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Can adults with Autism Spectrum Disorders infer what happened to someone
from their emotional response?

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Lay Abstract

The ability to infer others' thoughts and emotions is a skill which is essential for appropriate everyday social interaction. Researchers have argued that this ability may be deficit in Autism Spectrum Disorder (ASD) which could explain many of their socio-communicative difficulties. The literature exploring emotion processing in ASD has reported mixed findings, with more consistent difficulties being found with complex, dynamic stimuli that mimic the demands of everyday life.

This study used a novel method to investigate how adults with ASD process spontaneous emotions elicited during real-life social situations. Participants with and without autism watched videos of individuals receiving gifts which varied in level of appropriateness (i.e. chocolate, monopoly money, or a home-made novelty). Individuals were asked to 1) guess which gift the participant had received based on his or her reaction and 2) state the emotion they thought the individual was expressing upon receiving the gift. Eye movements were also measured while participants watched the videos. The results showed that individuals with ASD had particular difficulty inferring when someone had received chocolate or the home-made gift, suggesting problems with distinguishing between genuine and feigned happy emotional responses. Eye-tracking results showed that although individuals with ASD looked slightly less to the eye region, this did not explain their difficulty interpreting these particular emotion expressions. Overall, these findings provide evidence of processing differences when inferring spontaneous emotion and situational antecedents of behaviour with real-life stimuli.

Scientific Abstract

Can adults with Autism Spectrum Disorders (ASD) infer what happened to someone from their emotional response? Millikan has argued that in everyday life others' emotions are most commonly used to work out the antecedents of behaviour, an ability termed retrodictive mindreading. As those with ASD show difficulties interpreting others' emotions, we predicted that these individuals would have difficulty with retrodictive mindreading. Sixteen adults with high functioning autism or Aspergers Syndrome and 19 typically developing adults viewed 21 video clips of people reacting to one of three gifts (chocolate, monopoly money or a home-made novelty) and then inferred what gift the recipient received and the emotion expressed by that person. Participants' eye movements were recorded while they viewed the videos. Results showed that participants with ASD were only less accurate when inferring who received a chocolate or home-made gift. This difficulty was not due to lack of understanding what emotions were appropriate in response to each gift, as both groups gave consistent gift and emotion inferences significantly above chance (genuine positive for chocolate and feigned positive for home-made). Those with ASD did not look significantly less to the eyes of faces in the videos, and looking to the eyes did not correlate with accuracy on the task. These results suggest that those with ASD are less accurate when retrodicting events involving recognition of genuine and feigned positive emotions, and challenge claims that lack of attention to the eyes causes emotion recognition difficulties in ASD.

Keywords: Autism, Retrodictive Mindreading, Eye Tracking, Spontaneous Emotion Recognition, Face Processing.

Introduction

Successfully interpreting others' emotional responses is key for successful social interaction. It is widely reported that individuals with Autism Spectrum Disorders (ASD), who experience profound difficulties with social interaction (Wing and Gould, 1989), also experience difficulties in emotion recognition. Indeed, Kanner (1943) originally described autism as a disorder of 'affective contact', and difficulties with processing emotion are part of the current diagnostic criteria for autism (APA, 2000). However, studies of emotion processing in ASD have shown highly inconsistent results; some finding differences in emotion recognition and others failing to find differences between individuals with and without ASD. This is particularly the case for adults with ASD who have average intelligence, who tend to pass simpler emotion recognition tasks using static, posed expressions (see Uljarevic and Hamilton, 2013; Gaigg, 2012; Harms, Martin and Wallace, 2010). To resolve this debate, and assess the subtle difficulties adults with ASD exhibit, we need to develop tasks that match the demands of everyday life, while maintaining experimental control. This is the purpose of the current study.

As stated above, studies using a recognition paradigm with basic emotions (e.g. happy, sad, angry) often report ceiling effects or fail to find differences between individuals with and without ASD (see Adolphs et al., 2001; Loveland et al., 2008; Neumann et al., 2006; Ogai et al., 2003; Rutherford and Towns, 2008; Spezio et al., 2007a,b). In contrast, emotion recognition research which has used either more complex emotions (e.g. guilt), dynamic stimuli, or emotions with lower intensity tend to reveal impairments in adults with ASD (e.g. Baron-Cohen et al. 2001a; Philip et al., 2010; Humphreys et al., 2007; Roeyers et al., 2001; Golan et al., 2006). These results suggest that stimuli

which more closely reflect the demands of everyday processing are more likely to reveal differences between adults with and without ASD.

However there are reasons to question whether these more naturalistic tasks mirror the demands of everyday life. For example these previous studies, (with the exception of Roeyers et al., 2001), used posed, rather than spontaneous expressions. Spontaneous expressions differ to posed expressions as they are not produced by a direct request by another person (Matsumoto et al., 2009), but rather occur naturally during social interaction. Thus, spontaneous expressions have lower signal clarity; they are far more subtle than posed expressions, can portray more than one emotion and be subject to display rules, such as trying to portray a positive, rather than a negative reaction to a social interaction partner (Matsumoto et al., 2009; Carroll and Russell, 1997; O'Sullivan, 1982). This may explain why studies have found spontaneous expressions to be harder to recognize than posed expressions (Hess and Blairy 2001; Naab and Russell 2007; Wagner et al., 1992; Wagner, MacDonald and Manstead, 1986; Wagner, 1990). Thus, the stimuli predominantly used in previous studies may not share the characteristics of emotion expressions encountered in everyday life, which are more subtle and challenging to interpret. This may help explain the inconsistent results of previous research exploring emotion recognition, particularly in the case of adults with ASD.

Another reason to question whether previous emotion recognition tasks mirror the demands of everyday life is the predominant focus on recognition. Millikan (2005) has argued that the most common form of emotion recognition is not inferring another's emotion (as in the tasks described above), rather we more typically observe a person's emotional response, and then go about

explaining this response after the event (e.g. Bartsch & Wellman, 1989; Robinson & Mitchell, 1995). This ability has been termed retrodictive mindreading (Goldman and Sripada, 2005; Millikan, 2005; Gallese and Goldman, 1998).

The only previous study of retrodictive mindreading was recently performed by Pillai, Sheppard and Mitchell (2012), who demonstrated that typically developing adults could systematically infer what happened to someone from watching a brief video clip of their response (whether the individual was told a story, a joke, was left waiting or received a compliment). However Pillai et al's study did not include any measure of emotion inference. As those with ASD may have difficulty understanding what behaviours are appropriate in certain social situations (Loveland et al., 2001; Baron-Cohen et al., 1999), in the current study, we record participants' estimations of the target's emotion, in addition to the situational inference. This is to explore whether those with ASD and typical controls understand what emotional responses are appropriate to the given range of social situations. This allows us to determine whether difficulty retrodicting the correct situational antecedent is due to impaired recognition of emotion as opposed to understanding what kind of reaction would be appropriate in a given social situation (such as being polite when receiving an unwanted gift).

In contrast to Pillai et al's (2012) study, we investigate a different, but commonly experienced social situation – receiving a gift. This social situation was chosen as it provides the opportunity to investigate adults with ASD's understanding and recognition of more complex emotions. For example 'social emotions' expressed in the presence of another person, such as feigning a positive response in order to be polite (Baron-Cohen et al., 1997; Kasari,

Chamberlain and Bauminger, 2001) or 'cognitive emotions', which involve understanding of belief, such as surprise (Baron-Cohen, 1991; Baron-Cohen, Spitz and Cross, 1993). We investigate whether adults with ASD can understand that a person may pretend to like a handmade novelty, be confused on receiving an unwelcome gift such as monopoly money, and be genuinely positive on receiving a welcome gift such as chocolate. Can participants with ASD successfully gauge these spontaneous emotional responses, in order to retrodict what gift a person received?

The benefit of this retrodictive mindreading task is that spontaneous emotion recognition and understanding can be assessed, while having an objectively correct answer (the situation that caused the response). Typically developing individuals can systematically retrodict what situation caused a reaction from a brief video clip of the response (Pillai et al., 2012). Thus it appears that spontaneous emotional responses provide information which typically developing adults can reliably recognize, in order to infer the antecedent situations that produce them (Matsumoto and Willingham, 2006; Matsumoto et al., 2009). Given that adults with ASD have difficulty interpreting complex emotions, we predicted that they would have difficulty interpreting such spontaneous emotional responses and thus exhibit difficulties with retrodictive mindreading.

We also explore the eye movements of participants, in order to investigate whether, as has been proposed by previous research, people with autism have difficulty inferring emotions from the eye region of faces (e.g. Baron-Cohen et al., 1997; 2001). Studies of adults with ASD have not always shown overall differences in visual attention to social information, such as the eyes (e.g. Hernandez et al., 2009; Rutherford and Towns, 2008), but rather first fixation,

suggesting a delay in looking to socially pertinent information, rather than an absence (Fletcher-Watson et al., 2008; Fletcher-Watson et al., 2009; Freeth, et al., 2010a,b). This delay in looking to pertinent social cues could particularly impact on processing of fast paced dynamic stimuli (Klin et al., 2002; Speer et al., 2007). Thus our task, which presents dynamic and complex facial expressions, investigates whether adults with ASD find retrodictive mindreading difficult due to lack of attention to pertinent social information, in particular the eye region of faces.

Method

Participants. The ASD group comprised 16 adults (6 female, 10 male) aged 20-61 years, recruited from adverts in local media, the National Autistic Society and through various autism support groups across the UK. All the participants with ASD had been formally diagnosed by a clinician according to DSM-IV criteria (American Psychological Association, 1994). Diagnosis was independently confirmed by the researchers through the Autism Diagnostic Observation Schedule (ADOS, Lord et al., 1999) and Autism Quotient (AQ, Baron-Cohen et al., 2001b). All participants met the criteria for ASD on the ADOS and/or the AQ. The typical group comprised 19 adults (7 female, 12 male) aged 17-67 years, recruited from Nottingham University campus and the general population through adverts to local media.

The full Weschler Abbreviated Subscales of Intelligence (WASI-III, Weschler, 1999) was administered to all participants. Groups were matched on gender, age, full scale, verbal and performance IQ (see table 1 below for participant characteristics and group comparisons).

INSERT TABLE 1 HERE

Materials. Twenty-one video clips (ranging from 1.3 to 6 seconds in duration) were selected as stimuli. The videos were presented on the Tobii (1750) eye-tracker in high definition (1920 X 1080i). Eye movements were recorded using Clearview software at a rate of 50 recordings per second.

Stimuli Development. Stimulus videos were collected from 44 University students who had volunteered to take part in an unrelated study. After approximately one hour of testing, each individual was paid their inconvenience allowance of £12 and asked if they would be willing to continue for a few more minutes by being filmed for a study investigating communication.

Participants sat in a comfortable chair and were filmed from two feet using a Sony HD Camcorder, while reading aloud a list of five randomly selected neutral words. Immediately after, the experimenter pretended to turn off the video camera, and thanked the person for staying behind. The experimenter then offered a reward, which was either a box of high quality chocolates ($N=9$), a poor quality handmade gift ($N=17$) or a wad of monopoly money ($N=18$). Unknown to the recipient, their ensuing reaction to the gift was filmed and subsequently their consent was obtained for using the video in psychology experiments.

Twenty-one videos were selected for use in the current experiment according to certain criteria: face remained in full view of the camera, there was a noticeable reaction, and the recipient did not say what the gift was. Twenty-seven videos did not meet these criteria leaving twenty-one videos (seven different people receiving chocolate, seven receiving Monopoly money and seven receiving a handmade gift).

These twenty-one videos were edited using final cut pro 4 to provide a short clip of each person's reaction to the gift: in most cases, neutral to the peak of their reaction and back to neutral again. If the recipient did not return to a neutral expression the clip consisted of the peak of their expression held for a few seconds. Given that the expressions were not contrived, the duration of the video clips varied somewhat, from 1.3 seconds to 6 seconds (mean chocolate = 2.99 ($SD=.98$), mean home-made = 3.63 ($SD=1.17$), mean monopoly money = 3.73 ($SD=1.18$)). A one-way ANOVA showed no significant difference in the mean length of the video clips for each gift ($F(2,18)=.91, p=.42$).

Procedure. Participants were given an information sheet about the study and asked to give their consent to take part. Participants sat approximately 40 cm's from the eye-tracking screen. A six-point calibration was conducted before the start of the experiment and participants were asked to remain as still as possible throughout the experiment to prevent any deterioration in calibration.

Participants were told that they would see 21 video-taped reactions of people receiving either a box of chocolates, a wad of monopoly money or a hand-made gift in exchange for doing a big favour for someone. They were asked to watch each video carefully and; 1) judge what gift the target had been offered (out of the three options), 2) estimate the emotion of the target on being offered the gift. All responses were verbal and digitally recorded.

The researcher was present to monitor the experiment and was not blind to the emotion viewed by the participant. Each trial presentation sequence consisted of a 500 millisecond blank screen preceding a video clip of a person reacting to getting a gift followed by another blank screen. The researcher would then ask the participant '*do you think the person in the video got a box of chocolates, a tacky glitter card made especially for them, or some fake money?*'

The participant was given as much time as they needed to respond to the test question. After giving a response the participant was then asked '*How do you think the person felt when they got the [participant's gift response]?*' After the participant had responded to both of the test questions, the researcher asked if the participant was ready for the next video and started the next trial by a key press. Participants were debriefed and paid £5 for their time. Ethical approval for the study was granted by the University of Nottingham, School of Psychology Ethics Committee.

Emotion description coding. As participants' estimations of the target's emotion were free response, in order to analyse these data a coding scheme was developed which adequately captured the range of emotion labels participants used. Participants' estimations of the recipient's emotion were coded as belonging to one of four valence categories:

Positive: Any label which had the connotation of being positive. For example, happy, glad, pleasantly surprised, pleased.

Negative: Any label which had a negative connotation. For example, displeased, unhappy, disappointed, angry, upset.

Pretend: Any label which referred to the participant concealing negative emotions. For example, hiding disappointment, fake smile, politely accepting.

Confused: Any label which did not have a positive or negative connotation. For example, surprised, confused, puzzled, thoughtful.

Inter-rater agreement: Inter-rater agreement for the above coding scheme was established in the current experiment for the typical and ASD group's emotion ratings. These emotion ratings were coded by the experimenter, along with two independent raters blind to methods and hypotheses. Cohen's Kappa was used to establish inter-rater agreement when

using the above coding scheme to code participants' estimations of emotion. Inter-rater agreement was $K=.76$ for typical participants responses and $K=.79$ for the ASD group's emotion responses. In the current study, participants' estimations of emotion were coded by the experimenter.

Results

Behavioural Results.

INSERT TABLE 2 and FIGURE 1 HERE

Are those with ASD less accurate than typical controls when inferring gift?

Table 2 shows the confusion matrices for participants' gift inferences in the typical control (a) and ASD (b) groups. The typical control group gave more correct than incorrect gift responses. However those with ASD only gave more correct than incorrect gift responses when inferring who received monopoly money.

To control for response bias (e.g. more don't know responses in the ASD group), the proportion of correct gift responses were calculated as the number of correct responses, divided by the total number of times a participant offered that gift response (figure 1).

A two way mixed ANOVA was conducted with group as a between subjects factor with two levels (ASD, typical control) and percentage of correct gift inferences as a within subjects factor with three levels (chocolate, home-made and monopoly money). Results showed a significant main effect of gift ($F(2,66)=16.65, p<.001$); significantly more correct home-made gifts were inferred than chocolate ($F(1,33)=8.65, p<.01$), and significantly more correct monopoly money gifts were inferred than chocolate and home-made

($F(1,33)=21.97, p<0.001$). There was a significant interaction between group and gift ($F(2,66)=3.35, p<.05$); those with ASD were significantly less accurate than controls when inferring who received a chocolate or home-made gift, but not monopoly money ($F(1,33)=4.2, p<.05$). There was also a significant main effect of group; those with ASD made significantly less correct gift inferences than the typical control group overall (ASD mean = 45.8%, Typical mean = 54.45%, $F(1,33)=4.42, p<.05$).

What was the pattern of participants' errors?

The raw frequencies in table 2 show that both groups tend to confuse reactions to home-made gifts with chocolate more than monopoly money. These confusions between chocolate and home-made responses are more pronounced in the ASD group. To compare this pattern of errors between groups, a three way mixed ANOVA was conducted with group as a between subjects factor with two levels (ASD, typical), correct answer (i.e. what gift the target received) as a within subjects factor with three levels (chocolate, home-made and monopoly money) and participants' response as a within subjects factor with three levels (chocolate, home-made and monopoly money).

The three way mixed ANOVA showed a significant three way interaction between group, correct answer and participants gift response ($F(4,132)=3.5, p<.01$). Simple main effects analysis showed no significant difference between correct and incorrect gift responses when participants with ASD inferred who received a chocolate gift ($F(2,32)=2.1, p=.14$). There was a significant difference between correct and incorrect gift responses when participants with ASD inferred who received a home-made gift ($F(2,32)=28.64, p<0.001$) and monopoly money ($F(2,32)=31.72, p<0.001$). Bonferroni corrected *t*-tests

showed no significant difference between correct home-made and incorrect chocolate inferences ($p=1$), but significantly more correct home-made gift than incorrect monopoly money inferences ($p<.001$) and significantly more correct monopoly money than incorrect chocolate ($p<0.001$) and home-made gift inferences ($p<.001$).

Simple main effects analysis showed a significant difference between correct and incorrect gift responses when typical controls inferred who received chocolate ($F(2,32)=7.29, p<0.01$), a home-made gift ($F(2,32)=35.05, p<0.001$) or monopoly money ($F(2,32)=31.72, p<0.001$). Bonferroni corrected t -tests showed that typical controls were significantly more likely to give a correct chocolate response than an incorrect home-made ($p<.01$) or monopoly money response ($p<.05$); give a correct home-made response than an incorrect chocolate ($p<.05$) or monopoly money response ($p<.001$); and give a correct monopoly money response than an incorrect chocolate ($p<.001$) or home-made response ($p<.001$).

Neither proportion of correct chocolate ($r=.02, p=.9; r=.02, p=.9$), home-made ($r=.0.1, p=.7; r=.0.3, p=.2$), or monopoly money responses ($r=.02, p=.9; r=.1, p=.6$) correlated with full scale IQ or AQ scores respectively in the ASD group.

Are gift and emotion inferences consistent in both groups?

Tables 3 and 4 show the observed and expected frequencies of emotion labels participants offered alongside their gift inference for correct (3) and incorrect (4) trials (e.g. observed and expected frequency of positive emotion

ratings for correct (3) and incorrect (4) chocolate responses)¹. If those with ASD were less accurate when inferring who received a chocolate or home-made gift because they did not understand which emotions were appropriate in response to these gifts, then emotion and gift inferences would not be consistent in each group. In table 3, values with subscript **A** denote correct gift inferences with consistent emotion labels, and in table 4 values with lower case subscript **a** denote incorrect gift inferences with consistent emotion labels (i.e. positive for chocolate, pretend for home-made and confused for monopoly money).

For correct trials, both typical controls (3a) and those with ASD (3b) rate reactions to chocolate as predominantly positive and monopoly money as predominantly confused. The observed frequencies are also far higher than expected, whereas inconsistent gift and emotion responses (e.g. positive for monopoly money) are far lower than expected. Although pretend emotion ratings were rare, both groups almost exclusively ascribe this rating to home-made gift inferences and above the level expected. This pattern is also evident for incorrect trials in the typical control (4a) and ASD (4b) groups, although both groups rate home-made responses as less positive (below expected) and more confused (above expected).

To explore whether participants in both groups tended to attribute similar emotions to each gift, regardless of whether the gift inferred was correct or incorrect, likelihood ratios were calculated from the observed frequencies in tables 3 and 4 for each group. The likelihood ratio is a chi-square statistic with the same distribution and degrees of freedom as Pearson's chi-square. It is based on maximum likelihood theory, where a model is created from the total

¹ Please see supplementary data tables 5 and 6 for a full breakdown of gift and emotion response combinations for correct and incorrect trials in the ASD and typical control group.

observed frequency of consistent (cells denoted by \mathbf{a} for correct and \mathbf{a} for incorrect gift responses) and total observed frequency of inconsistent gift and emotion responses, where the probability of obtaining these data is maximized, then compared to the probability of obtaining these data under the null hypothesis. The resulting statistic is therefore based on comparing the observed frequency of consistent and inconsistent gift and emotion responses with those predicted by the model.

Results showed that both groups gave significantly more consistent and less inconsistent gift and emotion inferences than predicted by the model, when the gift inferred was correct (Typical group, observed consistent=108, expected consistent=59.9, observed inconsistent=85, expected inconsistent=122.5, $L\chi^2(1)=17.8, p<0.001$; ASD group, observed consistent=81, expected consistent=36.2, observed inconsistent=76, expected inconsistent=82.4, $L\chi^2(1)=26, p<0.001$) or incorrect (Typical group observed consistent=90, expected consistent=49.4, observed inconsistent=76, expected inconsistent=137.2, $L\chi^2(1)=6.3, p<0.05$; ASD group observed consistent=92, expected consistent=46.8, observed inconsistent=104, expected inconsistent=149.1, $L\chi^2(1)=21.3, p<0.001$).

INSERT TABLES 3 AND 4 HERE

Eye Tracking Results.

Analysis

Regions of interest were defined using the Eye Tracker Output Utility (Van-Heuven, 2010) over a series of static pictures, representing the movement of the target over the course of the video. The Eye tracker Output Utility (Van-Heuven, 2010) calculated the number and duration of fixations in each area of

interest (figure 2). Percentage number and duration of fixations were calculated as the number/duration of fixations in the region of interest divided by the total number of fixations/total duration of the video. These percentages were used in analyses to control for differences in stimulus duration and number of fixations between participants. On perusal of the raw eye tracking data, it became apparent that loss of calibration (indicated by an error message that a majority of fixations were being made outside the area of the screen) occurred for one participant with ASD and six typical controls. These data were excluded from analysis.

INSERT FIGURE 2 HERE

Do participants with ASD look less to the eyes?

A three way ANOVA compared ROI (eyes, mouth) for each gift (chocolate, home-made and monopoly money) in each group (ASD, typical control). The three way ANOVA revealed a significant interaction between gift and ROI for proportion of fixations ($F(2, 52)=12, p<0.001$) and fixation duration ($F(2, 52)=8.3, p<0.01$), indicating that participants tended to look at the eyes and mouth differently depending on which gift response was viewed. Orthogonal contrasts showed that the proportion of fixations ($F(1,26)=.02, p=.9$), and fixation duration ($F(1,26)=.001, p=.9$) to the eyes and mouth were similar when viewing reactions to chocolate and home-made gifts. However when participants viewed reactions to monopoly money, the proportion of fixations ($F(1,26)=28, p=.001$) and fixation duration ($F(1,26)=17.3, p=.001$) to the eyes and mouth were significantly different compared to when viewing reactions to chocolate and home-made gifts; participants tended to look more to the mouth than the eyes when viewing reactions to chocolate and home-made and more to the eyes than the mouth when viewing reactions to monopoly money (Figures 3 and 4).

INSERT FIGURES 3 AND 4 HERE

Although participants with ASD looked longer to the mouth than the eyes compared to typical controls, this interaction was not significant for proportion of fixations ($F(1,26)=3.7, p=.07$) or fixation duration ($F(1,26)=2.9, p=.1$) (figures 5 and 6). There were no significant correlations between proportion of fixation or fixation duration to the eyes or mouth and correct gift responses when viewing the chocolate, home-made or monopoly money responses in the ASD or typical group.

INSERT FIGURES 5 AND 6 HERE

Discussion

This study aimed to develop a new naturalistic emotion recognition task to assess the subtle emotion recognition difficulties adults with ASD experience in everyday life. Can adults with ASD successfully infer what happened to someone from their emotional response? Adults with ASD were not less accurate than typical controls when inferring who received monopoly money from a brief video clip of a person's emotional response. However those with ASD were significantly less accurate when inferring who received a chocolate or home-made gift. This difficulty was not isolated to a subset of the ASD sample, as neither IQ nor a measure of self-reported autistic traits correlated with accuracy.

Problems inferring who received a chocolate or home-made gift could be due to difficulties with recognizing these emotions or failing to understand which emotions were appropriate when receiving these gifts. As both groups made consistent gift and emotion inferences significantly above chance, the findings suggest that adults with ASD understood which emotions were appropriate in response to each gift; positive for chocolate, confused for monopoly money and

pretend for home-made. Thus, reduced accuracy when inferring who received a home-made or chocolate gift was most likely due to difficulty recognizing positive and feigned positive emotions. However adults with ASD could successfully recognize who was confused, and thus correctly recognized who received monopoly money.

Understanding which emotions and behaviours are appropriate in different social situations has rarely been studied in ASD, and never before in adults with ASD. Children with ASD fail to identify which behaviours are inappropriate in a range of social situations (Loveland et al., 2001; Baron-Cohen et al., 1999), and have difficulty understanding what situation will cause a complex emotion such as surprise (e.g. Jane will be surprised on opening the empty box of coco pops), but not situations which cause basic emotions such as happiness and sadness (e.g. having a birthday party as opposed to grazing a knee) (Baron-Cohen et al., 1993). In the current study adults with ASD understood what situation would cause a complex emotional response (e.g. feigning a positive response to an unwanted gift). These results suggest that adults with ASD learn what complex emotional responses are appropriate in different social situations, but find it difficult to successfully recognize them.

An alternative interpretation of our findings is that perhaps people do not need to infer the emotion of the person in order to retrodict what happened to them. As participants with ASD find the task difficult, perhaps they guess the gift and consequently infer a consistent emotion. The upshot of this critique, termed 'Povinelli's challenge' (see Perner, 2010; Povinelli and Vonk, 2003), is that it can be applied to any task assessing emotion recognition. Our results also suggest that when participants correctly gauge the emotion of the person (e.g. positive) they also tended to correctly infer what gift the person received (chocolate). In

addition, when participants incorrectly interpreted the emotion of the person (e.g. positive, as opposed to confused) they also incorrectly, but consistently inferred what gift they received (chocolate, when they really received monopoly money). This association between gift and emotion inferences is unlikely to exist if what gift a person received can be inferred by some other means than interpreting their emotional response.

Why were participants with ASD less accurate when interpreting positive and feigned positive emotions, but not confused? Previous research has shown that complex mental states such as confused are difficult for people with ASD to recognize, particularly from dynamic facial expressions (e.g. Back et al., 2007). It could be the case that people with ASD can distinguish very different emotions (positive from confused), but have difficulty making more subtle distinctions (genuine from feigned positive). Analysis of participants' errors suggests that this was the case; participants with ASD were significantly more likely to mistake feigned positive reactions to the home-made gift as a genuine positive reaction to chocolate than typical controls. However both typical controls and participants with ASD did not tend to misinterpret feigned positive reactions to the home-made gift as confused reactions to monopoly money or vice-versa. Boraston et al. (2008) have presented a similar argument for adults with ASD having difficulty making subtle distinctions between genuine and posed smiles, which involve attention to subtle cues in the eye region of faces.

Can reduced accuracy in the ASD group be explained by reduced attention to the eye region of faces? Baron-Cohen et al. (1991; 2001a) have argued that people with ASD have difficulty inferring emotions from the eye region of faces, which may be particularly important for recognition of feigned positive expressions (Boraston et al., 2008; Ekman and Friesen, 1982; Ekman,

Friesen and O'Sullivan, 1988; Ekman, Friesen, and Davidson, 1990). In the current study, although participants with ASD spent less time looking to the eye region and more to the mouth region than controls, this difference failed to reach significance. Looking to the eyes also did not predict accuracy in either group. These results suggest that other available cues, such as auditory information, may be important when judging an individual's emotional response. Evidence of poor emotion recognition in vocalizations has been found in adults with ASD (Philip, et al. 2010; Heaton, et al. 2012). Furthermore, Golan et al. (2006) have suggested that individuals with ASD may be more focused on speech content, failing to integrate contextual and facial cues, causing adults with ASD to misinterpret complex emotions such as sarcasm as genuine responses. In the current study, those with ASD could have focused more on speech content (e.g. "thank you", for chocolate and home-made, versus "OK" for monopoly money), whereas typical controls may have integrated speech content with tone of voice and facial cues. This could have resulted in those with ASD confusing reactions to chocolate and home-made gifts, but not monopoly money.

Our results demonstrate the impact of emotion recognition difficulties in adults with ASD on an important social skill – being able to make sense of another person's behavior. Adults with ASD have difficulty retrodicting what caused an emotional response when this involves recognition of subtle emotion responses, requiring integration of cues across different modalities. These results challenge claims that emotion recognition difficulties in ASD are primarily due to lack of attention to the eye region of faces, and stress the importance of other emotional cues (e.g. auditory, body movement). Difficulties in retrodictive mindreading could impact on the way adults with ASD interact with others in

everyday life. Failure to recognise whether someone is genuinely happy or trying to put on a brave face could make the difference between mistakenly congratulating them on a positive event, or correctly consoling them after a disappointing outcome. Such difficulties in social interaction are a hallmark of adults with ASD's difficulties in everyday life. Future research should aim to elucidate the subtle nature of emotion processing difficulties in adults with ASD and their wider impact on social functioning.

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Tables

Table 1: Participant characteristics.

	AS/HFA group (N=16)			Control group (N=19)			t-test Result
	Mean	SD	Range	Mean	SD	Range	
Age (years)	36.44	12	20-61	30.42	13.49	20-67	$t(33)=1.38,$ $p=.18$
Full-Scale IQ	117.06	14.63	91-140	119.95	8.7	105-136	$t(33)=.7, p=.5$
Verbal IQ	114	14.63	92-143	114.58	9.64	97-137	$t(32)=.13, p=.9$
Performance IQ	115.13	14.45	86-138	119.89	8.99	107-136	$t(32)=1.2,$ $p=.23$
AQ	37.69	9.46	18-47	N/A	N/A	N/A	N/A
ADOS	9.27	4.13	4-18	N/A	N/A	N/A	N/A

N.B. Verbal and performance IQ is missing for one participant with ASD.

Table 2: Confusion matrices showing frequency of correct and incorrect gift inferences in the ASD and typical control group.

a) Typical Control Group		Correct Answer			Total
		Chocolate	Home-made	Monopoly Money	
Participant's Gift Response	Chocolate	59	45	29	133
	Home-made	31	76	29	136
	Monopoly Money	43	12	74	129
	Don't Know	0	0	1	1
	Total	133	133	133	

b) ASD Group		Correct Answer			Total
		Chocolate	Home-made	Monopoly Money	
Participant's Gift Response	Chocolate	37	50	22	109
	Home-made	40	44	27	111
	Monopoly Money	26	14	59	99
	Don't Know	9	4	4	17
	Total	112	112	112	

Note: Shaded cells indicate correct gift inferences.

Table 3: Frequency of emotion ratings for **correct** gift inferences in the ASD and typical group.

a) Typical Control Group		Correct Gift Response (Expected Frequencies in Brackets)			Total
		Chocolate	Home-made	Monopoly Money	
Emotion	Positive	46 \mathbf{A} (27.1)	42 (34.9)	8 (34)	96
	Pretend	0 (3.4)	12 \mathbf{A} (4.4)	0 (4.2)	12
	Confused	9 (19.5)	10 (25.1)	50 \mathbf{A} (24.4)	69
	Negative	3 (8.5)	11 (11)	16 (10.4)	30
	Don't Know	1 (0.6)	1 (0.7)	0 (0.7)	2
Total		59	76	74	209

b) ASD Group		Correct Gift Response (Expected Frequencies in Brackets)			Total
		Chocolate	Home-made	Monopoly Money	
Emotion	Positive	30 \mathbf{A} (13.2)	20 (15.7)	6 (21)	56
	Pretend	0 (3.3)	13 \mathbf{A} (3.9)	1 (5.3)	14
	Confused	2 (11.1)	7 (13.2)	38 \mathbf{A} (17.7)	47
	Negative	2 (4.5)	4 (5.3)	13 (7.1)	19
	Don't Know	3 (0.9)	0 (1.1)	1 (1.5)	4
Total		37	44	59	140

Note: Frequencies with subscript **A** denote correct gift and consistent emotion inference.

Table 4: The frequency of emotion ratings for **incorrect** gift inferences in the ASD and typical group.

a) Typical Control Group		Incorrect Gift Response (Expected Frequencies in Brackets)				Total
		Chocolate	Home-made	Monopoly Money	Don't Know	
Emotion	Positive	61 ^a (31.5)	13 (25.6)	6 (23.4)	1 (0.4)	81
	Pretend	0 (2.7)	5 ^a (2.2)	2 (2)	0 (0)	7
	Confused	9 (21)	21 (17)	24 ^a (15.6)	0 (0.3)	54
	Negative	3 (18.3)	21 (14.8)	23 (13.6)	0 (0.2)	47
	Don't Know	1 (0.4)	0 (0.3)	0 (0.3)	0 (0)	1
Total		74	60	55	1	190

a) ASD Group		Incorrect Gift Response (Expected Frequencies in Brackets)				Total
		Chocolate	Home-made	Monopoly Money	Don't Know	
Emotion	Positive	63 ^a (33)	16 (30.2)	6 (18.3)	3 (6.4)	88
	Pretend	0 (6.7)	15 ^a (6.2)	3 (3.7)	0 (1.3)	18
	Confused	1 (14.6)	24 (13.4)	14 ^a (8.1)	0 (2.8)	39
	Negative	1 (9)	7 (8.2)	13 (5)	3 (1.7)	24
	Don't Know	7 (8.6)	4 (7.9)	4 (4.8)	8 (1.7)	23
Total		72	66	40	14	192

Note: Frequencies with subscript **a** denote incorrect gift with consistent emotion inference.

Figure Legends

Figure 1: Percentage of correct gift inferences for the typical and autistic group for each gift. The red line denotes chance level (33%).

Figure 2: Example fixation and saccade data over regions of interest (eyes and mouth) for a participant with autism (above left) and typical participant (above right).

Figure 3: Percentage duration of fixations on the eyes and mouth for each gift.

Figure 4: Percentage of fixations on the eyes and mouth for each gift.

Figure 5: Percentage durations of fixations on the eyes and mouth in each group.

Figure 6: Percentage of fixations on the eyes and mouth in each group.