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Differences in discrimination of eye and mouth displacement in autism spectrum disorders

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Abstract

Individuals with Autism Spectrum Disorders (ASD) have been found to have impairments in some face recognition tasks [e.g., Boucher, J., & Lewis, V. (1992). Unfamiliar face recognition in relatively able autistic children. *Journal of Child Psychology and Psychiatry, 33*, 843–859.], and it has been suggested that this impairment occurs because these individuals do not spontaneously attend to the eyes [e.g., Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32*, 249–261.], or attend selectively to the mouth [e.g., Langdell, T. (1978). Recognition of faces—approach to study of autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 19*, 255–268; Joseph, R. M., & Tanaka J. (2003). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, 44*, 529–542.]. Here, we test whether the eyes or the mouth are attended to preferentially by 16 males with ASD and 19 matched controls. Participants discriminated small spatial displacements of the eyes and the mouth. If the mouth region were attended to preferentially by individuals with ASD, we would expect ASD observers to be better at detecting subtle changes in mouth than eye displacements, relative to controls. Further, following Barton [Barton, J. J. S., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology, 92*, 527–549.], we would expect to see differences in inversion effects as a function of feature manipulation between ASD and control groups. We found that individuals with ASD performed significantly differently than controls for the eye, but not the mouth, trials. However, we found no difference in inversion effects between the two groups of observers. Furthermore, we found evidence of distinct subclasses of individuals with ASD: those who performed normally, and those who were impaired. These results suggests that typical individuals are better able to make use of information in the eyes than some individuals with ASD, but that there is no clear autism "advantage" in the use of information in the mouth region.

Keywords: Face perception; Autism; Feature displacement

1. Introduction

Autism spectrum disorders (ASD) are characterized by deficits in social perception and cognition, language delay, and idiosyncratic interests and repetitive behaviors (American Psychiatric Association, 1994). The social deficits seen in ASD are universal and arguably the most clinically profound and debilitating symptoms (Kanner, 1943; Wing & Gould, 1979). In addition (and perhaps related) to these social deficits, people with ASD show a number of visual processing abnormalities, including advantages in Embedded Figures tasks (Shah & Frith, 1983), visual search tasks (Plaisted, O'Riordan, & Baron-Cohen, 1998), and visual attention (Mann & Walker, 2003).

People with ASD do not process faces in the same manner as typically developing individuals. Recent neuroimaging studies suggest that individuals with autism may use an atypical strategy in facial perception, associated with abnormal EEG activity (Dawson, Webb, & McPartland, 2005; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004), relatively reduced activation in the FFA than found in typical individuals (Pierce, Muller, Ambrose,

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Allen, & Courchesne, 2001; Schultz et al., 2000), and relatively increased activation in other brain areas (Baron-Cohen et al., 1999; Hubl et al., 2003). For example, Hubl and colleagues (Hubl et al., 2003) measured blood oxygen level dependent changes while participants with and without autism looked at faces and other complex objects. Participants with autism showed less activation in the fusiform gyrus, but greater activation in areas associated with object recognition (the medial occipital gyrus) and visual search (the superior parietal lobule and the medial frontal gyrus). These results suggest that individuals with autism may be using an atypical visuospatial strategy to process faces, possibly focusing on the different facial features in turn. Another study used magnetoencephalography (MEG) to find that people with ASD viewing faces showed weaker, less lateralized responses that were less affected by stimulus repetition compared to controls (Bailey, Braeutigam, Jousmaki, & Swithenby, 2005).

Behavioural evidence also points to potential face recognition deficits in ASD (Boucher & Lewis, 1992; Boucher, Lewis, & Collins, 1998; Braverman, Fein, Lucci, & Waterhouse, 1989; Ozonoff, Pennington, & Rogers, 1990; Tantam, Monaghan, Nicholson, & Stirling, 1989). In one early study, Boucher and Lewis (1992) found that children with autism were impaired in matching unfamiliar faces relative to an IQ matched control group, although children with autism were not impaired in matching houses and other buildings. Klin and colleagues found a similar face recognition deficit in individuals with classic autism, but not in those with pervasive developmental disorder, not otherwise specified, which is thought to be on the autism spectrum (Klin et al., 1999). Consistent with the conclusions of neuroimaging results, behavioral results suggest that there are differences in visual processing of faces between people with ASD and typical individuals.

What leads to differences in face processing between individuals with and without ASD? Some researchers have suggested that people with ASD process faces in a piecemeal fashion, relying more on analysis of individual features than on the configuration of features (van der Geest, Kemner, Verbaten, & van Engeland, 2002). For example, in typically developed observers, inverted faces are more difficult to identify than upright faces (Sekuler, Gaspar, Gold, & Bennett, 2004; Valentine, 1988; Yin, 1969), and parts of composite faces are more difficult to discriminate when irrelevant regions of the face are aligned than when they are misaligned (Maurer, le Grand, & Mondloch, 2002; Young, Hellawell, & Hay, 1987), both sorts of results have been taken by many researchers as an indication of configural processing of faces. However, some researchers have suggested that people with ASD do not show the usual "face inversion effect" (Langdell, 1978; Tantam et al., 1989), and other researchers found that young adults with autism did not show the typical composite face effect (Teunisse & de Gelder, 2003). It is important to note, though, that some recent work supports the idea that anomalous visual processing in ASD is not restricted to face processing or even to social domains. To wit, deficits in global visual processing are not limited to face processing (Behrmann, Thomas, & Humphreys, 2006).

Despite previous research, the idea that people with autism process faces using featural rather than configural cues is controversial. Although Teunisse and de Gelder (2003) found atypical composite face effects, they found normal face inversion effects for people with ASD when memory loads were minimized. Rouse and colleagues found a normal "Thatcher illusion," from which they concluded that those with autism could perceive second order relationships, and thus had typical face processing (Rouse, Donnelly, Hadwin, & Brown, 2004). Furthermore, recent work with typical individuals (Sekuler et al., 2004) calls into question the standard assumption that the face inversion effect is related to a difference in featural versus configural processing. Their results showed that, regardless of orientation, observers based their discrimination judgments on a limited amount of information centered around the eye/brow region. These authors suggest that the face inversion effect is a result of reduced efficiency at extracting relevant information from inverted faces compared to upright faces. Consistent with the view that processing the eye region is critical for recognition in typical individuals, Sadr and colleagues found that famous faces were significantly more difficult to recognize when the eyes or especially the eyebrows were removed from images (Sadr, Jarudi, & Sinha, 2003). Some research also suggests that the face sensitive N170 ERP component is driven, in large part, by information in the eye region (Itier, Latinus, & Taylor, 2006).

In contrast to the results with typical individuals, there is some evidence suggesting that people with ASD do not primarily orient to the eyes region of the face (Pelphrey et al., 2002; Pierce et al., 2001; Ristic et al., 2005). For example, eye-tracking studies suggest that people with ASD spend less time fixating on the eyes regions than do controls (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey et al., 2002; van der Geest et al., 2002). One recent study also showed that when people with ASD do fixate on the eyes, there is activation of the fusiform gyrus and the amygdala, suggesting that reports of lower activation in these areas in people with ASD may be explained by the decrease in eye gaze fixation (Dalton et al., 2005).

Indeed, some research has suggested that people with ASD orient selectively to the mouth region of the face, rather than to the eyes. For example, in one eye-tracking study in which participants viewed naturalistic images, participants with autism were more likely than controls to look at mouths, bodies, and inanimate objects, and less likely to look at eyes (Klin et al., 2002). Langdell (1978) asked children and adolescents with autism to perform a face recognition task for upright and inverted faces in which either the upper or lower part of the faces was masked. The younger children relied more on the mouth region to make their identifications compared to an age matched control group and an IQ matched control group.

Compared to controls, children with autism were better at recognizing faces when only the mouth region was visible, and the eyes region was occluded (Langdell, 1978). Similarly, Joseph and Tanaka tested typical children and those with ASD (ages 9–11) on a face recognition task, using both whole faces and parts of faces. They found that typical children were better than ASD children at recognition on trials that depended upon the eyes, but those with ASD were better than controls when the trial depended upon the mouth (Joseph & Tanaka, 2003). These authors concluded that children with autism derive more information from the mouth region of the face than do controls.

The current study is designed to test whether young adults with ASD treat the mouth as a more salient facial feature than the eyes (preferentially visually orienting to the mouth), under conditions in which IQ, sex and education matched typically developed controls preferentially attend to the eyes. To this end, we adapted the featural displacement discrimination paradigm of Barton and colleagues (Barton, Keenan, & Bass, 2001). Barton et al. created faces in which the eyes were laterally displaced by varying distances, or in which the mouth had been vertically displaced by varying distances, and observers were unaware from one trial to the next which feature had been manipulated. In the discrimination task, typical observers were presented three face images simultaneously and had to choose which of the three was dissimilar to the others. As feature displacement increased for upright faces, accuracy increased for both eye and mouth displacement stimuli, although smaller mouth displacements were required to reach the same level of performance as found with larger eye displacements. In the current study, therefore, multiple displacement distances were used to compare the rate at which increased displacement aids discrimination across eye and mouth trials.

For short duration stimuli, when the face was inverted, levels of performance were similar to those for upright faces for stimuli with eye displacements. In contrast, inversion impaired performance on the mouth displacement task, even when the displacement was relatively extreme. Barton et al. concluded that this pattern of results was evidence for the primacy of information in the eye region: if observers have a limited amount of time to process a face, the eye region will be processed first, and then, if there is time remaining, the mouth region may be processed after. When the face is presented in the familiar, upright orientation, observers are more efficient at extracting the relevant information from a face than when the face is presented in the unfamiliar inverted orientation, consistent with the idea that observers are more efficient at processing learned stimuli than novel stimuli (Gold, Sekuler, & Bennett, 2004; Sekuler et al., 2004). Therefore, when an upright face is presented for a limited duration, the observer has time to process both the eye and mouth regions. However, when an inverted face is presented for the same limited duration, the observer has enough time to extract information from the eye region, but processing is not efficient enough to enable complete processing of the mouth region as well. As a result, in typical individuals, one observes an inversion effect for the mouth region, but not for the eye region, when stimuli are presented for limited durations. To test this prediction directly in observers with and without autism, we presented trials of three different durations, varying the amount of time available to extract information about the less salient facial features.

Barton and colleagues have shown convincingly that the extent of the inversion effect is linked to the relative salience of a feature. For example, when mouth and eye displacements are equally likely, one sees a mouth inversion effect but no eye inversion effect. However, if the observer knows the displacement is much more likely to occur in the mouth than the eyes, this pattern reverses, and the mouth inversion effect is reduced while the eye inversion effect increases. As such, the unbiased feature inversion effect allows us to test whether people with autism similarly spontaneously orient to information in the eyes region of the face, or if they instead preferentially use information in the mouth region. If people with ASD preferentially use information in the mouth region, rather than the eye region, they should fail to show the mouth inversion effect observed by Barton et al. (2001). We would instead expect them to be better at discriminating mouth displacements of inverted faces relative to neurotypical observers. As well, if people with ASD use the eye region only secondarily, we would now expect to see a clear inversion effect appear for discrimination of eye displacements.

2. Methods

2.1. Observers

Thirty-six volunteers participated in the experiment. They were 16 high functioning adolescents and young adults in the ASD group (all male, average age 19.6 years; range 15–23), and 19 typical young adults in the control group (all male, average age 21.0 years; range 16–30; matched on performance IQ). All participants in the ASD group had previously received clinical diagnoses of autism before entering the study, and one of the authors (MDR) confirmed their diagnoses via two criteria: (1) Autism Diagnostic Interview (ADI-R) (Lord, Rutter, & LeCouteur, 1994); (2) the Autism Diagnostic Observation Schedule (ADOS-G) (Lord et al., 2000). They were free from other known medical conditions. One additional ASD observer was excluded from the analyses because she made her responses without looking at the computer screen. (See Table 1 for demographic information of observers included in the study).

2.2. Stimuli and apparatus

Visual stimuli were presented on a 22" NEC monitor (resolution 1024 by 768, refresh rate = 85 Hz), and responses were recorded via a keyboard. A Microsoft Pentium IV computer with a Windows XP operating system recorded responses and controlled stimulus presentation. The experiment was compiled on and presented by E-Prime software, Version 1.1.

The stimuli were modeled after those used by Barton et al. (2001), except that we did not show any hair or contour features, so only the internal features of the face were visible within a constant oval window. Two grayscale front-view face images, one showing a male, one showing a female, were used to create base faces (from the original set of faces used

Table 1
Chronological age and WAIS IQ scores for the ASD and control groups

	ASD ($n = 16$)	Control group ($n = 19$)	$t(31)$
Age	19.6 (2.13) 15–23	24.30 (7.71) 17.6–51.2	$t(33) = 1.42$ n.s.
Verbal IQ	90.44 (16.1) 71–114	104.26 (12.6) 83–127	$t(33) = 2.85$ $p < .01$
Performance IQ	92.7 (16.3) 80–117	102.4 (15.3) 68–130	$t(33) = 1.82$ n.s.
Full-scale IQ	90.5 (16.21) 71–116	103.9 (12.6) 81–130	$t(33) = 2.74$ $p < .01$

by Gold, Bennett, & Sekuler, 1999a, 1999b). Face images were centered within a grey square region 251 × 251 pixels, subtending 8.7 × 8.7 degrees of visual angle. The face itself was 7.4 degrees high by 4.8 degrees wide. Spatial displacement manipulations were made using Photoshop 7.0 software. Base faces were created from the original male and female face images by increasing the inter-ocular distances by four pixels (8.4 minarc) and displacing the mouths four pixels downward. Ten target faces were made for each base face. Five of these target faces were made by decreasing inter-ocular distance, and the other five target faces were made with upward mouth displacements. Inter-ocular distance manipulations were 4, 8, 10, 12, or 16 pixels (8.4–33.4 minarc). Mouth displacements were 2, 4, 6, 8, or 10 pixels (4.2–20.9 minarc). This range of displacements was chosen to mirror the stimuli used in Barton et al. (2001).

2.3. Procedure

An experimental session began with the assessment of an observer's near and far acuities, and contrast sensitivity, measured using the Pelli–Robson Contrast Sensitivity Chart (Pelli, Robson, & Wilkins, 1988) as well as the completion of an in-house general health questionnaire. In addition, all participants completed the Weschler Adult Intelligence Scales (Weschler, 1997). Participants were then given verbal instructions by the experimenter and presented with the same instructions presented visually on the computer screen, supplemented with illustrations of each task as needed. Observers then completed the primary experimental task. All testing was completed in one session that lasted approximately 2 h.

Before the experiment began, observers were shown the female base face and all 10 target faces (five eye displacement versions and five mouth displacement versions) printed out on a sheet of paper to illustrate how the inter-ocular distance and mouth position could vary. The observers were told that sometimes the different faces were easy to discriminate, and sometimes hard. Observers then completed two blocks, one upright and one inverted, of 10 practice trials with unlimited viewing duration.

Each trial consisted of the simultaneous display of three equidistant face images: two base faces and one target face. The centers of the three face images formed an equilateral triangle, which was rotated 7.5 degrees clockwise to eliminate alignment effects. The target face was equally likely to appear at any of the three positions, with the base face appearing in the other two positions. All target faces appeared equally frequently across trials. The observer's task was to determine which face differed from the other two. Fig. 1 shows these images.

The experimental session consisted of six blocks of 180 trials. Three viewing durations were used: 1, 2, and 4 s. Stimulus duration and orientation were held constant within each block, so that three blocks contained only upright faces and three blocks only inverted faces, but the order of blocks was randomized across observers. Of the 180 trials in each block, half showed mouths that were displaced, and half showed eyes that were displaced, with the order randomized across trials. There were two blocks of trials at each viewing duration: one with upright faces and one with inverted faces. Room lights were extinguished, and observers sat with their chin in a chin rest with their eyes 57 cm away from the monitor, and were tested binocularly.

3. Results

Figs. 2 and 3 show accuracy by feature displacement for each display time and for each group.

Our first question of interest was whether the ASD group differed from the control group in terms of thresholds to criterion (in this case 67% correct, a d′ of 2.4, as

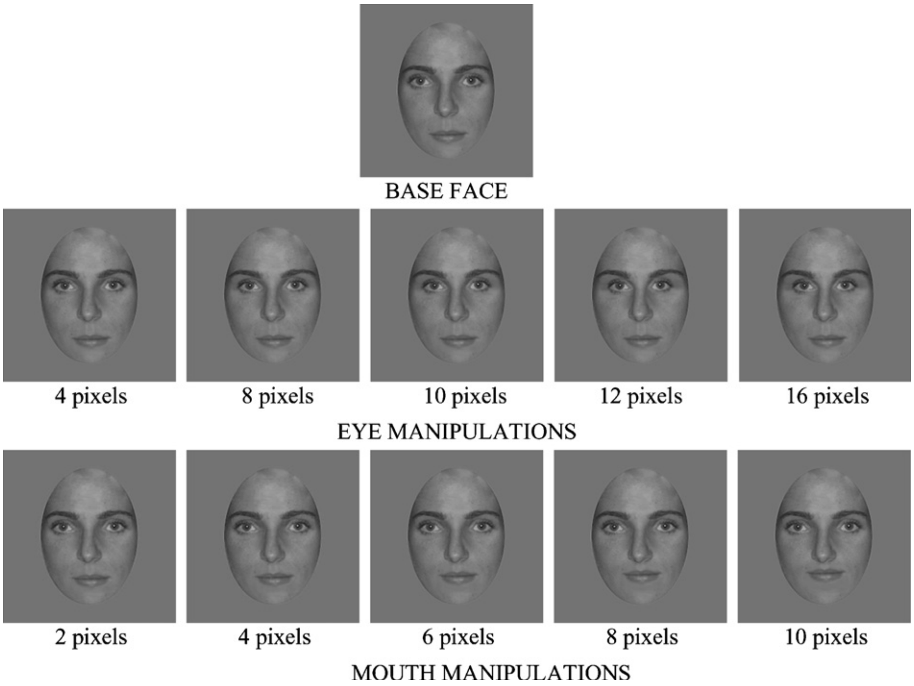

Fig. 1. Sample face stimuli. Top figure shows the "base face." Middle row shows the range of variations in eye position. Bottom row shows the range of variations in mouth position.

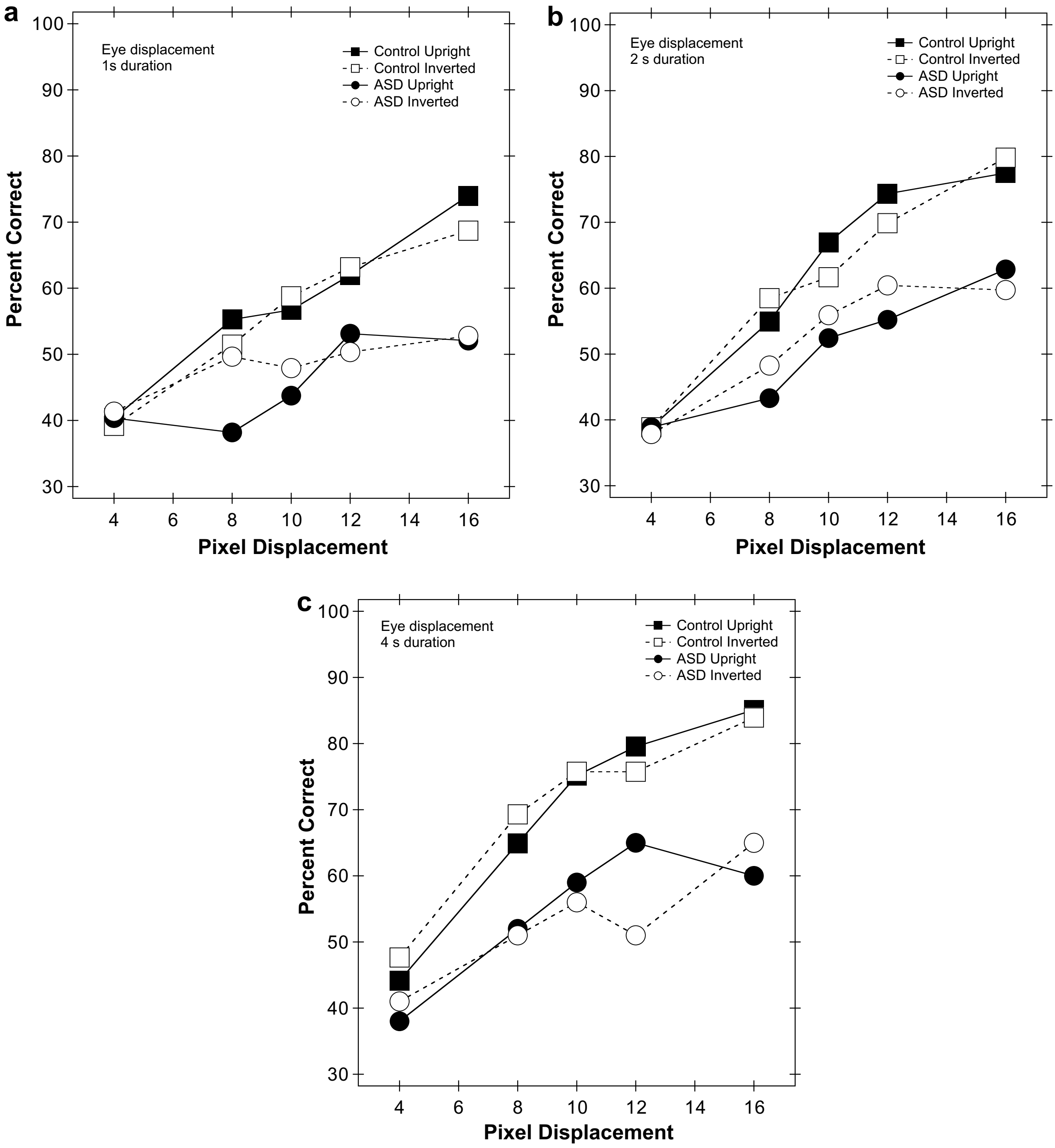

Fig. 2. Percent correct for each duration when the eyes were displaced.

used by Barton et al., 2001) for eyes and for the mouth at each display time. We found that patterns of thresholds differed markedly between the two groups for eye displacement. Indeed, thresholds were not even calculable for many individuals in the autism group at any of the three stimulus durations, because performance did not reach the 67% threshold at any displacement level. For the eye displays, with 1 s, upright presentations in the autism group, only six out of 16 people reached threshold, whereas in the control group 14 out of 19 did, which was a significant group difference ($z = 2.15$, $p = .015$, eta = .36). For the 2 s, upright displays, eight out of 16 people with autism and 17 out of 19 control observers reached threshold ($z = 2.57$, $p = .005$, eta = .44); and for the 4 s, upright displays, nine people in the autism group and 16 people in the control group reached threshold ($z = 1.82$, $p = .03$, eta = .31). Thus, for each of the upright presentations there was a significant group difference in discrimination of eye displacement.

Similarly, with the inverted presentations, there were significant group differences in the proportion of observers reaching threshold for eye displacement discrimination. For the eye displays, with a 1 s, inverted presentations in the autism group, seven out of 16 people reached threshold;

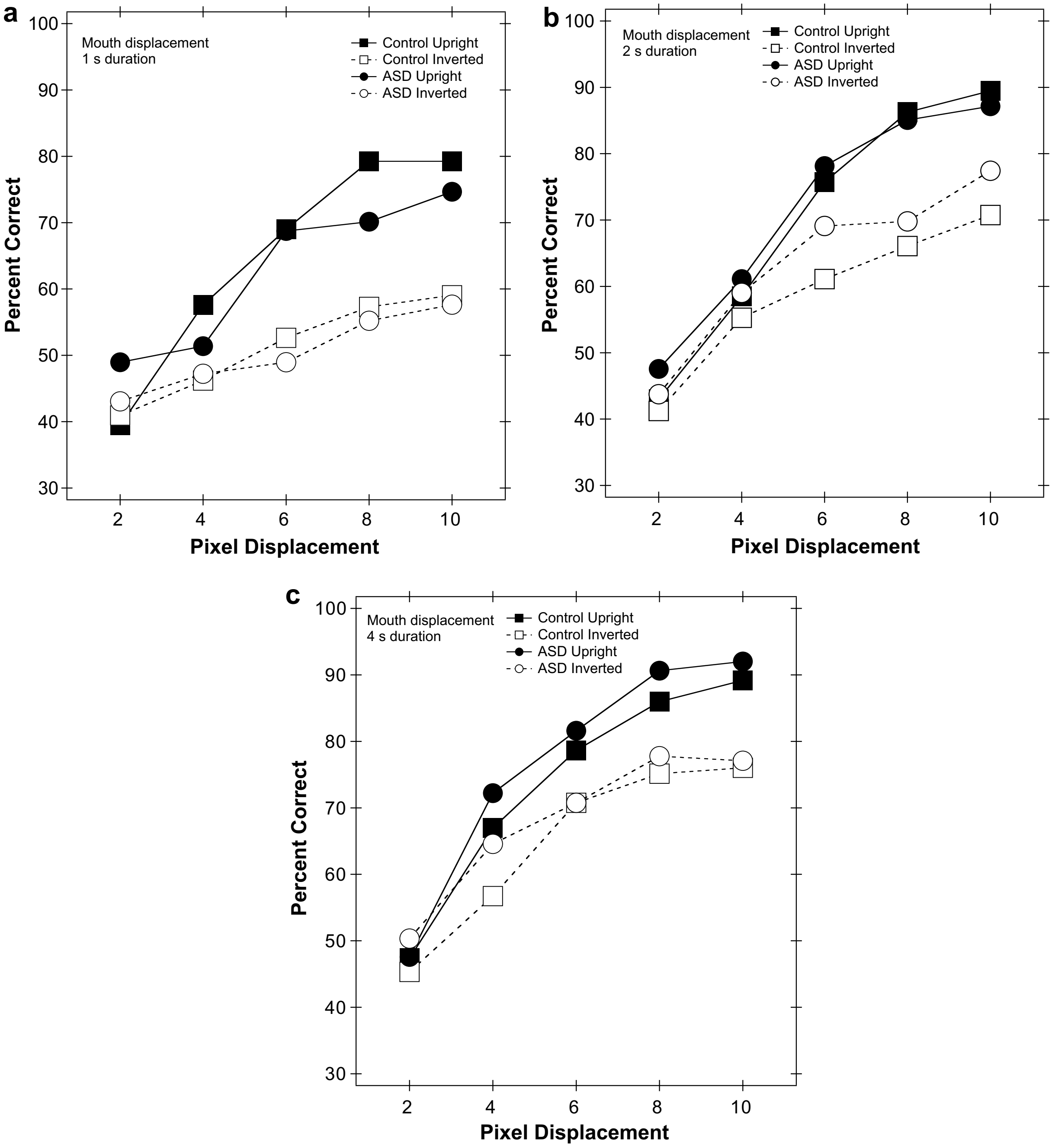

Fig. 3. Percent correct for each duration when the mouth was displaced.

whereas in the control group, 13 out of 19 reached threshold, resulting in a nearly significant group difference ($z = 1.47$, $p = .07$, eta = .25). For the two second, inverted presentations, eight out of 16 people with autism and 15 out of 19 control observers reached threshold ($z = 1.79$, $p = .04$, eta = .30). For the 4 s, inverted presentations, eight people in the autism group and 17 people in the control group reached threshold ($z = 2.58$, $p = .005$, eta = .44).

In contrast to the results for the eye displacements, the groups did not differ in the proportion of people who reached threshold when discriminating any of the mouth displacements. Fig. 4 shows the relative proportion of people who reached thresholds for upright and inverted faces.

Among those observers who were able to reach the threshold, there was not a significant group difference in the threshold itself. For the ASD group, average upright thresholds on eye displacement trials were 10.04 pixels for 1 s duration stimuli, 10.45 pixels for 2 s durations, and 9.63 pixels for 4 s durations. For the control group, these same averages were 10.91 pixels for 1 s durations, 10.26 pixels for 2 s durations, and 8.03 pixels for 4 s durations, with no significant differences between the groups.

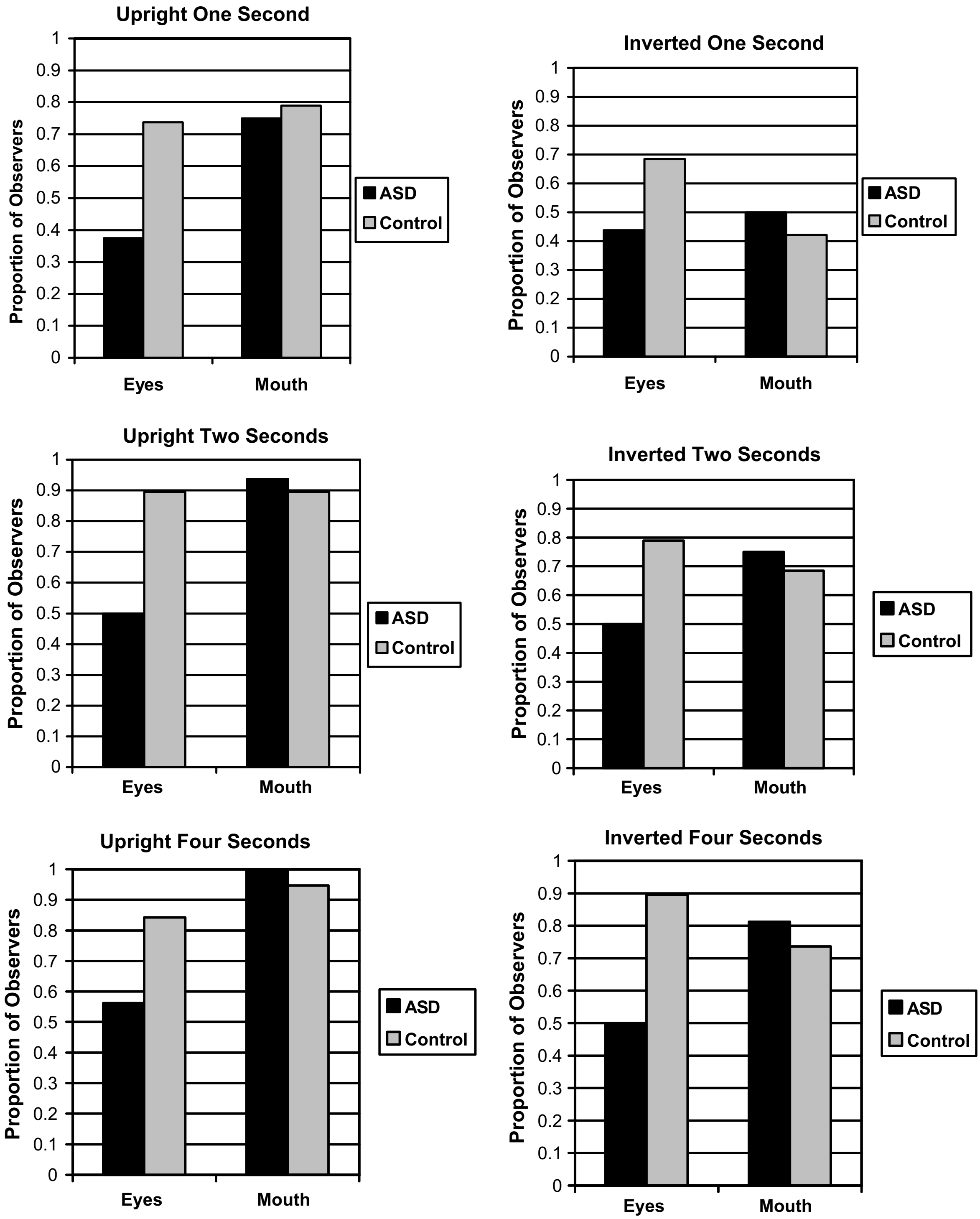

Fig. 4. Proportion of observers who reached threshold for both groups.

Similarly, for just those observers who reached threshold, there were no significant differences for inverted trials. For the ASD group, average inverted thresholds on eye displacement trials were 11.8 pixels for 1 second durations, 10.18 pixels for 2 s durations, and 9.26 pixels for 4 s durations. These averages for the control group were 10.44 pixels for 1 s durations, 8.92 pixels for 2 s durations, and 8.12 pixels for 4 s durations, again with no group differences.

3.1. How did observers in each group perform at the most extreme displacements?

Given the fact that we were unable to obtain clear thresholds in many cases with our observers with ASD, we conducted a s analysis testing group differences at the greatest displacements. Two separate 2 (group) × 2 (inversion) × 3 (duration) ANOVAs were performed on percent correct measures—one ANOVA for the eye displacement trials, and one for the mouth displacement trials. There was a significant group difference in the eye displacement condition ($F(1,33) = 6.62$, $p = .01$), and on average over conditions, the group with autism performed worse (58%) than the control group (78%). In contrast, there was no significant difference between groups in the mouth displacement trials, ($F(1,33) = .006$, n.s.), and on average, the group with autism (71%) performed similarly to the control group (77%).

There was a significant effect for duration for both the eye displacement ($F(2,66) = 18.87$, $p < .001$) and the mouth displacement ($F(2,66) = 11.63$, $p < .001$) trials. Not surprisingly, in both cases accuracy increased with the duration of the stimulus presentation. There was, however, no interaction between duration and group for either the eye displacement ($F(2,66) = .036$, n.s.) or the mouth displacement ($F(2,66) = 0.309$, n.s.) conditions.

A key question of theoretical interest is whether inversion affected performance. As Barton and colleagues found, there was not a significant effect of inversion for eye displacement ($F(1,33) = 0.99$, n.s.). However, like Barton et al., we did find a significant effect of inversion for mouth displacement ($F(1,33) = 23.88$, $p < .001$). Observers on average performed much better on upright mouth trials (85%) than inverted mouth trials (69%). Surprisingly, there was no interaction between inversion and population for either eye displacement ($F(1,33) = 0.04$, n.s.) or mouth displacement ($F(1,33) = 0.196$, n.s.). In other words, both ASD and control groups showed a strong cost of inversion when the information was in the mouth region, but not when the information was in the eye region. All of these effects for the largest displacements are illustrated in Table 2.

Given that fact that only half of our ASD observers could reach our threshold criterion level, we decided to explore individual differences in performance in the group, to determine the extent to which the group averages were representative, or whether, as suggested previously for a broader group of observers with social disorder deficits (Barton et al., 2004), there might be performance subcategories, even within our relatively narrowly defined ASD group. Such an analysis seemed particularly important given the relatively high threshold criterion level we had used (consistent with previous researchers, e.g., Barton et al., 2001), and the fact that observers who did meet threshold criterion did not seem to differ from control observers, even for eye displacements. Fig. 5 shows a scatter plot of individual's performance levels (percent correct) for the upright and inverted eye displacement tasks. As seen in the Figure, observers do not seem to fall along a clear continuum, but cluster into two relatively well-defined groups. The observers shown in black (ASD I) are those who were able to reach our threshold criterion; those in white (ASD II) were not able to meet the criterion. Results from a hierarchical cluster analysis using the single linkage method (Maechler, Rousseeuw, Struyf, & Hubert, 2005; R Development Core Team, 2006), support the idea that our ASD population contained two separate groups of observers when considering performance on the eye discrimination task (Fig. 6a). For comparison, a comparable analysis was performed for the mouth discrimination task, and no differentiated clusters emerge (Fig. 6b), indicating that the sub-grouping in ASD is specific to performance on the eye task, rather than to some general deficit in one sub-group compared to the other. Interestingly, when we now compare perfor-

Table 2
Performance on most extreme displacements: proportion correct

	ASD ($n = 16$)	Control group ($n = 19$)
1 s		
Eyes upright	.52	.74
Eyes inverted	.51	.69
Mouth upright	.75	.79
Mouth inverted	.58	.59
2 s		
Eyes upright	.61	.77
Eyes inverted	.57	.80
Mouth upright	.87	.89
Mouth inverted	.77	.71
4 s		
Eyes upright	.69	.85
Eyes inverted	.55	.84
Mouth upright	.92	.89
Mouth inverted	.77	.76

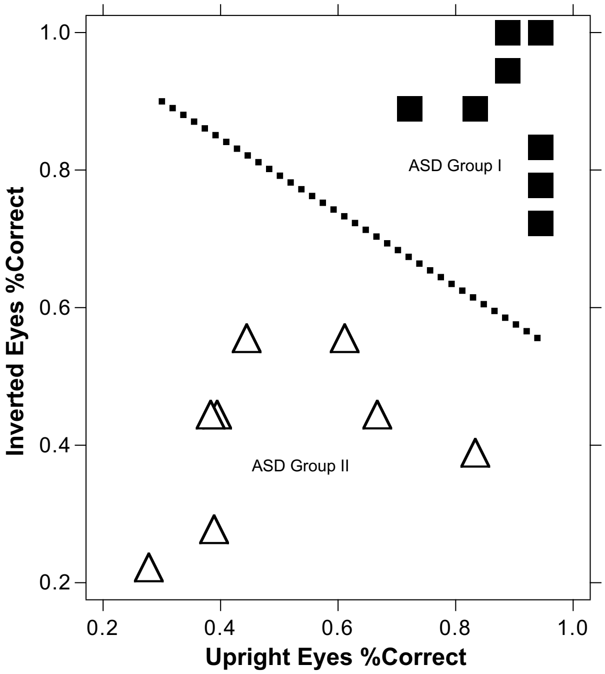

Fig. 5. A scatter plot of individual's performance levels (percent correct) for the upright and inverted eye displacement tasks for the 4 s duration stimuli.

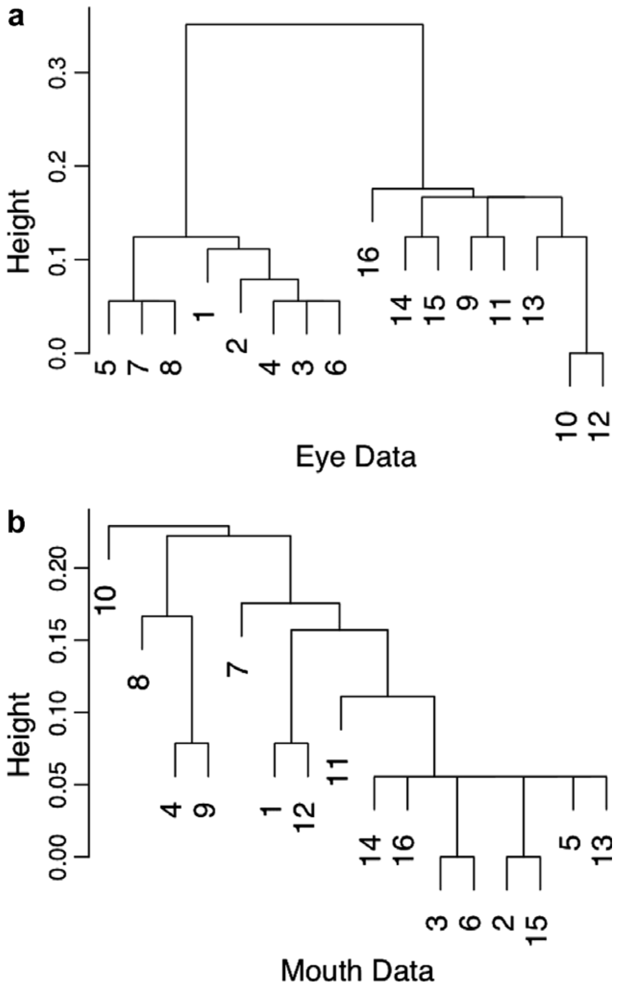

Fig. 6. (a) Results from a hierarchical cluster analysis of ASD observers for eye discrimination data plotted in Fig. 5 and an equivalent analysis for mouth discrimination (b). Subject numbers assigned in the eye analysis are held constant in the mouth analysis for comparison. Whereas ASD observers cluster into two distinct groups based on performance on the eye discrimination task, no clear clusters emerge based on performance on the mouth discrimination task.

mance of observers in each of the two sub-groups with performance of control observers, illustrated in Fig. 7. For upright trials, we see no differences in performance for the ASD I group for either eye ($t(25) = 0.32$, n.s.) or mouth displacements ($t(25) = 0.17$, n.s.) at the most extreme displacements, but we see very strong differences in performance between control observers and ASD II observers for the eye displacement tasks ($t(25) = 4.39$, $p < .001$), but not the mouth displacement tasks ($t(24) = 0.66$, n.s.). Very similar results were found for inverted trials: there was no difference in performance for the ASD I group for either eye ($t(25) = 1.26$, n.s.) or mouth displacements ($t(25) = 0.12$, n.s.) compared to control observers at the most extreme displacements; but we see very strong differences in performance between control observers and ASD II observers for the eye displacement tasks ($t(25) = 5.77$, $p < .001$), but not the mouth displacement tasks ($t(24) = 0.36$, n.s.).

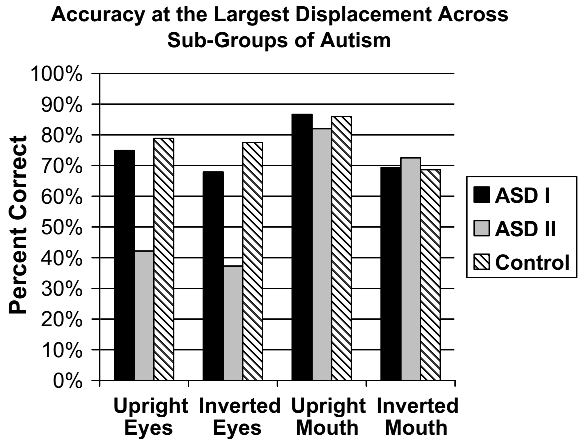

Fig. 7. One ASD subgroup, but not the other, performed relatively poorly on eye discrimination.

4. Discussion and conclusions

Two different and important questions can be answered by this experiment. First, do individuals with autism spectrum disorders show normal processing of information in the eyes region of the face? That is, are they as able as controls to make use of the information in the eyes region of the face? Many past studies strongly suggest that those with ASD are less likely to orient to the eyes, and that they are less able to make use of the information in the eyes region. Second, do people with autism show the same ‘‘mouth inversion effect’’ as our controls and the observers of Barton et al. (2001)? If there is no mouth inversion effect, and if there is instead an eye inversion effect, that would suggest that individuals with ASD visually attend to the mouth more than the eyes. We will address these two questions in turn.

Our results are consistent with the idea that many people with autism are not processing information in the eyes region of the face in the same way that controls do. They are less adept at making discriminations based on differences in the eyes. Many fewer of the ASD observers reached threshold levels for discrimination in the eye displacement trials, suggesting that many of the observers with autism had greater difficulty either attending to or using the information in the eyes region of the face compared to our control group. For comparison, this was not true for mouth displacement trials suggesting that the deficit is not due to an in ability to understand the task, or to a general visual deficit.

Similarly, our examination of performance at the most extreme displacements, which should be the easiest trials, show a group difference for performance on eye displacement trials, but not mouth displacement trials. Again, this suggests that, as a whole, our ASD group was less able to attend to and make use of information in the eye region of the face. Even with the eyes displaced 16 pixels (33.4 minarc), people with autism showed relatively poor performance whether the image was presented upright or inverted, and even when the image was presented for a full 4 s.

Overall, our results are therefore consistent with the idea that people with ASD have a relative deficit in the ability to perceive and process information around the eyes region of the face. This could be because people with autism have an aversion to eyes, and/or that people without autism are more likely to orient to the eyes region of the face, and are particularly adept at using information in this region of the face.

However, it is important to note that there seemed to be two separate sub-categories of our ASD observers: those with severe impairments in processing information in the eye region, and those who seem to process eye displacement information similarly to control observers. As such, the group data are somewhat misleading, suggesting modest impairment overall, when in fact for some observers the impairment was completely absent and for others it was extremely severe. These two groups did not differ in age, both with a mean age of 20 ($t(14) = 0.32$, n.s.), nor did they differ on performance IQ (means 94.37 vs. 86.68 for Groups 1 and 2, respectively; $t(14) = 1.07$, n.s.) or full-scale IQ (means 97.5 vs. 84.63 for Groups 1 and 2, respectively; $t(14) = 1.83$; n.s.). The two groups did differ, however, in terms of verbal IQ (means 100.5 vs. 85.31 for Groups 1 and 2, respectively; $t(14) = 2.18$, $p = .03$). These results point to the critical importance of examining data from ASD observers at the level of individuals, rather than relying exclusively on group data, as is conventionally done. The presence of sub-categories is seen in other tasks could go a long way toward explaining some of the variability in findings across autism studies.

The second major question centers around the nature of the inversion effect. If there were a mouth inversion effect in the autism group, this would suggest that they, like typical observers, visually attend to the eyes region preferentially to the mouth region. If there were instead an eye inversion effect for ASD observers, this would suggest that individuals with ASD treat the mouth as more salient (cf., Joseph & Tanaka, 2003).

Our control observer results replicate those of Barton et al. (2001), showing similar performance for upright and inverted eye discriminations, and superior performance for upright mouth discriminations compared to inverted mouth discriminations (the mouth inversion effect). Interestingly, our ASD observers showed a similar pattern of results, although overall performance on the eye tasks was substantially reduced in a sub-section of observers. That is to say, among our ASD observers, there were similar results for upright and inverted eye discriminations, and an advantage for upright mouth compared to inverted mouth discrimination. Furthermore, we wanted to know whether an increase in looking time would increase performance on the mouth discrimination task, suggesting that observers first look at the eyes, and inspect the mouth only if there is time. As can be seen in Fig. 4, increased looking time led to substantially increased performance on inverted mouth performance, both for the ASD group and the control group, whereas any increase in performance on eye discrimination was minimal. We found no interaction between inversion and population for either eye displacement or mouth displacement, indicating that both ASD and control groups showed a strong cost of inversion when the information was in the eye region, but not when the information was in the mouth region. Together these findings suggest that our participants, both with and without ASD, show the mouth inversion effect, and apparently extract information from the eye region of the face first, and only make use of information around the mouth if exposure time permits. Therefore, we have replicated Barton et al.'s (2001) findings, and extended these findings to include individuals with Autism Spectrum Disorder.

Overall, these results do not support the idea that individuals with ASD attend selectively to the mouth. In our experiment, contrary to suggestions from some previous researchers (e.g., Klin et al., 2002; Langdell, 1978), the ASD group did not show an advantage in processing information around the mouth region of the face. In fact, there were no significant group differences on mouth displacement trials. Overall, our results provide no evidence that individuals with autism orient preferentially to the mouth region of the face nor that they use information about the mouth especially efficiently. For example, although the ASD II group performed on average better with the mouth stimuli than with the eye stimuli, these observers did not perform differently than control observers for mouth stimuli, and still showed a significant mouth inversion effect. The observed performance of the group with autistic spectrum disorders is not consistent with what would be predicted if this population had an unusually strong reliance on the mouth area of the face.

More generally, these results are consistent with past results that suggest that face perception can be different in autism than typical face processing, including anomalies in the autistic perception of emotional facial expressions (Celani, Battacchi, & Arcidiacono, 1999; Critchley et al., 2000; Kikuchi & Koga, 2001; Rutherford & McIntosh, 2007). Our group with ASD performed significantly differently from our control group, suggesting that there are differences in face processing between the two groups. Notably, though, the data showed a strong inherent heterogeneity of people with autism spectrum disorders. Recent research has suggested that in addition to there being variance in IQ, social skills functioning, and strength of autistic symptoms among individuals with social developmental disorders, SDD observers may fall into distinct sub-categories for perceptual performance on a range of tasks, and no specific SDD diagnosis nor rating of social impairment predicted performance (Celani et al., 1999; Critchley et al., 2000; Kikuchi & Koga, 2001), whereas other studies refute that notion (Buitelaar, Van der Wees, Swabb-Barneveld, & Van der Gaag, 1999; Ozonoff et al., 1990; Serra, Minderaa, van-Geert, & Jackson, 1999). Regardless of whether there is a deficit in the perception of emotional facial expressions, emotions in general may be processed differently in autism: One recent study suggests that people with autism may use a more rule-based strategy rather than a template based strategy in the visual perception of emotional facial expression (Rutherford & McIntosh, 2007). It would be useful to know whether the processing of facial emotional expressions and general emotional processing could be dissociated in terms of individual differences in basic visual processing deficits among a sub-population, like that identified here for face discrimination.

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