixation was made to the region. We then subtracted one group's fixation-dependent "Bubbles" mask from that of the other group, for each region.

In order to select regions of statistically significant difference, we converted all pixel values in a difference mask into Z-scores relative to that mean and standard deviation. The statistical analyses of the Z-scored classification image[2] proceeded by a recently developed method (Chauvin, Worsley, Schyns, & Gosselin, in press) that uses the same approach as that used for the statistical analysis of significant clusters of activation in fMRI and PET data (Friston, Worsley, Frackowiak, Mazziotta, & Evans, 1994). After smoothing with a Gaussian filter having sigma = 5, we subjected this Z-scored classification image to cluster tests, setting a threshold $t = 2.5$ and a significance $p = 0.001$. This resulted in a group diagnostic difference image for each region, showing which group demonstrated greater association between information in facial regions and fixations to those regions.

We used the procedure described above to determine statistically significant group differences, resulting in diagnostic difference images for each region. For each group, these images showed those regions more associated with fixation to a given region, compared to the other group.

All trials were used for this analysis, including all fixations that occurred between 50 ms following image onset and the end of the trial (i.e., image offset at response).

1.5. Association of saccades from the eyes and mouth with facial information

We followed the same procedure as described, but modified to examine saccade-related facial information. To calculate a saccade-dependent "Bubbles" mask for a given region, we summed all "Bubbles" masks for trials on which fixations in the region were immediately followed by a saccade out of the region.

1.6. Directional analysis of saccades from the eyes and mouth

To determine whether there were group differences in the directionality of eye movements from the eyes and mouth, we examined the directions of saccades initiated from fixations to the eyes and mouth. Our analysis included all fixations to the right eye region, left eye region, and mouth, that occurred between 50 ms after image onset to the end of the trial. We analyzed the directionality of saccades from each region by including all saccades initiated within the region but ending outside of the region.

Circular rose plots were used for descriptive purposes. Rose plots are histograms displaying the saccade angle in bins and the number of saccades in a bin. We used a bin size of 5°. Calculation of circular means and dispersions and non-parametric statistical differences proceeded using circular statistics (Fisher, 1995) implemented in the PhasePACK toolbox in Matlab (http://www.vis.caltech.edu/∼rizzuto/phasepack/).

2. Results

Findings regarding performance on the "bubbles" discrimination task (i.e., accuracy, reaction time), the use of facial information on which this performance was based (as revealed with the "Bubbles" method), and overall fixation behavior across all the trials, are reported elsewhere (Spezio et al., submitted) and summarized here only for background reference. Briefly, there were no group differences in accuracy, reaction time, the number of bubbles required for the task, or overall fixation to either eye: HFA subjects performed entirely normally on these measures. Despite this equivalent overall performance, there were statistically significant group differences in how specific facial areas were used to achieve it. In particular, the "Bubbles" method revealed that the HFA group had a greater reliance on the mouth and a decreased use of both eyes. In addition to this different use of facial information in the "bubbles" task, the HFA group also showed an overall increased fixation to the mouth, compared to controls. The aim of the present study, however, was not to analyze emotion discrimination performance or global fixation tendencies, but rather specifically to investigate the fixations made onto facial features as a function of what features were actually revealed in the "bubbles" image.

[2] (see http://mapageweb.umontreal.ca/gosselif/stat4ci.html).

2.1. Fixations and facial information in the eyes and mouth

We sought to determine whether people with autism were more or less likely than controls to demonstrate an association between gaze to the eyes and mouth and the information displayed in those regions. The "Bubbles" method varies the amount of information in a given region of a face on each trial, allowing us to determine the average amount of information present in a region when a participant looked at that region, compared to when the participant looked at the other regions.

We hypothesized that controls would be fairly specific in their face gaze. That is, we expected that when they looked at

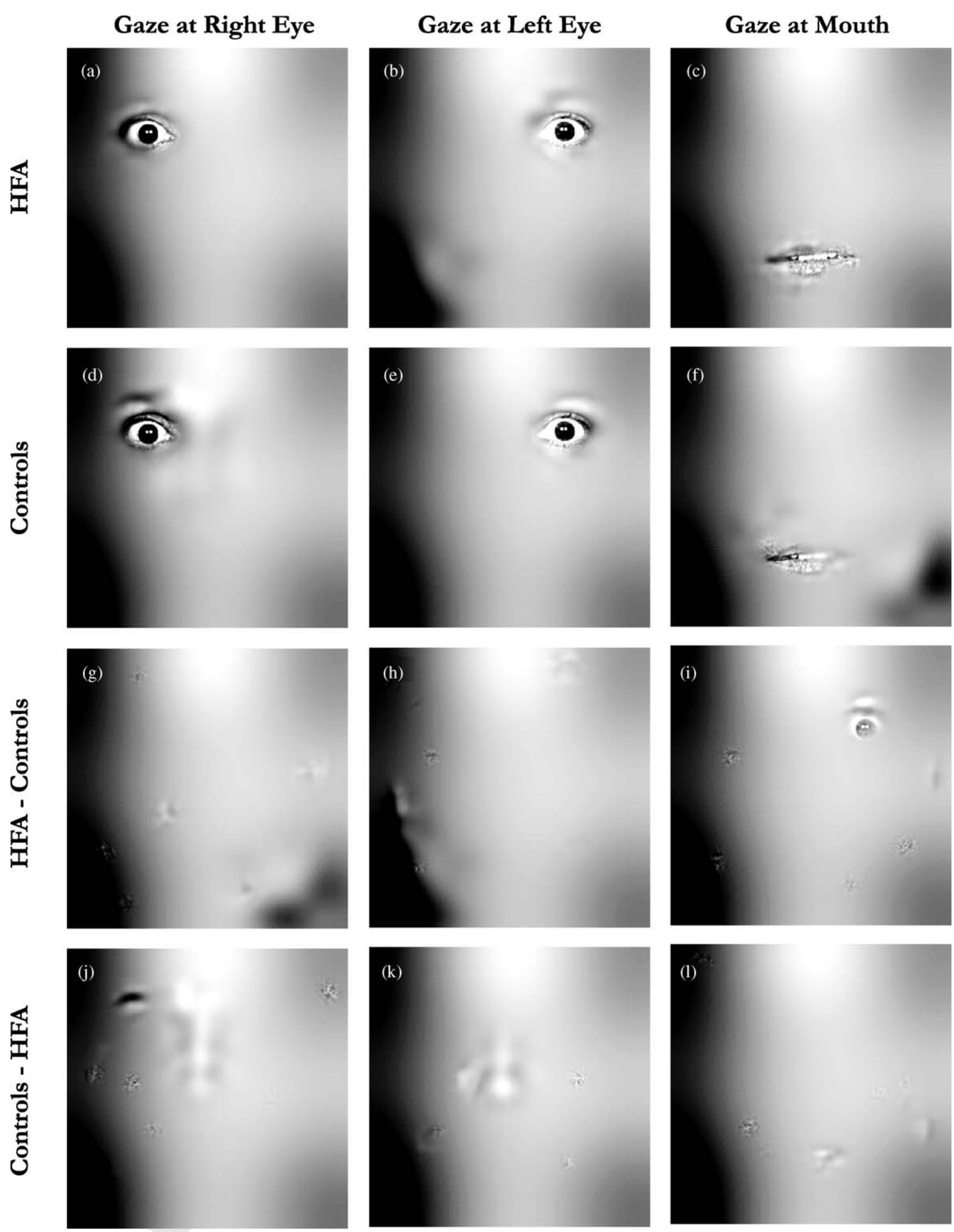

Fig. 1. Fixations and facial information in the eyes and mouth (a–f). The information associated with gaze fixation to the right eye region (a,d), the left eye region (b,e), and the mouth (c,f), compared to gaze fixation to the other two regions (g–l). Group differences in facial information associated with gaze fixation to the right eye region (g,j), the left eye region (h,k), and the mouth (i,l). Note that these images depict statistically thresholded differences; the facial features shown are thus those that differed significantly ($p < 0.001$ with a cluster threshold $t = 2.5$) in their use between the two subject groups.

the eyes, there would, on average, be more information in the eyes than when they looked at the mouth, and vice versa. However, we hypothesized that the HFA group would not show the same gaze specificity for gaze to the mouth as was shown by controls. That is, we expected the HFA group to gaze at the mouth even when information was available in the eyes. We calculated diagnostic difference images to determine the group differences in fixation specificity (see Methods). In what follows, the names of defined regions of interest during fixation analyses are capitalized, while facial features in general are in lower case.

The results are shown in Fig. 1a–f for HFA-Controls (Fig. 1a–c) and Controls-HFA (Fig. 1d–f). There was a slight group difference for information associated with gaze to the mouth (Fig. 1c,f). The HFA group showed greater information in the left eye during gaze to the mouth, compared to controls (i.e., for those trials in which HFA participants looked at the mouth, there was more information available in the left eye than for those trials in which controls looked at the mouth). Controls, on the other hand, showed greater information in the mouth associated with gaze to the Mouth, compared to the HFA group. This suggests both that the HFA group was slightly less dependent upon information in the mouth area in making fixations to that area and that the HFA group fixated the mouth when there was information present in the left eye. Thus, the HFA group showed less gaze specificity to the mouth. A weaker group difference was seen for the right eye region. Here, the HFA group showed decreased information at low spatial frequencies in the right eye during gaze to this region, again suggesting a decrease in gaze specificity. No group difference in the eyes or mouth was seen for the left eye region (Fig. 1a,d).

2.2. Saccades and facial information in the eyes and mouth

To examine whether the HFA group showed a greater propensity to make eye movements away from fixations to the eyes, compared to controls, we analyzed the association between facial information in the eyes and saccades from these areas. We proceeded using the approach described above (see Methods). Since some reports suggest that people with autism find direct eye gaze aversive (Dalton et al., 2005; Hutt & Ounsted, 1966; Richer & Coss, 1976), we predicted that on trials when the HFA group made saccades out of the eye regions, we would find greater information in the eyes, compared to when controls made saccades out of the eye regions. Fig. 2a,b shows this result. When the HFA group made saccades leaving the right eye region (Fig. 2a) or the left eye region (Fig. 2b), there was more information in those areas, and only in those areas, than when controls made the same saccades. Controls did not show any greater information in the eyes or mouth (Fig. 2d,e). Interestingly, there was also a greater amount of information in both eyes when the HFA group made saccades leaving the mouth, compared to controls (Fig. 2c).

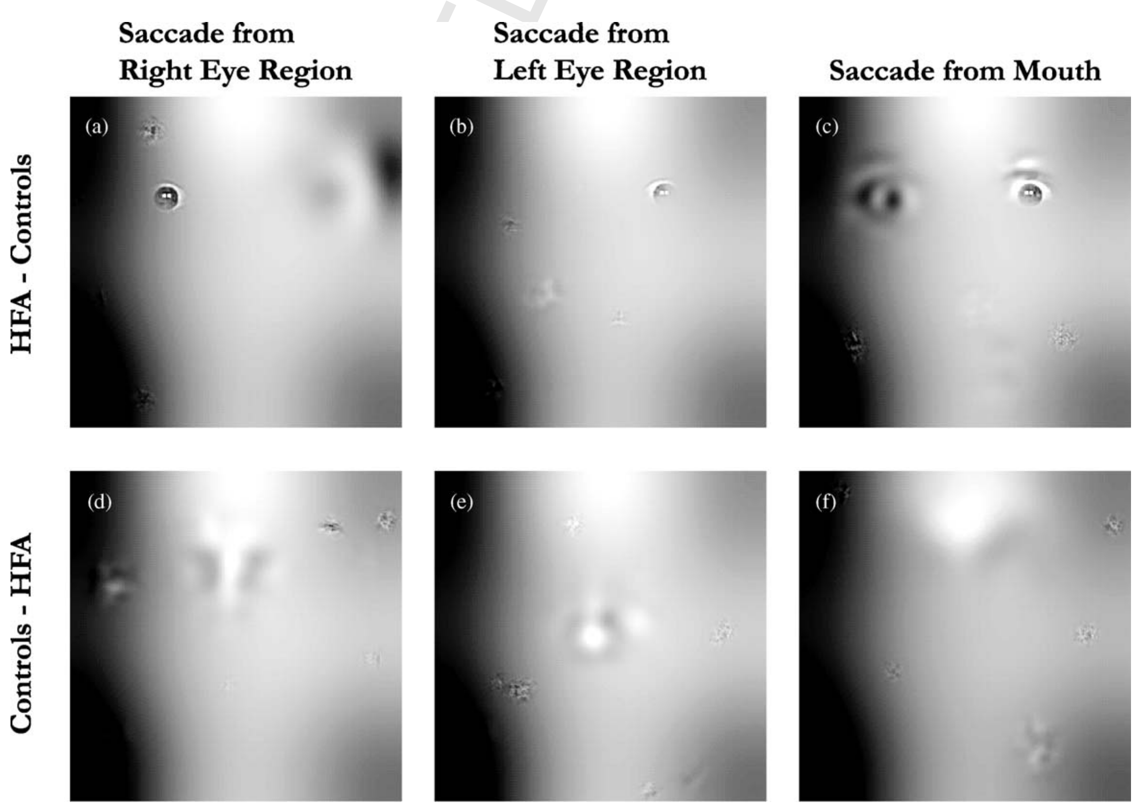

Fig. 2. Saccades and facial information in the eyes and mouth. Shown are group differences in the information associated with saccades leaving the right eye region (a,d), the left eye region (b,e), and the mouth (c,f).

2.3. Directional analysis of saccades leaving the eyes and mouth

Given that the HFA group showed an increased tendency compared to controls to make saccades leaving the eyes when there was information in the eyes, we sought to determine whether the direction of these saccades was also abnormal. We analyzed all saccades leaving the eyes and mouth that immediately followed fixations in those regions. We found no directional difference for the right eye region (HFA, $330° \pm 46°$; C, $330° \pm 61°$; $p > 0.1$; M $\pm$ circular dispersion), shown in Fig. 3a,d. However, there was a difference for the left eye region (Fig. 3b,e), such that the HFA group made a greater proportion of saccades in the direction of the mouth than did controls (HFA, $223° \pm 52°$; C, $214° \pm 42°$; $p < 0.002$). We also found a difference for saccades leaving the Mouth (Fig. 3c,f), in that the HFA group showed a greater propensity to make saccades in the direction of the left eye (HFA, $80° \pm 18°$) than did controls, who showed nearly equal tendencies to make saccades toward both eyes (C, $87° \pm 17°$; $p < 0.0001$). Taken together, these findings suggest that the HFA group showed saccade behavior that was different from controls even when both groups fixated the same key facial regions.

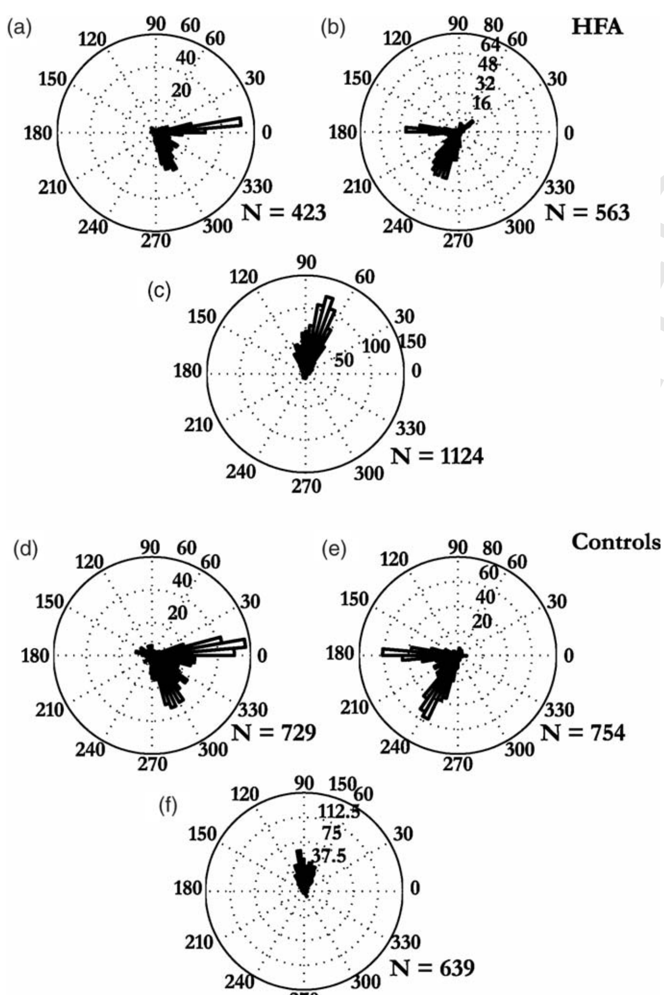

Fig. 3. Directionality of saccades leaving the eyes and mouth. Each circular, or "rose," plot is a histogram of the number of times a saccade leaving a region of interest was in a given direction; bin size was 5°. Shown are data for the right eye region, the left eye region, and the mouth, pooling all saccades leaving the regions immediately following fixations in the region, for the HFA group (a–c) and controls (d–f).

3. Discussion

This is the first report to assess directly how information from different features of the face affects face gaze during emotion judgment in autism. We isolated several face processing impairments in people with autism by employing a novel approach to facial information processing, compared to a group matched for IQ, performance accuracy, and reaction time. We showed that individuals with autism were distinguished from controls in that they exhibited less specificity of fixation to the mouth, an increased tendency to make saccades away from information in fixated eye regions, and abnormal saccade directionality leaving the left eye and mouth. All face gaze abnormalities were observed in the absence of group differences in accuracy and reaction time. Thus, eyetracking in combination with the Bubbles method yielded sensitive measures of behavioral abnormalities in how people with autism process faces, and those abnormalities could not be attributed simply to impaired performance accuracy on the task.

These impairments were revealed using facial expressions of fear and happiness in an emotion judgment task. The primary reason that we limited our study to these two emotions was the large number of trials required in the "bubbles" task, making it infeasible to include additional emotion categories. It is therefore important to consider whether the findings we report are specific for these two emotions, or whether they would generalize to other emotions as well, or even to face processing under other cognitive demands (e.g., identity matching, gender discrimination). Green, Williams, & Davidson (2003) found that people made more fixations to facial features when shown facial expressions of anger and fear, compared to non-threatening facial expressions. No specific featural differences, though, were noted. Similarly, we have not found any major differences in fixation patterns onto facial features between the six basic emotions (Adolphs et al., 2005). Moreover, the highly expression-dependent face gaze specificity seen in a Rhesus monkey model, wherein different facial expressions elicit different amounts of gaze to eyes and mouth (Nahm, Perret, Amaral, & Albright, 1997), has not been observed thus far in humans. Additionally, Klin and coworkers (Klin, Jones, Schultz, Volkmar, & Cohen, 2002a; Klin et al., 2002b) do not report expression-dependent fixation patterns in participants with autism or in controls. It is thus likely that the associations between gaze and facial information that are reported here would generalize to other facial expressions.

Yet, we expect that the same may not be true of other behavioral tasks. For example, judging gender and identity appears to rely on areas of the face beyond the eyes and mouth (Gosselin & Schyns, 2001; Schyns, Bonnar, & Gosselin, 2002). Thus, people with autism may be less oriented to the mouth in tasks not requiring emotion judgment, and there is little evidence that would lead one to expect that people with autism would have a lower specificity of gaze to facial features such as the nose or the hair or the chin when judging identity or gender. To be sure, we expect that the relation between eye information and saccades away from the eyes would still be observed in tasks of identity and gender identification.

In interpreting these findings, one should recall that some have raised the possibility that the "Bubbles" method, which reveals only certain areas of an object on any given trial, alters strategies of visual processing (Murray & Gold, 2004). However, a strong argument has been made that the "Bubbles" method does not elicit an altered visual processing strategy for faces in emotion judgment tasks (Gosselin & Schyns, 2004). That this conclusion applies also in our study is further corroborated by the identical performances on the "Bubbles" task (both in terms of accuracy and reaction times). Thus, it is likely that our findings reflect facial information processing strategies typically employed by the HFA participants and controls when they process whole faces.

The HFA group showed reduced specificity in gaze to the mouth (Fig. 1c,f), suggesting that the participants with autism made fixations to the mouth even when information in the eye areas was present and could presumably have contributed to the emotion judgment task. Several hypotheses could account for this result. The HFA group may have a propensity to look at the mouth whether or not there is any useful information present there at all. However, the slight difference between controls and the HFA group seen in Fig. 1f suggests that this is not the case. Another explanation for the lower specificity shown in Fig. 1c is that the HFA group may show a greater propensity to look at the mouth when there is task-relevant information equally present in the eyes and mouth. Still another hypothesis is that the HFA group's fixation behavior is guided more by task-irrelevant, low-level attention cues, and that the mouth region provides more of those even when there is task-relevant information in the eye regions. We are testing this hypothesis by examining the HFA fixation behavior in relation to predictions made by a computational model of low-level attention (Itti & Koch, 2001).

Several studies and anecdotal reports suggest that people with autism find direct eye gaze aversive (Dalton et al., 2005; Hutt & Ounsted, 1966; Richer & Coss, 1976). We reasoned that if this were the case with the HFA participants in this study, we would see a higher level of information in the eyes when the HFA group made saccades leaving the eyes, compared to controls. Controls, of course, would likely not have made saccades away from the eyes if task-relevant information were present in those regions. Our findings confirm that the HFA group showed greater information in the eyes associated with saccades leaving the left eye. It is likely that we did not observe this difference for the right eye due to the low number of fixations the HFA group made to the right eye. Had more fixations to the right eye been available for analysis, we expect that the increased statistical power would have revealed the same association for the right eye. Our findings are consistent with the notion that people with autism tend to find direct eye contact aversive. Unfortunately, we did not interview the HFA participants to determine whether they in fact report an aversion to direct eye gaze. Nor did our experimental design lend itself to the recording psychophysiological measures that could shed light on this issue. Such design considerations are planned for future experiments.

Saccade behavior in autism has been examined primarily to identify oculomotor deficits in autism, relating these to putative cortical and cerebellar dysfunction (Chawarska, Klin, & Volkmar, 2003; Minshew, Luna, & Sweeney, 1999; Rosenhall, Johansson, & Gillberg, 1988; Takarae, Minshew, Luna, Krisky, & Sweeney, 2004a; Takarae, Minshew, Luna, & Sweeney, 2004b). Here, we analyzed saccade directionality to determine whether there is an impairment in how people with autism make saccades during emotion judgment when they fixate the same key facial features as controls. Our findings, which showed such an impairment for saccades leaving the left eye and mouth, are consistent with the view that face processing deficits in autism are partially independent of the foveated visual information. That is, face processing deficits in autism cannot be fully accounted for by differences in fixation behavior alone, suggesting that the brains of people with autism treat facial information differently, even when the visual stimulus overtly attended is the same.

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