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Do the Eyes Have It? Inferring Mental States From Animated Faces in Autism

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The ability of individuals with autistic spectrum disorders (ASD) to infer mental states from dynamic and static facial stimuli was investigated. In Experiment 1, individuals with ASD (10- to 14-year olds; $N = 18$) performed above chance but not as well as controls. Accuracy scores for mental states did not differ between dynamic and static faces. Furthermore, participants with ASD gained higher scores when the eyes conveyed information than when this region remained static and neutral. Experiment 2 revealed that those with ASD (11- to 15-year olds; $N = 18$) were as successful as controls in recognizing mental states when the eyes were presented in isolation or in the context of the whole face. Findings challenge claims that individuals with ASD are impaired at inferring mental states from the eyes.

The ability to read mental states from facial expressions plays a vital role in social interaction and interpersonal communication, helping us to approach and regulate conversation. For example, failing to recognize a person's lack of interest could result in unwelcome persistence on a topic. Some researchers believe that a lack of ability in reading mental states from facial expressions could be central to the social difficulties experienced by individuals with autistic spectrum disorders (ASD). This suggestion arises from a number of studies exploring mental state recognition in both adults and children with the disorder. Baron-Cohen, Wheelwright, and Jolliffe (1997) found that individuals with ASD were able to recognize basic emotions such as happy, sad, and angry, but had difficulties recognizing more complex mental states such as *scheme*, *admire*, and *interest*. They suggest that being able to interpret information from the eyes is vital especially for recognizing mental states rather than basic emotions. Furthermore, studies have shown that difficulty in attributing mental states is most obvious when the eye region alone is presented in individuals with autism (Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001). Similar results were also found in children with ASD (average age 13) who had lower recognition scores for mental states than typically developing children (aged 6–8 and 8–10) when only the eye area was presented (Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001). Baron-Cohen argues that collectively these findings underline difficulties in autism specifically with processing information from the eye region.

Other research has also found evidence of atypical processing of the eye region in those with ASD, which adds support for Baron-Cohen's suggestion. Both children and adolescents with ASD were found to be less proficient in processing information from the eyes than the lower parts of faces (e.g., mouth region) when recognizing faces (Joseph & Tanaka, 2003; Langdell, 1978). Swettenham et al. (2001) found further relevant evidence in that people with ASD were poor at judging gaze direction when the eyes were slightly averted. Additionally, Klin, Jones, Schultz, Volkmar, and Cohen's (2002) investigation with eye-tracking revealed that while individuals without ASD preferentially attended to the eye region, those with ASD attended to the mouth region when viewing social scenes. Some research has even suggested that individuals with autism avoid eye contact (Buitelaar, 1995; Volkmar & Mayes, 1990). This behavior may result in those with autism failing to develop expertise in judging mental states in faces where the eye region is particularly important.

Although the evidence from these studies suggests that difficulties processing the eye region may be a plausible explanation for Baron-Cohen et al.'s results, some researchers have not always been able to replicate the findings. Roeyers, Buysse, Ponnet, and Pichal (2001) and Ponnet, Roeyers, Buysee, De Clercq, and Van Der Heyden (2004) found that adults with ASD performed as successfully as typically

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developing adults when attributing mental states to photographs of the eye region. Although these studies were similar to Baron-Cohen's in a number of ways (e.g., chronological age [CA], diagnosis, number of participants, and type of model) there are some differences. Ponnet et al. (2004) suggested that participants in Roeyers et al.'s (2001) study had higher IQs than in Baron-Cohen, Wheelwright, and Jolliffe (1997) and Baron-Cohen, Wheelwright, and Hill et al.'s (2001) and this may explain failed replication. Moreover, Ponnet et al. (2004) asked participants to choose only from three options in the forced-choice procedure, which may have made the task easier than in Baron-Cohen, Wheelwright, and Hill et al.'s (2001) study that included four options. Nevertheless, these studies question the replicability of Baron-Cohen et al.'s findings, and suggest a need to establish the extent to which inferring mental states from the eyes is a problem in those with ASD.

There are methodological aspects of some of the earlier studies by Baron-Cohen and colleagues that also need to be considered. Some used photographs as stimuli without controlling variables such as head orientation and head tilt (e.g., Baron-Cohen, Wheelwright, & Jolliffe, 1997). Research shows that children with ASD have a tendency to attend to outer or nonfeatural areas, such as the hairline (e.g., Pelphrey et al., 2002), and variations in head tilt may further distract children with ASD from processing the featural information that would reveal mental states.

Besides, many researchers suggest that using dynamic facial stimuli may give a more accurate measure of performance as it is similar to what we experience in everyday life (e.g., Klin et al., 2002; Moore, 2001; Moore, Hobson, & Lee, 1997). Indeed, Moore (2001) argued that using static stimuli could underestimate a person's ability to recognize emotions. Studies with typical populations found better performance with dynamic than with static faces in identity recognition (e.g., Knight & Johnston, 1997; Lander & Bruce, 2000, 2003; Lander & Chuang, 2005) and in emotion recognition (e.g., Harwood, Hall, & Shinkfield, 1999; Wehrle, Kaiser, Schmidt, & Scherer, 2000). This dynamic advantage could be explained by the additional information that may facilitate recognition, such as temporal cues (e.g., onset and offset of a facial expression) that are absent in static stimuli. Even individuals with face processing deficits, such as prosopagnosia, have benefited from working with dynamic stimuli when asked to identify emotional expressions (Humphreys, Donnelly, & Riddoch, 1993).

Only one study has directly explored the recognition of mental states from dynamic facial stimuli in autism. Gepner, Deruelle, and Grynfeltt (2001) found that children with ASD performed in a manner similar to controls when recognizing basic mental states presented dynamically and statically. The authors suggest that this was due to the surprisingly good performance of those with ASD on the static condition, leaving little scope for detecting even better performance under the dynamic condition. Interestingly, however, those with ASD did show an increased level of accuracy in identifying basic mental states on a stroboscopic condition when dynamic stimuli were presented at a slower rate.

Researchers have proposed that the ability to process fast-moving visual events could be impaired in autism. While some (Gepner & Mestre, 2002) argue that this is due to a general deficit at lower levels of visual-motion integration; others believe that this might be specific to processing emotional states (Moore et al., 1997). In sum, there are mixed views as to whether or not individuals with ASD benefit from dynamic information when recognizing mental states from faces.

The experiments reported in this article used a technique that animates either the entire face or particular regions within the context of a seamless whole face. This enabled accuracy scores in recognizing mental states to be compared between dynamically and statically presented faces. Additionally, the dynamic stimuli were digitally edited so that a particular region of the face could be kept static and neutral (frozen). This allowed us to test whether certain facial features (e.g., eyes) were more important than others in identifying mental states. This has not been addressed in previous research on mental state recognition largely because of the technical challenge in creating appropriate stimuli. This approach is valuable because it allows us to present stimuli that more closely reflect one's experience of faces in the real world and thus can give an informative measure of performance.

We pose various testable questions: Do participants with ASD have lower rates of success than comparison participants in recognizing mental states? Do participants fare better in recognizing mental states when face-stimuli are animated than when static? If there is an advantage for animated over static, is this apparent in individuals with and without ASD? Do participants have lower rates of success in recognizing mental states when some of the information is not available? Specifically, if the eye region is frozen by digital editing, such that participants had to rely only on information from other facial regions, would they have much greater difficulty recognizing mental states? If the eye region is a major source of information about mental states, then there should indeed be a severe deterioration in performance when this is not available. However, if individuals with ASD are impaired in interpreting information from the eye region, then freezing information from the eyes should make no difference to their performance. Conversely, if individuals with ASD rely on a compensating strategy of processing information from the mouth (see Joseph & Tanaka, 2003; Klin et al., 2002; Langdell, 1978) then freezing this region should cause a decrement in their performance, perhaps more so relative to individuals who do not have ASD.

Experiment 1

Method

Developing the stimuli. A set of 32 complex mental states (*admiring, amazed, amused, anguish, anxious, arrogant, ashamed, confident, confused, deceitful, not interested, distrustful, embarrassed, enjoyment, excited, flirtatious, friendly, guilty, interest, jealous, pain, panicked, proud, preoccupied, quizzical, relieved, scheming, serious, sympathetic, stern, thoughtful, and unfriendly*) was compiled from previous research (Baron-Cohen et al., 1996; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen, Wheelwright, & Hill et al., 2001). The list was presented along with definitions to an untrained actor (female, 22 years old), including an example situation to aid the actor's understanding (selected from Baron-Cohen, Wheelwright, & Hill et al., 2001). For example, ''think of a time when you were amused by a funny joke that someone told you.'' This procedure was based on the Stanislawski (1975) technique, where actors retrieve past experiences that evoked those emotions or mental states that they are being asked to enact. Mental states were read aloud, and the actor proceeded to pose the suggested facial expression. Approximately six takes for each of the 32 facial expressions were filmed. Only a single actor was filmed due to time constraints in stimuli editing and validation.

Editing stimuli. The experimenter selected the best digital video recording from each set of six according to whether the mental state seemed recognizable and that there was no head movement or excessive eye blinking. Seven facial expressions were eliminated (*deceitful*, *enjoyment*, *friendly*, *interest*, *proud*, *serious*, and *sympathetic*). The selected facial expressions were logged and captured on an Apple Macintosh G4 using postproduction video editing software (Final Cut Pro, 2001). These facial expressions varied in length between 6 and 8 s and were edited so that there was a neutral face for a 1-s duration before and after each facial expression. The duration of the apex in each of the dynamic facial expressions averaged approximately 5 s. Clips were exported as quick-time movies and made into quality-enhanced images to run in real time (25 frames per second) using QuickTime Pro (2001).

Stimuli validation. The stimuli were validated over four stages. In overview, the first stage identified the mental state term that accurately described each facial expression by collecting participants' free-reports. A second stage confirmed that each facial expression was labeled appropriately by asking participants to choose a word from a set of five. These alternatives included the mental state as given to the actor, plus the four most commonly free-reported in Stage 1. The third stage involved simplifying the mental states for use with 10- to 15-year olds and identifying appropriate foils for each mental state by using rating scales. The fourth stage involved presenting the stimuli to children aged 8–12 years in order to confirm that they were appropriate for use with participants of this age.

Two different samples of 16 individuals, composed of undergraduates and postgraduates from the University of Nottingham, participated in Stages 1 and 2. They were aged between 18 and 35, with an equal number of males and females. All had normal, or corrected to normal vision. Twenty-five quick-time movie clips of facial expressions were presented. There were four presentation blocks, each consisting of 25 trials, one trial for each facial expression (100 trials in total for each participant), that were presented in a different random order to each participant. The stimuli were presented on PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) using an Apple Macintosh G4. Each participant sat 1 m from a 22-in. (56 cm) LCD monitor. The dimensions of the face were 15 cm (height) $\times$ 10 cm (width), subtending $8.5 \times 5.7^\circ$ of visual angle. After seeing each clip, participants were asked to type one word that accurately describes what the person was thinking or feeling.

The second stage presented the same movie clips and followed the same procedure, except that after seeing each clip, participants were asked to choose from a set of five words. Participants responded by clicking on the word with a mouse cursor that they thought most accurately described what the person was thinking or feeling. The most common word for each mental state was chosen 50–80% of the time.

In adapting the stimuli for 10- to 15-year olds, certain mental states were simplified by referring to a thesaurus or by taking terms from Baron-Cohen, Wheelwright, and Spong et al. (2001)—see Table 1. The third stage was carried out to determine whether these simplified mental state terms would be chosen as more accurately describing each facial expression over the respective foils and to decide which three foils were the most appropriate to include within each forced-choice procedure. Foils were selected from a taxonomy of emotions that were generated for "Mind Reading: The interactive guide to emotions" (Baron-Cohen, Hill, Golan, & Wheelwright, 2002).

Ten participants (5 males and 5 females) aged between 18 and 27 took part in Stage 3. Based on the findings from Stages 1 and 2, nine facial expressions were selected on the grounds that there was a strong consensus in each case on the appropriate label (*deciding*, *disapproving*, *don't trust*, *not interested*, *not sure*, *relieved*, *sure about herself*, *surprised*, and *worried*).

Table 1
Labels and Foils that Related to Each Facial Expression

Enacted mental state	Mental state label after Stages 1 and 2	Simplified mental state (mean rating)	Foils (mean rating)
Anxious	Anxious	Worried (6.45)	Cross (2.7) Muddled (5.7)[a] Not interested (2.7) Unkind (2.2)
Admiring	Considering	Deciding (5.15)	Believing (3.1) Pleased (2.8)[a] Trusting (3.0) Understanding (3.3)
Disinterest	Disinterest	Not interested (5.0)	Nasty (3.2) Not sure (5.2)[a] Stern (3.3) Unkind (3.5)
Unfriendly	Disapproving	Disapproving (5.6)	Cross (4.5)[a] Hopeless (3.1) Muddled (4.2) Unkind (3.6)
Quizzical	Doubtful	Not sure (5.7)	Cross (3.9) Disliking (5.4)[a] Nasty (3.5) Not interested (3.8)
Relieved	Relieved	Relieved (4.4)	Cheerful (3.0) Interested (3.2)[a] Pleased (2.9) Trusting (3.1)
Confident	Smug	Sure about herself (3.9)[b]	Believing (3.3) Hopeful (3.4) Interested (3.6) Trusting (2.6)
Scheming	Suspicious	Don't trust (5.5)	Cross (3.9) Stern (4.4) Sulky (5.1)[a] Unkind (3.4)
Amazed	Surprised	Surprised (6.15)	Believing (3.7) Hopeful (4.1)[a] Liking (3.8) Understanding (3.45)

Note.
[a]Foils eliminated.
[b]Mental state eliminated.

Participants viewed 18 clips in total, which included nine dynamic and nine static–apex facial images. Facial expressions were presented in a different random order for each participant.

Because it would ultimately be necessary to test participants in school settings, it was appropriate to pilot the stimuli on a laptop computer that would be suitably portable. Each participant sat 0.5 m in front of a G4 Apple Macintosh laptop (17 in./43 cm screen). The dimensions of the face were 11 cm (height) $\times$ 7 cm (width), subtending $12.5 \times 8.0^{\circ}$ of visual angle. The program ''PsyScope'' presented the facial images. After viewing each facial image, participants were presented with five words and asked to rate on a scale from 1 to 7 how accurately each word described the facial expression (1 = *extremely poor*, 2 = *very poor*, 3 = *quite poor*, 4 = *average*, 5 = *quite well*, 6 = *very well*, 7 = *extremely well*).

Based on the findings of Stage 3, the selection criteria for mental states and foils that would be included in Experiment 1 were as follows: mental states were only selected if (a) rated at a mean of 5 or above and (b) if Tukey's post hoc tests revealed that mental states were given a significantly higher rating than all other foils. Additionally, the set of alternatives was selected to contain a maximum of one foil that was rated as ''average.'' In most cases foils were rated as 2 or below, while mental states were rated as 5 or above. The foil that was given the highest rating (e.g., 4) or the lowest rating (e.g., 2) was usually eliminated. The simplified mental state *sure about herself* was eliminated as it did not gain a significantly higher score than its foils.

Previous studies on mental state recognition have utilized forced-choice procedures of two words with contrasting meaning (e.g., Baron-Cohen et al., 1996; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen & Jolliffe et al., 1997). Participants could have made their choice by excluding words that are obviously incorrect. To ensure that participants could not use this strategy in the current study, more foils were included that had a similar emotional valence as the target within a forced-choice procedure. This would allow us to be more confident that participants had actually inferred the correct mental state.

Table 1 shows the words that were rated as most accurately describing each mental state and subsequently used in Experiment 1. It also displays the mental state specified to the actor (enacted mental state), the label chosen after Stages 1 and 2, and mean ratings for simplified mental states (dynamic and static) and respective foils.

The fourth stage involved piloting the tasks on 40 typically developing 8- to 12-year olds (mean age 10). This confirmed that tasks were of appropriate difficulty in terms of understanding the instructions, comprehension of words, and the experimental procedure.

A further check was made at a later stage to ensure that the stimuli in the part moving conditions did not appear less natural than the whole dynamic face. Ten typically developing adults were presented with the eight mental states in the three different conditions (whole dynamic face, eyes static, mouth static) in a counterbalanced order. They were asked to rate on a scale from 1 to 7 how natural each face looked (1 = *extremely unnatural*, 7 = *extremely natural*). The average ratings across conditions (whole dynamic face = 4.9, eyes static = 4.3, mouth static = 4.7) did not significantly differ in terms of naturalness, $F(2, 18) = 1.510$, $p > .05$.

Participants. Eighteen individuals with ASD aged between 10 and 14 participated. This age group was chosen because adolescents took part in Baron-Cohen, Wheelwright, and Spong et al.'s (2001) study and the words had been validated on children of similar age. Individuals were only selected as participants if they had been diagnosed by an experienced clinician and met *Diagnostic and Statistical Manual of Mental Disorders*–4th ed. (*DSM–IV*) criteria (American Psychiatric Association, 1994) for autistic disorder, but not for any other developmental disorder (e.g., attention deficit hyperactivity disorder). The ASD group included 11 participants with autism and 7 with Asperger's syndrome. A further 18 participants without ASD were tested, consisting of 13 typically developing individuals and 5 with a developmental delay. None in the control group had any autistic features. Those with ASD were recruited from specialist schools in Nottinghamshire and Surrey, and those without ASD were recruited from schools in Nottinghamshire. Participants were from a middle socioeconomic background and they were from a range of ethnic groups and English was their first language. All were tested in a familiar setting within their school, after obtaining consent from parents or head teachers.

The Wechsler Abbreviated Scale of Intelligence (WASI) was administered to obtain full-scale IQ (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) scores. Each participant with ASD was individually matched with a comparison participant according to gender (17 males, 1 female), CA, and FSIQ. Independent samples t tests did not identify significant differences between participants with ASD and controls on FSIQ, VIQ, and PIQ. The mean CA of the ASD group was 12 years 4 months and the mean FSIQ was 83.8, while the respective means for the control group were 12 years 3 months and 87.1. Table 2 displays participants' details.

Table 2
Details of Participants in Experiment 1

Group	CA (years/months)	FSIQ
ASD ($N = 18$)		
Mean	12/4	83.8
SD	1/2	17.27
Range	10/8–14/9	53–107
Control ($N = 18$)		
Mean	12/3	87.1
SD	1/3	21.5
Range	10/2–14/7	55–118

Note. ASD = autistic spectrum disorders; CA = chronological age; FSIQ = full-scale IQ; *SD* = standard deviation.

Stimuli. The stimuli consisted of eight mental states (*deciding*, *don't trust*, *disapproving*, *not interested*, *not sure*, *relieved*, *surprised*, *and worried*), each of which was presented in five types of faces: a whole dynamic face, a whole static–apex face (i.e., mental state expression at apex), eyes static–neutral, mouth static–neutral, and nose static–neutral. In the latter three the rest of the face was dynamic. Whole static face images were created by taking a frame at the apex of each dynamic expression and freeze-frames were made, which involved copying the selected frame a number of times in order to make it of the same duration as the relevant dynamic expression. This eliminated any possibility of facial movement within a movie clip. An additional technique known as "freezing" was also used to create seamless facial images while maintaining the spatial relations within the context of the whole face (Thomas & Jordan, 2004). In the last three types of faces motion was frozen (i.e., kept static and neutral so that there was no expressive information) in a particular facial region (eyes, mouth, nose) while the rest of the face moved to form the facial expression. This set of stimuli was created using Commotion Pro (2001). A comparison of whole face dynamic and static–apex faces addresses whether facial movement facilitates the identification of mental states. A comparison of the whole dynamic face with eyes static–neutral and mouth static–neutral faces shows whether removing mental state information from a particular facial region degrades performance, which would indicate that participants tend to use information on mental states from that region. The nose trials were fillers and were not included in the analysis as the data were not relevant to the hypotheses.

All clips were exported from Final Cut Pro (2001) as quick-time movies and quality enabled. Figure 1 shows the stimuli used in Experiment 1. The first eight faces show the whole static–apex condition, which was the same as the stimuli that appeared in the dynamic condition at the apex of expression. In the last two faces, one feature is static–neutral and the rest of the face is dynamic. The dynamic whole face and parts of the face moving can be viewed at the

Figure 1. Stimuli (Experiment 1).

web page: http://www.psychology.nottingham.ac.uk/staff/lpxeb.

Design. This experiment involved two sessions that were counterbalanced so half the participants in each group undertook Session 1 (whole dynamic face and whole static–apex face), followed by Session 2 (freezing motion in different facial regions so that these facial regions become neutral), and the rest carried out Session 2, followed by Session 1. There was at least a day's break between the two sessions. Independent samples *t* tests indicated that it made no difference to performance whether Session 1 preceded or followed Session 2.

In both sessions there were two within-subject factors: mental state (eight different mental states) and display type (whole face dynamic or whole face static–apex in Session 1; eyes static–neutral, mouth static–neutral in Session 2). There was also one between-subject factor classifying which group each participant belonged to (ASD and control). For each session, facial images and word orders within each forced-choice procedure were presented in a different random order for each participant.

Procedure. Before each session commenced, the experimenter read aloud each mental state label and foils with an example context, such as, "when her cat went missing the girl was very *worried*" (adapted from Baron-Cohen, Wheelwright, & Hill et al., 2001). Then the experimenter read aloud the task instructions, "There will be lots of faces appearing on the screen in front of you, please look at each face carefully. After each face four words will appear on the screen; please choose the word that best describes what the person was thinking or feeling and say it out loud." Each participant started with a practice trial to ensure they understood the task before proceeding with the experimental trials. Each participant sat half a meter from a G4 Apple Macintosh laptop (17 in./43 cm screen). The dimensions of the face were 11 cm (height) $\times$ 7 cm (width), subtending $12.5 \times 8.0^{\circ}$ of visual angle. In Sessions 1 and 2 facial images were presented twice on "PsyScope," giving 32 facial images in total (16 dynamic, 16 static–apex) for Session 1 and 48 facial images (eyes static–neutral, mouth static–neutral, nose static–neutral [fillers]) for Session 2. The experimenter recorded responses to each trial and commanded the program to present the next clip when the participant was ready.

Results

Preliminary screening of the data revealed a skew in some of the experimental cells that was not eliminated by transformation. This arose because, not surprisingly, there was a floor effect in some conditions, with a concomitant narrowing of variance. As a precaution, we conducted nonparametric tests (which do not assume a normal distribution) and results were consistent with those of the parametric analyses (the same applied to the Experiment 2 data analysis). Parametric analyses are reported as this allowed us to address questions relating to interaction effects, considering that statisticians argue that parametric tests (e.g., analyses of variance [ANOVAs]) are robust to violations of normal distribution (e.g., Clark-Carter, 1998).

Dynamic whole face versus static whole face. The purpose of the first analysis was to discover whether participants with ASD were generally weaker at recognizing mental states than participants without ASD. A further aim was to discover whether mental states presented dynamically would be easier to recognize than when presented as static–apex images. A three-way ANOVA (Mental State $\times$ Display Type $\times$ Group) revealed that performance varied across mental states, $F(7, 238) = 11.91$, $p < .001$, accuracy rates did not differ between dynamic and static–apex displays, $F(1, 34) = 2.0$, $p > .05$, and participants without ASD gained higher scores than those with ASD, $F(1, 34) = 6.29$, $p < .01$. None of the interaction terms were significant. Cohen's f revealed a large effect size for mental state ($f = .54$) and a large effect size for group ($f = .43$).

One-sample *t* tests indicated that both groups of participants were significantly more likely to select the correct word than would be expected by chance (.25 of the time) in each display type, averaged across the different mental states ($p < .001$ in all cases). Table 3 summarizes the means and standard deviations for both groups on the whole dynamic face and the whole static–apex face.

A one-way ANOVA was carried out on data combined over the two display types and across the two groups of participants to determine the order of difficulty in recognizing the different mental states: $F(7, 245) = 11.89$, $p < .001$. Post hoc tests (Tukey's Honestly Significant Difference [HSD] test) revealed that *disapproving* was harder to recognize than all other mental states ($p < .001$) and *don't trust* was more difficult to recognize than *not sure* ($p < .01$). Table 4 ranks the order of difficulty for the recognition of mental states averaged across display types and groups. One-sample *t* tests revealed that both groups analyzed separately recognized each mental state significantly above chance ($p < .001$), with the exception of *disapproving* ($p > .05$).

Overall, participants with ASD had lower accuracy scores for the identification of mental states than

Table 3
Mean (and SD) for Groups in Experiment 1

Group	Dynamic face	Static – apex face	Eyes static – neutral	Mouth static – neutral	Display types total
ASD ($N = 18$)	0.54 (0.17)	0.49 (0.14)	0.45 (0.14)	0.39 (0.14)	0.47 (0.16)
Range	0.19 – 0.81	0.19 – 0.75	0.19 – 0.63	0.12 – 0.63	0.27 – 0.64
Control ($N = 18$)	0.63 (0.17)	0.63 (0.16)	0.60 (0.19)	0.48 (0.17)	0.59 (0.18)
Range	0.31 – 0.94	0.25 – 0.88	0.19 – 0.81	0.31 – 0.69	0.36 – 0.81

Note. ASD = autistic spectrum disorders; *SD* = standard deviation.

those without ASD, although they were performing well above chance. Both groups had similar accuracy scores across dynamic and static – apex faces, indicating no advantage (or disadvantage) with moving stimuli.

Dynamic/frozen parts of the face. The aim of this analysis was to examine the recognition of mental states from three different display types (whole dynamic face, eyes static – neutral, mouth static – neutral). If participants rely on motion information from the eyes, then performance will be worse when eyes are kept static and neutral relative to the whole dynamic face condition. A three-way ANOVA (Mental State × Display Type × Group) revealed main effects for all three factors. Scores varied across different mental states, $F(7, 238) = 9.82$, $p < .001$, across different display types, $F(2, 68) = 19.54$, $p < .001$, and participants with ASD gained lower scores than those without ASD, $F(1, 34) = 6.62$, $p < .01$. None of the interaction terms were significant. Cohen's *f* revealed a large effect size for mental state ($f = .54$), a large effect size for display type ($f = .76$), and a large effect size for group ($f = .44$). Post hoc tests (Tukey's HSD) revealed lower accuracy scores when both the eyes ($p < .05$) and the mouth ($p < .001$) were static and neutral when compared with the whole dynamic face. In addition, accuracy rates were lower when the mouth region was static – neutral compared with when the eye region was static – neutral ($p < .01$). Thus, both regions were important but the mouth area was particularly important.

A main theoretical issue of interest required an analysis of whether mental states were harder to identify when information from the eyes remained static – neutral in each participant group independently. Surprisingly, those with ASD had significantly lower accuracy scores when the eyes were static – neutral compared with the whole dynamic face, $t(17) = 3.14$, $p < .01$, which suggests that they had been using information about the eyes in the dynamic face condition. Surprisingly, in the control group, a paired samples *t* test did not reveal a significant difference between the eyes static – neutral and the whole dynamic face, $t(17) = 0.72$, $p > .05$. The mean accuracy scores and standard deviations for each group in each display type appear in Table 3. One-sample *t* tests indicated that each group of participants selected the correct word significantly more than .25 of the time in each display type ($p < .001$ in all cases). Thus, overall even those with ASD were processing some information regarding mental states, even when some facial information was missing.

Table 4 illustrates the mean accuracy scores for the recognition of each mental state averaged across group and display type. One-sample *t* tests revealed

Table 4
Mean Accuracy Scores (and SD) for the Recognition of Each Mental State

Mental states	Mean accuracy score (Experiment 1, Session 1)	Mean accuracy score (Experiment 1, Session 2)	Mean accuracy score (Experiment 2)
Disapproving	.24 (.30)	.27 (.32)	.26 (.16)
Don't trust	.52 (.35)	.46 (.38)	.35 (.20)
Relieved	.54 (.40)	.45 (.40)	.57 (.27)
Deciding	.56 (.35)	.55 (.37)	.58 (.22)
Not interested	.63 (.42)	.53 (.41)	.67 (.27)
Surprised	.67 (.40)	.57 (.41)	.47 (.20)
Worried	.68 (.30)	.63 (.40)	.41 (.26)
Not sure	.72 (.35)	.67 (.37)	.57 (.21)

Note. Chance responding would be .25.

that those with ASD as well as those without ASD recognized each mental state significantly above chance ($p < .05$ in all cases) apart from *disapproving* ($p > .05$). A one-way ANOVA on data combined over the three display types and across the two groups of participants determined which mental states were easier and more difficult to recognize, $F(7, 245) = 10.06$, $p < .001$. Post hoc tests (Tukey's HSD) showed that *disapproving* was again recognized less accurately than other mental states ($p < .001$) except *relieved* ($p > .05$). Furthermore, *don't trust* and *relieved* were recognized less well than *not sure* ($p < .001$) and participants had lower accuracy scores for *relieved* compared with *worried* ($p < .01$).

Discussion

Consistent with previous research, participants with ASD were generally poorer at recognizing mental states than matched controls (e.g., Baron-Cohen, Wheelwright, & Jolliffe, 1997; Baron-Cohen & Jolliffe et al., 1997). Findings also revealed that participants performed similarly when presented with dynamic and static stimuli, which suggests that participants did not especially benefit from temporal information when inferring mental states. This corroborates with previous studies (e.g., Gepner et al., 2001). Importantly, participants with ASD were not found to be impaired at processing mental state information from moving faces as they performed similarly when presented with dynamic and static stimuli; in fact, there was a trend for better performance with dynamic images than static ones.

A reason for participants with ASD performing less well than those without ASD could be that they were not attending to or deriving information from a particular facial region, such as the eyes. Previous research, such as studies using eye-tracking technologies (Klin et al., 2002), suggests that participants with ASD focus less on the eyes than comparison participants and instead prefer to focus on the mouth. Although individuals with ASD in the current study did rely more on information from the mouth region, they had significantly lower accuracy scores when the eyes were static–neutral than when they saw the whole dynamic face. This suggests that the presence of eye information facilitates recognition of mental states in autism even if previous research suggests they tend not to fixate on this region.

Both groups were significantly worse at recognizing mental states when the mouth region was kept static and neutral than when they saw the whole dynamic face. Evidently, information from the mouth was also important for the recognition of mental states. Moreover, findings indicated that participants relied more on information from the mouth than the eyes when attributing mental states, which is a novel finding. Perhaps the mouth was a more salient facial feature for participants because this is the region where speech comes from (e.g., Klin et al., 2002).

In summary, participants with ASD were poorer than those without ASD at attributing mental states to facial expressions. Participants with ASD were worse at recognizing mental states when there was no relevant information available from the eyes or the mouth. If participants with ASD had not relied on information from the eyes to interpret mental states, then freezing this region would not have affected their performance. Therefore, the general difference between groups in the ability to recognize mental states from faces is not explained by individuals with ASD failing to interpret relevant information from the eyes.

Experiment 2

Previous research by Baron-Cohen and colleagues has shown that participants with ASD have greater difficulty than comparison participants in recognizing mental states when presented with the eye region in isolation. These researchers concluded that participants with ASD have a specific impairment in reading mentalistic information from the eyes. Our findings, though, suggest that individuals with ASD do read mentalistic information from the eyes. How can we reconcile these two findings? One possibility is that individuals with ASD are hampered to a greater degree than comparison participants when they see eyes separated from the rest of the face. Such stimuli are unnatural and somewhat arresting, perhaps especially so for individuals with ASD. Indeed, recent evidence shows that individuals with some autistic features follow eye gaze better when viewing a normal face as opposed to scrambled face parts (Bayliss & Tipper, 2005). Therefore, individuals with autism may be more likely to infer mental state information from the eyes when presented in the context of a whole face. In Experiment 2, we compared the performance between groups in recognizing mental states from the eyes in isolation and in the context of the whole face. Can we replicate previous findings that individuals with ASD perform particularly poorly when presented with eyes in isolation? Will participants with ASD benefit from presenting the eyes in the context of the whole face?

Method

Participants. Eighteen individuals with ASD (11 with autism and 7 with Asperger's syndrome) participated. All had been diagnosed by experienced clinicians and met *DSM–IV* criteria (American Psychiatric Association, 1994) for autistic disorder, but not for any other developmental disorder. A further 18 typically developing individuals took part in this study of whom none had any autistic features. Both groups of participants were different from those who took part in Experiment 1. Individuals with ASD were recruited from specialist schools in Nottinghamshire and Surrey. Control participants were recruited from a secondary school in Nottinghamshire. All participants were from a middle socioeconomic background. They were from a range of ethnic backgrounds and English was their first language. Participants were tested in a familiar setting within their school. Consent for participation was obtained from parents or head teachers.

The WASI was administered to obtain FSIQ, VIQ, and PIQ scores (Table 5). Each participant with ASD was individually matched with a typically developing participant on gender (17 males, 1 female), CA, and FSIQ. Independent samples *t* tests did not detect differences between individuals with ASD and control participants on FSIQ, VIQ, and PIQ.

Stimuli. Thirty-two facial images were created using the same mental states as in the previous experiment. These images included eight mental states where the eyes were dynamic and presented in isolation from the face and eight mental states where the eyes were static (apex) in isolation of the face. Commotion Pro (2001) was used to create the stimuli. A composite was created for each facial expression by making two rotorsplines (the name of the tool in Commotion Pro that is used to track the region of interest) that encircled each eye (including eyebrow). Therefore, the stimuli contained only information about the eye region. Each composite was imported into Final Cut Pro (2001) where clips were exported as quick-time movies that run in real time.

Additionally, there were eight images where the eyes moved within the context of the whole face while the rest of the face was static (neutral—no expressive information), and eight images of the static eyes (apex) within the context of the static whole face (neutral—no expressive information). These images were again created in Commotion Pro (2001). There were three rotorsplines, two of which encircled each eye and one outlined the whole face. The superclone tool was used to freeze motion in facial regions other than the eyes in a neutral and nonexpressive state. Each composite was imported into Final Cut Pro (2001) where clips were exported as quick-time movies. Figure 2 shows examples of the stimuli and quick-time movies, which can be viewed at http://www.psychology.nottingham.ac.uk/staff/lpxeb.

Design and procedure. The three within-subject factors were mental state (eight different mental states), context (whole face or isolation), and condition (eyes dynamic or eyes static–apex). There was also one between-subject factor (ASD and control). Each facial image was presented twice, making 64 trials in total. Participants undertook two sessions. In one, the dynamic and static eyes (apex) were presented in isolation from the face; the other session presented the dynamic and static eyes (apex) within the context of the whole face, where the rest of the face remained neutral and unexpressive. Sessions were counterbalanced. Independent samples *t* tests suggested that it made no difference to performance irrespective of whether Session 1 preceded or followed Session 2. In each session facial images and word orders within each forced-choice procedure were presented in a different random order for each participant. The same procedure was carried out as in Experiment 1.

Table 5
Details of Participants in Experiment 2

Group	CA (years/months)	FSIQ
ASD ($N = 18$)		
Mean	12/8	94
SD	1/2	12.0
Range	11/3–15/7	73–113
Control ($N = 18$)		
Mean	12/7	94
SD	1/1	9.9
Range	11/4–14/11	72–107

Note. ASD = autistic spectrum disorders; CA = chronological age; FSIQ = full-scale IQ; *SD* = standard deviation.

Results

Parametric tests are reported here for the reasons mentioned in the results section of Experiment 1. A

Eyes static in isolation   Eyes static in context

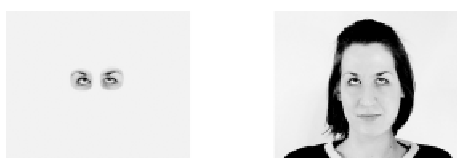

Figure 2. Examples of display types for the mental state "relieved" (Experiment 2).

four-way ANOVA (Mental State $\times$ Group $\times$ Context $\times$ Condition) identified a main effect of mental state, $F(7, 238) = 13.86$, $p < .001$, but the other three main effects were not significant. There was a significant interaction between condition and group, $F(1, 34) = 8.48$, $p < .01$, mental state and context, $F(7, 238) = 2.28$, $p < .05$, mental state and group, $F(7, 238) = 2.32$, $p < .05$, and mental state and condition, $F(7, 238) = 3.99$, $p < .001$. None of the other interaction terms were significant. Cohen's f indicated a large effect size for mental state ($f = .64$), a large effect size for the interaction between condition and group ($f = .50$), and a medium effect size for the interaction between mental state and context ($f = .26$), mental state and group ($f = .26$), and mental state and condition ($f = .34$). To explore the interaction between condition and group (see Figure 3), data were combined over the eight mental states. Typically developing participants had significantly higher accuracy scores when the eyes were dynamic rather than static (apex), $t(17) = 2.73$, $p < .05$. Accuracy scores between the dynamic and static (apex) eyes for individuals with ASD did not differ, $t(17) = 1.50$, $p > .05$, although the mean was higher when the eyes were static (apex). There were no differences between individuals with ASD and typically developing participants on the dynamic eyes, $t(34) = 1.26$, $p > .05$, and the static eyes (apex), $t(34) = 1.95$, $p > .05$.

Post hoc tests (Tukey's HSD) were unable to elucidate the weak interaction between mental state and context: There were no differences between contexts for each mental state considered individually. However, the ordering of difficulty of mental states was slightly different between the two contexts. With respect to the weak interaction between mental state and group, it was similarly difficult to identify the basis of the effect. Curiously, participants with ASD gained higher recognition for *worried* than control participants ($p < .05$), but there was no difference between groups for the other mental states. Also, the rank ordering of difficulty of mental states was slightly different between the two groups.

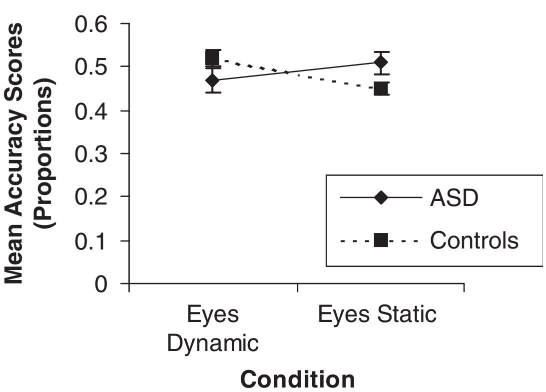

Figure 3. Mean accuracy scores (proportions) and standard error bars for the interaction between group (ASD or control) and condition (eyes dynamic or eyes static) in Experiment 2.

To explore the interaction between mental state and condition, paired samples t tests were carried out and this revealed that *not sure*, $t(35) = 2.87$, $p < .01$, and *surprised*, $t(35) = 2.45$, $p < .05$, were recognized better when the eyes were dynamic rather than static (apex) whereas *don't trust* was recognized better when the eyes were static (apex) than dynamic, $t(35) = 2.25$, $p < .05$.

A one-way ANOVA carried out on data combined over the different display types and across the two groups of participants identified differences in difficulty in recognizing the various mental states: $F(7, 245) = 10.06$, $p < .001$. Post hoc tests (Tukey's HSD) showed that *disapproving* was again recognized less accurately than other mental states ($p < .001$), except *don't trust* and *worried* ($p > .05$). *Don't trust* ($p < .001$) and *worried* ($p < .05$) were recognized less accurately than *deciding* and *not interested* (both $p < .001$). Furthermore, *not sure* and *relieved* were recognized better than *don't trust* ($p < .001$). *Not interested* was recognized better than *surprised* ($p < .01$) and *worried* ($p < .001$). Table 4 ranks the order of difficulty for the recognition of mental states averaged across display types and groups. One-sample t tests revealed that those with ASD and the typically developing group independently recognized each mental state significantly above chance ($p < .001$), except *disapproving* in both groups, and *don't trust* and *worried* in the typically developing group. Table 6 shows both groups' mean accuracy scores for the recognition of mental states in different display types. One-sample t tests indicated that both groups of participants selected the correct word significantly above chance in each display type ($p < .001$).

Discussion

There was no evidence to suggest that individuals with ASD were inferior to comparison participants in interpreting mental states from the eyes, whether the eyes were presented in isolation or in the context of the whole face. Superficially, the latter finding seems to contradict the results of Experiment 1, which suggested that individuals with ASD were inferior to comparison participants in inferring mental states from the whole face. However, there is an important difference between the two experiments. In Experiment 1, information relevant to the mental state was conveyed by the whole face; in

Table 6
Mean (and SD) for Groups in Experiment 2

Group	Isolation dynamic	Isolation static – apex	Context dynamic	Context static – apex	Display types total
ASD (*N* = 18)	0.46 (0.13)	0.52 (0.16)	0.48 (0.15)	0.50 (0.11)	0.49 (0.14)
Range	0.31 – 0.69	0.25 – 0.81	0.13 – 0.81	0.31 – 0.69	0.30 – 0.64
Control (*N* = 18)	0.50 (0.14)	0.45 (0.08)	0.52 (0.11)	0.44 (0.08)	0.48 (0.11)
Range	0.31 – 0.75	0.31 – 0.56	0.38 – 0.81	0.31 – 0.56	0.41 – 0.59

Note. ASD = autistic spectrum disorders; *SD* = standard deviation.

Experiment 2, in contrast, relevant information was conveyed only by the eyes, whether in isolation or in the context of a static whole face. In short, the findings suggest that individuals with ASD are as effective as those without ASD in interpreting mental states from the eyes, irrespective of whether the eyes are in or out of context.

Our findings contrast with previous research (Baron-Cohen, Wheelwright, & Spong et al., 2001), which suggests that children with ASD are poor at recognizing mental states from the static eye region. However, our findings are consistent with more recent studies involving participants with Asperger's syndrome, who recognized as many mental states as controls when presented with static eyes in isolation of the face (e.g., Ponnet et al., 2004).

Typically developing participants had significantly higher accuracy scores when the eyes were dynamic rather than static (apex) and there was a slight trend in the opposite direction for participants with ASD. The apex is displayed for a longer period (i.e., for the duration of stimulus presentation) when the eyes are static. Perhaps typically developing participants perform optimally when they have temporal information even if there is a trade-off in exposure time of the apex.

General Discussion

In Experiment 1, participants with ASD were generally poorer at recognizing mental states than those without ASD and overall, accuracy scores did not differ between dynamic and static – apex presentation of mental states. When the eye region was frozen, participants with ASD were poorer at recognizing mental states than when information from the eyes was available. Note that this is the first developmental study investigating the recognition of individual mental states. Previous research (e.g., Baron-Cohen, Wheelwright, & Spong et al., 2001; Ponnet et al., 2004; Roeyers et al., 2001), in contrast, investigated participants' general accuracy rates across all mental states. In Experiment 2, participants with ASD were just as accurate as typically developing participants at recognizing mental states when shown information from the eye region. Moreover, participants were as accurate at recognizing mental states when the eyes were in isolation as when the eyes were presented in the context of the whole face.

The results of the two experiments converge in showing that participants with ASD use information from the eyes in attributing mental states. These findings contradict Baron-Cohen, Wheelwright, and Spong et al. (2001), who proposed that children with autism are impaired in reading information from the eyes. In summary, although individuals with ASD find it difficult to attribute mental states to other people's facial expressions, our findings suggest that this is not due to a specific inability in reading information from the eyes. Possible reasons why we did not replicate Baron-Cohen et al.'s findings include the presentation of only a female model in our experiments. Perhaps females are more expressive in the eyes than males. However, no differences in accuracy rates between male or female models were reported in Baron-Cohen, Wheelwright, and Jolliffe's (1997) study. Additionally, Ponnet et al. (2004) and Roeyers et al. (2001) used both male and female models and yet failed to replicate Baron-Cohen et al.'s findings. The mean age and IQ of participants tested in our study was slightly lower than in Baron-Cohen, Wheelwright, and Spong et al.'s (2001) research with children and adolescents. This, however, does not provide an explanation for the differences in results between studies, as we would expect individuals of a lower developmental level to have even more difficulty reading mental states from the eyes.

If individuals with ASD are not specifically impaired in reading information from the eyes, we must seek another explanation for the aspects of their autistic features associated with social impairment. One possibility is that individuals with autism primarily do have an impaired theory of mind, but that it is wrong to suppose that the seat of theory of mind is associated with reading mentalistic information from the eyes. Rather, perhaps an impaired theory of mind in autism is associated with impairments in another domain, such as communication or executive function deficits. Communication affords a window on the mind, and therefore impairment in communication could seriously limit one's opportunities to learn about other minds (e.g., Woolfe, Want, & Siegal, 2002). Alternatively, it might be that despite being able to read mental states from faces (even if not as well as typically developing people), a primary impairment in executive function gives rise to behaviors that are not optimally adapted to the social context, thereby leading to a lack of effective interpersonal connectedness in individuals with ASD.

Various questions raised by the research are worthy of further investigation. First, we cannot be sure that the findings would generalize to different actors posing facial expressions for mental states. That is, the differences in difficulty of the mental states could be due to the actor being more expressive for some mental states than others. We were careful to ensure that the posed mental states were identified by adults without ASD, and where appropriate we changed the labeling of certain mental states, relying more on the results of the adult survey than on what the actor had been instructed to enact. Still, it might be that different actors would express mental states differently. Indeed, there might be several ways of facially expressing a given mental state, and the results of the present study do not tell us whether these are all equally recognized by individuals with and without ASD.

A second consideration is that our data are confined to participants' choice of response from alternatives. If participants with ASD are inferior in processing mental states as expressed in faces, this could manifest in ways other than being able to choose the correct response from alternatives. For example, if individuals with autism have difficulty with generativity (Turner, 1999), then even though they might be able to select the correct response from alternatives, they might not be able to formulate the correct response when a set of options is not available such as in everyday life. A generativity problem might then account for the discrepancy between the current result (good mental state recognition) and poor social functioning in ASD. Hence, group differences might be even more pronounced in a procedure that does not involve forced choice. Also, we did not investigate response time. It might be that impairment in processing mental states from faces gives rise to slower responding as well as lower accuracy. Alternatively, it might be that the lower accuracy scores in participants with ASD in Experiment 1 amount to a trade-off from responding too quickly. This might result from insufficient executive control, causing a lack of inhibition.

It is worth considering the avenues that could be explored by adapting the techniques developed in the current research. In particular, it might be informative to investigate how participants respond when they see a face that contains the eyes associated with one mental state and the mouth associated with a different mental state. If people primarily focus on the eyes for inferring mental states, then the eyes should take precedence in determining participants' responses. If we do find evidence for such a bias in typically developing individuals, then it will be valuable to explore whether similar signs of precedence emerge in individuals with ASD. The findings from Experiment 1 suggested that participants also greatly relied on the mouth region when attributing mental states and therefore it will be interesting to explore the relative importance of both the eyes and the mouth.

Another suggestion for future research relates to our speculation about individuals with ASD using peripheral vision when apprehending information from the eyes. We offer this speculation in an attempt to reconcile two apparently contradictory findings: (1) Individuals with ASD rely on information from the eyes when inferring mental states, as demonstrated by our finding that their rate of success decreases when information from the eyes is withheld; (2) Individuals with ASD spend relatively little time looking at the eyes of people in a dramatized social scene (Klin et al., 2002). This could be investigated by using eye tracking in conjunction with our task: Would the level of fixation on certain facial regions (e.g., the eyes) predict success in identifying mental states? Would this be true to the same degree in individuals with ASD as with individuals without ASD? Alternatively, would we find dissociation specifically in individuals with ASD in the amount of time they spend looking at the eyes and in their success in correctly identifying the mental state?

In sum, the findings show that individuals with ASD can use information from the eyes to infer mental states. The technique developed in the current paper has advantages that may be useful in future research. It allows for systematic manipulation of motion information in different facial regions within the context of a whole face. This enables researchers to explore participants' performance with more naturalistic facial stimuli. A more accurate picture of the abilities of those with ASD can be obtained through the use of these sophisticated digital imaging techniques.

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