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Using other minds as a window onto the world: Guessing what happened from clues in behaviour.

[a]Dhanya Pillai, [a]Elizabeth Sheppard, [b]Danielle Ropar, [b]Lauren Marsh, [b]Amy Pearson, & [a]Peter Mitchell

[a]University of Nottingham Malaysia Campus,
Jalan Broga,
43500 Semenyih
Selangor Darul Ehsan, Malaysia

[b]University of Nottingham,
University Park,
Nottingham, NG7 2RD
United Kingdom

*Correspondence author, Email: khpx9dkr@nottingham.edu.my

It has been proposed that mentalising involves retrodicting as well as predicting behaviour, by inferring *previous* mental states of a target. This study investigated whether retrodiction is impaired in individuals with Autism Spectrum Disorders (ASD). Participants watched videos of real people reacting to the researcher behaving in one of four possible ways. Their task was to decide which of these four "scenarios" each person responded to. Participants' eye movements were recorded. Participants with ASD were poorer than comparison participants at identifying the scenario to which people in the videos were responding. There were no group differences in time spent looking at the eyes or mouth. The findings imply those with ASD are impaired in using mentalising skills for retrodiction.

Keywords: Mentalising, retrodiction, social cognition, mental states, face processing, eye tracking

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Impairments in social communication are one of the key diagnostic features of autism spectrum disorders (ASD; Schultz 2005). One theory proposes that individuals with ASD are impaired in developing a 'theory of mind,' along with the associated mentalising skills (Baron-Cohen et al. 1985), a capacity that enables us to impute mental states to others. Being able to identify mental states is an important cognitive process that equips us to understand a person's behaviour. Mentalising thus allows us to make predictions about the future behaviour of an individual based on our knowledge of relevant aspects of the situation. Conversely, the same skills allow us to reason backwards from observed behaviour to an antecedent cause, a process sometimes referred to as retrodiction (Gallese & Goldman, 1998; Goldman, 2009; Milikan, 2005; Robinson & Mitchell, 1995).

The majority of research conducted with both ASD and neurotypical populations has focused on behavioural prediction as a particular kind of mentalising. For example, in its typical form the classic false belief task involves predicting where an individual will look for an item based on his/her knowledge of the situation at hand (Baron-Cohen et al. 1985), and numerous other tasks conceived subsequently have also involved behavioural prediction (Hirschfeld et al. 2007; LeBlanc et al. 2003; Perner et al. 1989; Senju et al. 2009). This is perhaps surprising given that another function of mentalising, retrodiction, is arguably more prevalent in everyday experience. In our daily lives we frequently observe people reacting or behaving in a particular manner, leading us to try to determine what provoked that reaction. If we are successful, then effectively we come to know an aspect of the world through the lens of another mind, where the mind in question is embodied in a behavioural reaction. Little is known about these retrodictive mind reading processes in people with ASD. In so far as mentalistic prediction is impaired in ASD, one might extrapolate to suppose that retrodiction is impaired also, but it does not necessarily follow. Hence, the current study will investigate the scope of mentalising impairments in ASD – do such impairments extend to retrodiction or is the process of retrodiction intact in ASD?

Considerable research has been conducted in which individuals with ASD were presented with samples of behaviour (usually facial expressions) and asked to identify the mental state of the individual, without requiring any inference about the situation that might have caused the mental state in question. Baron-Cohen, Jolliffe, Mortimore, and Robertson (1997) devised a task they called "Reading the Mind in the Eyes" and reported that individuals with ASD were impaired in identifying complex mental states from images of the eye region of the face. They argued, contrary to previous claims (Premack and Woodruff 1978), that mental states are often directly observable from our behaviour, especially from facial expressions. In making this case, Baron-Cohen et al. (1997) distinguished between high-level and low-level mentalising skills (see also Goldman and Vignemont 2009; Tager-Flusberg 2001). High-level mentalising involves reasoning about mental states based on prior knowledge of their relationships with one another and with specific situations; low-level mentalising involves inferring mental states from indicators such as behavioural cues, especially facial expressions.

Baron-Cohen et al. (1997) postulated that the eye region is crucial for identifying mental states in facial expressions (see also Smith et al. 2005) but that people with ASD are uniquely less able to use information from the eyes to infer such mental states. This appears to be consistent with research which has found that individuals with ASD have a lesser tendency to look at the eye region than neurotypical individuals (Hernandez et al. 2009; Klin et al. 2002). The argument can be made that early differences in attention to social stimuli, especially to the eye region of the face, leads to difficulties acquiring social information, resulting in a myriad of social abnormalities including difficulties in interpreting facial expressions along with more general mentalising difficulties (Corden et al. 2008).

This viewpoint encounters some anomalous data. Firstly, a number of studies have either failed to report reduced looking at the eyes in those with ASD (Bar-Haim et al. 2006; Freeth et al. 2010; Freeth et al. 2010; Freeth et al. 2011; Rutherford and Towns 2008; Van Der Geest et al. 2002; Wagner et al. 2013) or failed to support the claim that those with ASD are impaired specifically in interpreting information from the eyes (e.g. Back et al. 2007; Song et al. 2012). Secondly, a relationship between looking at the eye region and actual task performance has not always been found experimentally. For example, Corden, Chilvers and Skuse, (2008) found that the time spent looking at the eye region of faces correlated with success in identifying fearful faces, but no other facial expressions. Moreover, Boraston et al. (2007) found no relationship between expression identification and time spent looking at the eye region. Third, while some studies have found a relationship between severity of social symptoms of autism as measured by the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 2000) and mentalising task performance including performance in looking at the eyes (e.g. Klin et al. 2002), others have not (e.g. Corden et al. 2008; Joseph and Tager-Flusberg 2004) questioning the causal relationship between mentalising deficits and the social difficulties in ASD.

One reason for inconsistencies in the literature may be associated with the range of different paradigms that have been used. Perhaps group differences are most likely to be found in studies with naturalistic stimuli which closely approximate the complexities of everyday social interaction where facial expressions are dynamic, brief and subtle. The majority of previous studies used posed static images of exaggerated emotional expressions, frequently presented for several seconds (Kennedy and Adolphs 2012; Tanaka et al. 2012). Moreover, even those using dynamic stimuli have typically included expressions posed by actors making it unclear what the "correct" answer should be. Usually, the answer is agreed upon by consensus, yet this may not reflect the actual mental state of the actor.

A notable exception to this was a study conducted by Boraston et al. (2008) who presented pictures or sounds of highly positive valence (such as a photo of kittens or a baby’s laugh) and filmed participants’ resulting spontaneous expressions. Later, participants with or without ASD were required to distinguish between these real "happy" expressions and other “happy” expressions posed by the same individuals. While both groups of participants could distinguish between real and posed expressions to some degree, participants with ASD were impaired. Moreover, those with ASD spent less time looking at the eyes than the comparison participants, suggesting the eyes may be crucial for interpreting naturalistic expressions, particularly genuine smiles. While the findings suggest that people with ASD are less able to see the difference between the two types of smile (genuine and posed), they do not tell us whether people with ASD are impaired in differentiating between different types of naturalistic expression.

In light of the comments made above, Pillai et al. (2012) developed a retrodictive mindreading task to provide a measure of mentalising that requires participants to interpret naturalistic stimuli. Participants were shown people’s (targets’) spontaneous reactions to four scenarios filmed during an interaction with the researcher; participants were asked to determine which of the four scenarios the targets had experienced. A key strength of this task is that there is a definite correct answer against which the participants’ response can be compared. That is, the researchers know independently of the targets’ reaction which scenario the targets experienced. The participant, in contrast, can only base his or her judgment on the targets’ reaction. In some ways, this might be seen as preferable to a task in which the participant is asked to estimate the target’s emotion, for we have no certain way of determining the target’s true state of emotion other than by interpreting his or her reaction.

Pillai et al. (2012) discovered that neurotypical individuals could infer previous events from brief samples of behaviour with considerable success. Pillai et al. also recorded eye movements and discovered surprisingly that most time was spent looking at the mouth not the eyes, and moreover that good performance in identifying the scenario was associated with looking less at the eyes and more at the mouth. These findings supported the view that looking at the eye region is not always conducive to good performance when interpreting facial expressions.

Here we used the same task developed by Pillai et al (2012) to investigate retrodictive mindreading in groups of individuals with and without ASD. We predicted that a) people with ASD would have difficulty determining the scenario that the target had experienced, b) consistent with the previous study, we predicted that neurotypical participants would look more at the mouth than the eyes.

Methods

The study was divided into 2 parts; Stimulus Development and Main Experiment. Ethical approval was obtained from the Ethics Committee, School of Psychology, University of Nottingham.

Stimulus Development

Please refer to Pillai et al. (2012) for a comprehensive description of the Stimulus Development phase of the study (e.g. procedure, editing of videoclips). A brief description follows.

A total of 40 neurotypical students (19 male and 21 female) aged between 19 and 34 (mean age=22.2 years) were recruited from the University of Nottingham for stimulus development. The primary aim of this phase of the study was to create video stimuli which would later be used in the main part of the experiment. Participants were informed that they were to model several facial expressions while being video-recorded to create stimuli for another study. However, they remained unaware that the actual purpose was to film their natural reactions to an aspect of the researcher's behaviour that happened prior to recording the posed facial expressions.

Four scenarios (Joke, Waiting, Story and Compliments) were created that were expected to elicit a range of reactions. The researcher either told a joke, kept the participant waiting, told a story that might provoke an empathic reaction or paid compliments to the participant. This was done while the participant's reaction was surreptitiously filmed. Henceforth, these participants are referred to as 'targets'. Targets' responses were then edited into short videoclips depicting their distinct reactions to the varying scenarios. The audio component was excluded from the edited videoclips as it would have resulted in unequivocal behavioural reactions.

Main Experiment

Participants

Thirty male participants took part in the study. Written informed consent was obtained from all. Neurotypical participants (*n*=15) were recruited from the University of Nottingham while participants with an ASD (*n*=15) were recruited from across the United Kingdom through their respective schools or centres associated with the National Autistic Society. Participants with ASD had been formally assessed by mental health professionals in line with DSM-IV criteria (American Psychiatric Association, 2000) and subsequently received a Statement of Special Education Needs for Autism or ASD. The researchers conducted the Autism Diagnostic Observation Schedule (ADOS; Lord et al. 1999) on the participants with ASD to independently confirm their diagnosis. Communication (*M*= 3.3), reciprocal social interaction (*M*= 7.3), and total ADOS (*M*= 10.67) scores were obtained. Three of the fifteen participants did not meet the cut-off for ASD on the ADOS, but were included in the study as all had a previously established diagnosis of ASD or autism by trained mental health practitioners. Nevertheless, all analyses were repeated with the three participants who did not meet the cut-off for ASD removed from the data set and the pattern of results was identical to those reported in the following sections. All participants completed the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler 1997) which provided measures of verbal IQ, performance IQ and full scale IQ. All participants also completed the Autism Spectrum Quotient (AQ;

Baron-Cohen et al. 2001) which measures levels of autistic traits in adults. An independent-samples *t*-test showed that the ASD group scored significantly higher on the AQ than the comparison group $t(28) = 4.45$, $p < .001$. No significant differences were found in age or any IQ measures between the groups (all *ps* >.05). See Table 1 for summary details.

(insert Table 1 here)

Materials & Apparatus

Video-recordings of the researcher enacting each of the four scenarios (while looking directly at the camera) were created. The videoclips were then edited using VirtualDub (v1.9.10) video capture and video processing software, with both audio and visual information included. Coloured borders (measuring 0.5 centimetres in width) were created for each scenario clip: Scenario 1 (Joke)- Green border, Scenario 2 (Waiting)- Red border, Scenario 3 (Story)- Blue border, and Scenario 4 (Compliments)- Yellow border. The videoclips necessarily differed in length depending on the varying content and dynamics of each social scene with Scenario 1 (Joke)- 11 seconds, Scenario 2 (Waiting)- 89 seconds, Scenario 3 (Story)- 34 seconds, and Scenario 4 (Compliments)- 27 seconds. Video frames were 720 pixels in width and 576 pixels in height and the rate of presentation was at 25 frames per second. The bit rate for the audio track was 352 kbps.

The main stimuli for this study were the 40 edited videoclips showing targets' reactions from the Stimulus Development phase. Each videoclip was interspersed with a rectangular image of the four scenario names (i.e. *Joke*, *Waiting*, *Story*, *Compliments*) in black font on white background. The rectangular shaped image was divided equally into four parts for each scenario name. Consistent with the coloured borders in the scenario videoclips, the perimeters enclosing each scenario name in the image had the same corresponding coloured borders. This was done in order to assist memory recall of the scenario videoclips as enacted by the researcher. The 40 videoclips showing the targets' reactions did not have coloured borders. All videoclips (i.e. scenario clips enacted by researcher and target reaction clips from the Stimulus Development phase) were shown on a 17 inch TFT monitor which was incorporated into the Tobii T60 Eye Tracker (data rate 60 Hz) and presented using Tobii Studio software.

The AQ (Baron-Cohen et al. 2001) consists of 50 questions with a four-option forced choice response format (*strongly agree, slightly agree, slightly disagree, strongly disagree).* Participants were given as much time as they required to complete the questionnaire.

Design

A mixed-model design was used, where all participants viewed the four scenario videoclips as enacted by the researcher followed by the 40 target reaction videoclips.

Procedure

At the start of the experiment, participants were shown the scenario videoclips enacted by the researcher in a counterbalanced order. The purpose of presenting the scenario videoclips was to provide the participants with vivid information on what the targets experienced.

Participants sat approximately 60 centimetres from the Tobii T60 screen, subtending a visual angle of 28 degrees horizontally and vertically. A 9-point eye-tracking calibration procedure was then conducted. Upon successful calibration, the 40 target reaction videoclips were presented in random order by the Tobii studio software. After each videoclip was shown, an image of the four scenario names appeared and the researcher asked, "Which of these scenarios had just occurred?" This image remained on the screen until participants gave an answer verbally to the previously presented videoclip, whereupon the researcher clicked the mouse to move on to the next videoclip. Participants' verbal responses were recorded on a data sheet for all 40 videoclips. The participants then completed the AQ questionnaire.

Results

Can participants determine what happened to a target from their spontaneous reactions?

As with previous research (Pillai et al. 2012), signal detection was used to analyse participant responses in order to investigate our key question: Are there significant group differences in the success in discriminating between the four scenarios according to the targets' reaction? The signal detection procedure takes into account biases in responding to any particular scenario by producing a *d*'prime index (*d*') from participant hit rates (number of times participants correctly identified the scenario that the target reacted to) and false alarm rates (number of times participants identified the scenario when it was the incorrect response). The current study computed the hit rate from the responses to the ten videoclips showing target reactions to a particular scenario whereas false alarm rate was computed for the responses to the remaining thirty videoclips which did not depict target reactions to the scenario in question. Hit rate and false alarm rate calculations which had cells with the number 0 were corrected by adding 0.5 to all cells (Snodgrass and Corwin 1988). *d*' is then calculated by subtracting the *z*-score for the false alarm rate from the *z*-score of the hit rate [$d' = Z(\text{hit rate}) - Z(\text{false alarm rate})$, where function $Z(p)$, $p \in [0,1]$ is the inverse of the cumulative Gaussian distribution. The *d*' prime construct effectively gives an indication of participants' abilities in distinguishing target reactions across the scenarios. If it were the case that participants were unable to distinguish target reactions across the four scenarios, the hit rate and false alarm rate would be proportionately identical, resulting in a *d*' score of 0.

The neurotypical participants were able to correctly discriminate differences between target reactions across scenarios as *d*' scores were significantly greater than 0 for all four scenarios [Joke $t(14)=12.07$, $p<.0005$; Waiting $t(14)=25.08$, $p<.0005$; Story $t(14)=9.18$, $p<.0005$; Compliments $t(14)=11.32$, $p<.0005$]. Participants with ASD also successfully discriminated between target reactions across all four scenarios: Joke $t(14)=8.39$, $p<.0005$; Waiting $t(14)=11.9$, $p<.0005$; Story $t(14)=5.92$, $p<.0005$; and Compliments $t(14)=3.38$, $p<.05$. See Figure 1 for participant mean *d*' scores and Table 2 for participant mean accuracy and false alarm rates.

(insert Figure 1 here)

(insert Table 2 here)

A 2x4 (group x scenario) ANOVA was performed in order to examine whether the groups (between participants factor) differed in how well they could discriminate between scenarios (within participants factor) based on their interpretation of the targets' reaction. A main effect of scenario was found, $F(3,84)=59.28$, $p<.0005$. Posthoc *t*-tests with Bonferroni correction revealed that participants were better at discriminating when targets were reacting to the Waiting scenario than the other three scenarios (all *ps*<.0005). Additionally, reactions to the Story scenario was easier to identify than the Compliments scenario ($p<.0005$). There was also a main effect of group, $F(1, 28)= 8.95$, $p < .001$, indicating that ASD participants were significantly poorer at discriminating between scenarios according to target reactions as compared to their neurotypical counterparts. The interaction between scenario and group was not significant.

As discriminability scores were much higher for reactions to the Waiting scenario compared with the other three scenarios, in further analyses data associated with the Waiting scenario were considered separately. Overall success in discriminating between target reactions across the scenarios was positively related with full scale IQ, $r = .38$, $n =30$, $p=.04$. Similarly, the relationship between full scale IQ and discrimination of the targets' reaction in the Waiting scenario approached significance, $r = .33$, $n =30$, $p=.07$. When considering each group separately, overall scenario discrimination (excluding the Waiting scenario) was positively related with full scale IQ in the ASD group, $r = .54$, $n =15$, $p=.04$. There was a positive relationship between accuracy in detecting reactions to the Compliments scenario and full scale IQ scores in the ASD group ($r = .63$, $n =15$, $p=.01$). The same relationship approached significance for reactions to the waiting scenario ($r=.47$, $n=15$, $p=.08$) and nonsignificant positive correlations were observed for responses to the other two scenarios. In the neurotypical group, all correlations between IQ and ability to discriminate the scenario based on targets' reactions were close to 0 apart from the Joke scenario where a negative relationship approached significance ($r=-.47$, $n=15$, $p=.10$), suggesting that the reported positive correlations for full-scale IQ in the overall participant sample may be explained by the ASD group. Finally, as some significant correlations with IQ were observed for the ASD group, the ANOVA comparing the two groups for ability to discriminate scenarios based on targets' reactions was repeated with IQ entered as a covariate. This ANCOVA revealed the same pattern of main effects of scenario, $F(3,81)=4.12$, $p=.009$ and group, $F(1,27)=7.96$, $p=.009$, suggesting that any group differences in the ability to discriminate target reactions across the scenarios cannot be explained by the way IQ might have affected performance differentially between groups.

Eye-tracking analyses

The objectives of conducting eye-tracking analyses were to ascertain: a) whether participants preferred to look at the mouth more than the eyes of the targets b) whether those with ASD had different looking preferences than neurotypical participants and c) whether participants' ability to discriminate the scenarios according to target reactions was related with looking at certain regions of the target's face (eye or mouth). The dynamic areas of interest (AOIs) function in Tobii Studio 3.0 was utilised to analyse and code the eye-tracking data. This enables the specification of AOIs which move and change form with the movements of the target. AOIs were outlined on the eye and mouth regions of the video stimuli to determine the eye movement metrics. The Total Fixation Duration (seconds) metric was used to calculate the total duration for all fixations within the AOIs separately. Fixation is defined by the standard Tobii fixation filter as two or more consecutive samples falling within a 35 pixel radius.

Figure 2 shows the mean percentage of total gaze time for the eye and mouth of the target when reacting to each of the four scenarios. As the duration of the videoclips differed and the participants varied in their total time looking at the videos, the percentage of gaze time spent looking at the eye and mouth regions of targets for each videoclip was calculated (i.e. time spent looking at eye/mouth region ÷ total gaze time * 100). The data were normalized by a square root transformation but untransformed means appear in the figure for ease of understanding.

(insert Figure 2 here)

An ANOVA was performed on gaze time, with group (ASD or neurotypical) as a between-participants factor and scenario experienced by the target (Joke, Waiting, Story, Compliments) and region of the face (eyes or mouth) as within-participants factors. No main effects for scenario experienced by the target (p =.09) and group (p =.26) were found but there was a main effect for face region, $F(1,28)= 6.86$, $p=.01$, indicating that participants spent more time looking at the targets' mouth as compared with the targets' eyes. Furthermore, a significant interaction between scenario and face region was found, $F(3, 84)= 27.6$, $p < .0005$. In order to interpret this interaction, separate one-way ANOVAs were performed to examine the effect of the scenario experienced by the targets on gaze time for the targets' eye and mouth regions separately. There was a significant effect of scenario the targets experienced on the time the participant spent looking at the targets' eye region, $F(3,87)= 21.21$, $p < .0005$. Posthoc *t*-tests with a Bonferroni correction showed that participants spent more time looking at the targets' eye region when the targets were reacting to the Waiting scenario compared with the other three scenarios (all *ps* < .0005). Participants also spent more time looking at the targets' eye region when the targets were reacting to the Story scenario compared with the Joke scenario ($p=.03$). There was also a significant effect of scenario on time spent looking at the targets' mouth region, $F(3,87)= 19.21$ $p < .0005$. Posthoc *t*-tests with a Bonferroni correction revealed that participants spent more time looking at the targets' mouth when the targets were reacting to the Joke, Story and Compliments scenarios compared with the Waiting scenario ($p < .0005$). The interaction was further investigated using paired sample *t*-tests, to assess the effect of face region (eye or mouth) for each scenario. Participants spent more time looking at the targets' mouth than eyes when the targets were reacting to the Compliments scenario, $t(29)= -3.82$, $p< .005$; the Joke scenario, $t(29)=-4.15$, $p< .0005$; and the Story scenario $t(29)= -2.57$, $p= .02$. However, participants looked equally at both the eye and mouth regions when the targets was reacting to the Waiting scenario, $t(29)=.84$, $p=.41$. All other main effects and interactions were not significant. Notably, there was no interaction between time spent looking at the different facial regions and participant group, meaning that there was no evidence to suggest that the two participant groups differed in their attentional priority for the targets' eyes and mouth.

Discussion

Consistent with previous findings (Pillai et al. 2012) in spite of differences in the level of success across scenarios, participants were generally able to distinguish the event which took place merely by viewing several seconds of a target's behavioural reaction. This suggests that both neurotypical and ASD participants employed effective strategies to determine the cause of the presented behavioural responses, and this qualifies as something that Gallese and Goldman (1998) call *retrodiction*. Effectively, participants could access something in the world that they could not sense directly through the window of another person's mind – assuming that the other person's mind is embodied in their behaviour.

The findings followed the same pattern as Pillai et al. (2012), with the waiting scenario being identified more easily than the other three scenarios. This is likely to be because the actual responses of the targets in the videos were more distinctive in the waiting scenario than in the other three scenarios. Because a forced choice format was used, the success of identifying one scenario was partly a function of being able to rule out other scenarios. While they selected scenarios which they believed would give rise to a range of expressive reactions, it was difficult to predict exactly how the targets would respond. In real life, different people respond in many ways to the same event. It is an impressive feat of human mentalising that we are able to estimate fairly accurately what caused a target's reaction from a limited range of possible causes, despite the fact that the targets' reactions can be varied. Because the stimuli we used were spontaneous rather than standardised target reactions, the current study effectively embraces this human capacity to connect a range of behavioural responses with a specific causal antecedent. This is discussed in more detail in Pillai et al. (2012).

The current study aimed to determine whether individuals with ASD would be less successful in interpreting target reactions and this proved to be the case. This finding is consistent with the suggestion that group differences in mentalising can be found in naturalistic tasks which reflect some of the demands of everyday social situations, where facial expressions are brief and subtle. Our finding is perhaps comparable with the report that individuals with ASD have difficulties in tasks that require them to infer complex emotions (e.g. Golan et al. 2006). Similarly, Sawyer, Williamson, and Young, (2012) found that individuals with Asperger's Syndrome were less accurate than neurotypical adults in recognising complex mental state expressions.

It could be argued that in order to successfully identify the scenario in the mentalising task, one would only need to 'match' the responses using behavioural rules, while completely bypassing an inference of mental state that underlies the behavioural reaction ("Povinelli's challenge", Povinelli and Vonk 2003). It was previously argued that this is unlikely to be the case (Pillai et al. 2012): given the variety of reactions to the same scenario made by the targets in the videos, surely no simple behavioural matching strategy could be used. Besides, Perner (2010) pointed out that even behavioural rules are not 'mind-blind behaviourism,' implying that being able to acquire and use such rules is tantamount to having a 'theory of mind' of a kind. Nonetheless, if this task does involve matching responses using behavioural rules, the impaired performance of those with ASD is still interesting insofar as it would suggest that people with ASD have difficulties in applying behavioural rules (or behavioural matching strategies) effectively.

Participants spent longer looking at the mouth than the eye region for targets' reactions to all the scenarios apart from the Waiting scenario, for which participants spent a similar amount of time looking at the eyes and mouth. These findings are consistent with Pillai et al. (2012) where it was found that more time was spent looking at the mouth than the eye region for reactions to all four scenarios with this effect reduced (although not absent) for the waiting scenario. Most importantly for the aims of the current research, there were no differences between the groups with and without ASD in the time spent looking at the eyes. This suggests that the impairment in interpreting the target reactions in those with ASD is not explained by failure to use information from the eye region of the targets' face. Instead we conclude that both people with and without ASD approach this task by looking at the parts of the face that are most diagnostic for inferring which scenario caused the targets' reaction, but that people with ASD for some as yet undetermined reason appear to be poorer at making the correct inference.

Much previous research has emphasised the importance of using information from the eye region of the face to recognise facial expressions (e.g. Baron-Cohen et al. 1997; Smith et al. 2005). Moreover, studies have suggested that impairments in mentalising in ASD may partly be explained by a tendency not to use information from the eye region of the face (e.g. Corden et al. 2008; Spezio et al. 2007). While our findings may seem surprising in light of this, they are consistent with a growing body of research which suggests that the mouth may be more important than previously recognised. For example, Blais, Roy, Fiset, Arguin, and Gosselin (2012) conducted ideal observer analyses and found that the mouth region contains the most useful information for recognition of dynamic facial expressions. They speculate that this may be because the movements of the mouth are most useful for recognising natural facial expressions. Thus it is possible that people tended to gaze more at the mouth region of the face in certain scenarios due to the functional benefits of the movements of the mouth in deciphering mental states, Nevertheless, it has frequently proved difficult to find a relationship between facial viewing strategy and task performance (e.g. Sawyer et al. 2012) and this highlights a possible dissociation between where a person is looking and the information that is actually processed (Arizpe et al. 2012). It is fair to speculate that perhaps people tend to look at the mouth region when considering the correct answer i.e. when reasoning from mental state to the situation which gave rise to it. On the other hand, it is also possible that people look at the mouth as it is more central resulting in a holistic impressing of the face. Again, this would entail that eye gaze behaviour may not be fully indicative of the information that is actually being processed.

Participants' ability as indexed by full-scale IQ was related with success in discriminating between the scenarios based on the targets' reaction, although this could not explain the group differences in interpreting the reaction of the targets. Further analyses revealed that these relationships between IQ and task performance only held for those diagnosed with ASD. This suggests that in neurotypical individuals, the ability to discriminate the scenario to which a target is reacting is relatively independent of a person's IQ. However, for the participants with ASD, the relationship could suggest that those who are higher functioning have worked out strategies for identifying the scenario to which the targets responded, strategies that might be different from those used by comparison participants. As the participants in our study were high-functioning individuals with ASD we felt it was appropriate to compare with neurotypical adults of similar intellectual capacity, a strategy used in several similar studies previously (e.g. Kirchner, Hatri, Heekeren, & Dziobek, 2010; Sawyer et al., 2012). However future studies may consider comparing with a group of individuals with other known developmental conditions. In addition, one limitation of the current study is that we did not have information in regards to the psychiatric comorbidity of participants.

The fundamental strength of this study is the design, development and utilisation of naturalistic stimuli which represent an ecologically valid account of real-world social interactions. has Although the methodology used in this study was not designed for clinical use, in the future it may be possibleto use similar methods in social skills training interventions whereby more challenging and true-to-life depictions of social interactions are portrayed.

In summary, our findings suggest that, despite focusing on the same regions of the face, individuals with ASD had difficulties inferring what event caused an individual to behave in a particular way. The ability to make such inferences may be useful not only because it enables us to make sense of others' behaviour, but perhaps even enables us to benefit indirectly from the experiences of others. Through observing the reactions of others we may be able to learn something about events (both positive and negative) that we have not witnessed ourselves. Hence, participants effectively used the mind of the targets as a window to a view of the world that was beyond what they could apprehend with their ordinary senses. If individuals with ASD do not perform well in making such inferences, this could indicate not only that they have difficulty understanding other minds but they also experience a barrier to aspects of the world that most of us can see through the lens of other minds.

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Figure 1. Correct scenario discriminability based on target reactions (mean *d*' score)

	ASD Mean (*SD*)	Neurotypical Mean (*SD*)
N	15	15
Age	20.6 (5.6)	18.7 (3.7)
Verbal IQ	100.5 (21.7)	105.5 (18.0)
Performance IQ	95.5 (18.7)	101.1 (16.6)
Full Scale IQ	98.5 (21.1)	104.2 (18.3)
AQ	25.7 (7.0)*	16.7 (3.5)*

Table 1. Participant characteristics
* Significant difference between groups, $p < .001$

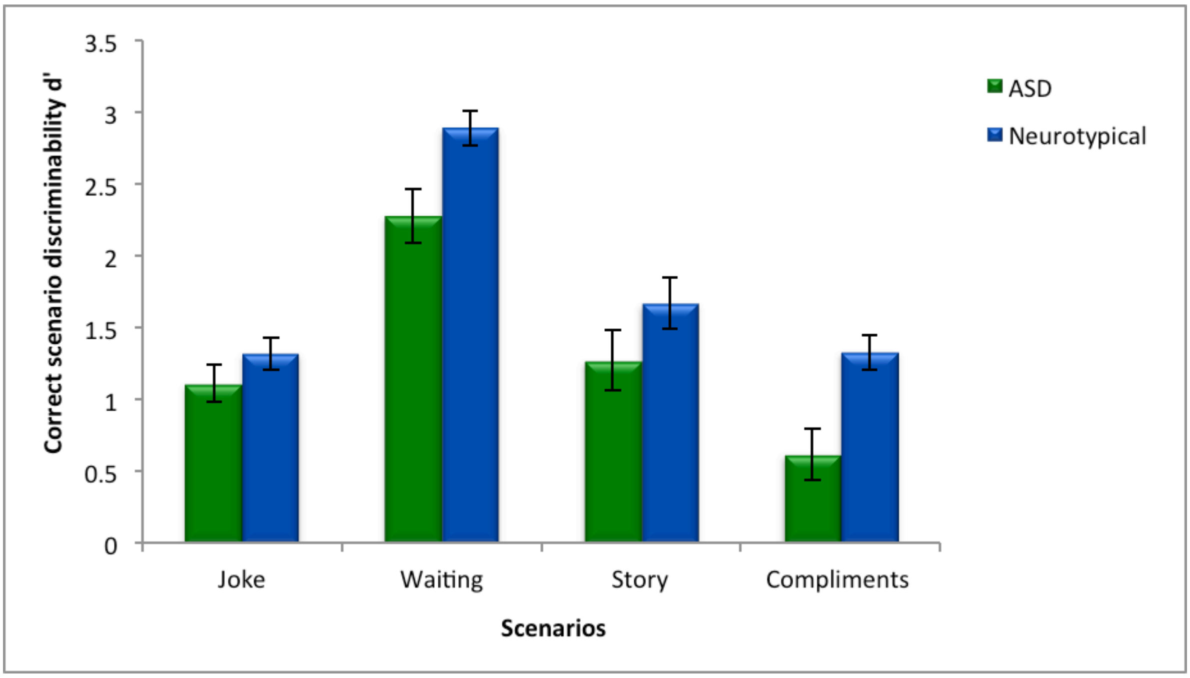
	ASD		Neurotypical	
	Accuracy	False alarm	Accuracy	False alarm
Joke	6.07 (60.7%)	6.13 (20.4%)	5.47 (54.7%)	3.13 (10.4%)
Waiting	8.60 (86.0%)	3.63 (12.1%)	9.87 (98.7%)	3.00 (10.0%)
Story	5.07 (50.7%)	3.33 (11.1%)	6.67 (66.7%)	2.93 (9.8%)
Compliments	3.20 (32%)	3.67 (12.2%)	5.47 (54.7%)	3.27 (10.9%)

Table 2: Participant mean accuracy rates and false alarm rates.

Accuracy : Number correct out of 10 (% in brackets)
False alarm: False alarms out of a possible 30 (% in brackets)

Figure 1. Correct scenario discriminability based on target reactions (mean *d*’ score)

Figure 2. Mean percentage of total gaze time at the eye and mouth of targets across four scenarios (error bars represent standard errors of the mean)


3.5
3
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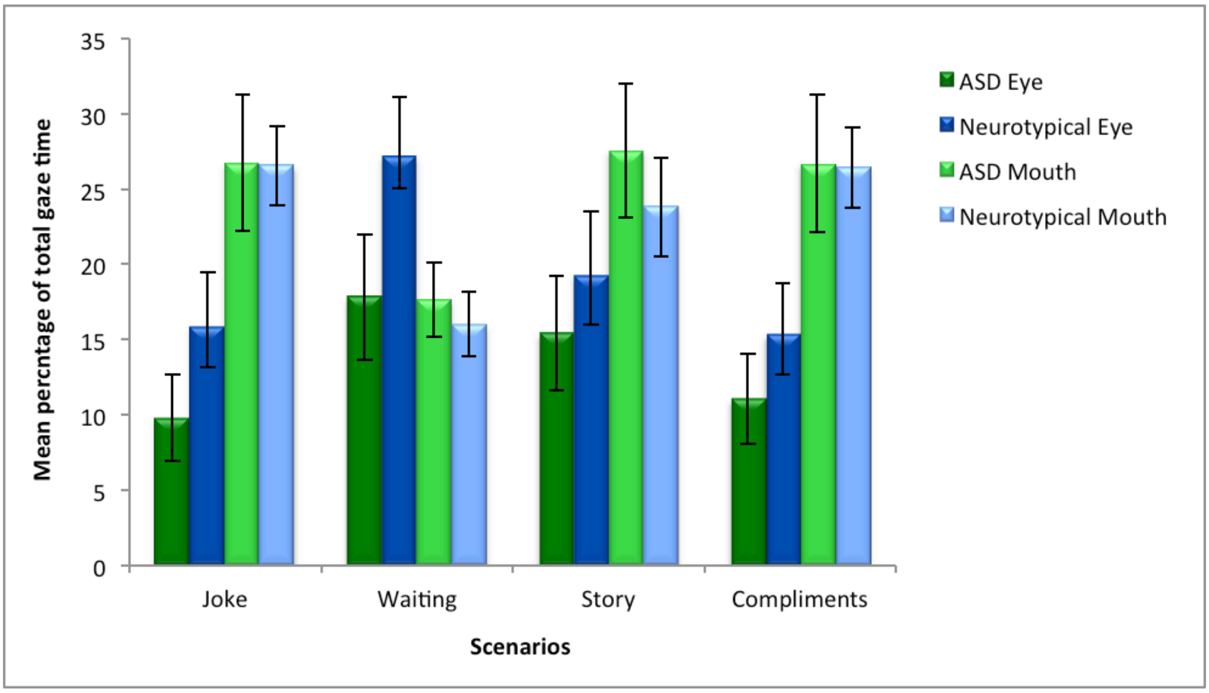
Correct scenario discriminability d'
ASD
Neurotypical
Joke
Waiting
Story
Compliments
Scenarios


Mean percntage of total gaze time
35
30
25
20
15
10
5
0
Joke
Waiting
Story
Compliments
Scenarios
ASD Eye
Neurotypical Eye
ASD Mouth
Neurotypical Mouth