Eye movements reveal no immediate "WOW" ("which one's weird") effect in autism spectrum disorder

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Eye movements reveal no immediate "WOW" ("which one's weird") effect in autism spectrum disorder

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Autism spectrum disorder (ASD) and typically developed (TD) adult participants viewed pairs of scenes for a simple "spot the difference" (STD) and a complex "which one's weird" (WOW) task. There were no group differences in the STD task. In the WOW task, the ASD group took longer to respond manually and to begin fixating the target "weird" region. Additionally, as indexed by the first-fixation duration into the target region, the ASD group failed to "pick up" immediately on what was "weird". The findings are discussed with reference to the complex information processing theory of ASD (Minshew & Goldstein, 1998).

Keywords: Autism spectrum disorder; Eye movements; Online cognitive processing; Complex information processing.

Autism spectrum disorder (ASD) describes a lifelong neurodevelopmental condition that is characterized by impairments in social (*Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition; DSM–IV*; American Psychiatric Association, 1994) and cognitive (Happé & Frith, 2006; Minshew, Goldstein, & Siegel, 1997; Russell, 1997) processing domains. However, people with ASD, especially high-functioning autistic (HFA) individuals or those diagnosed with Asperger's disorder (AS), a milder form of autism, can often look "normal" on paper in terms of IQ scores, and subtle processing differences that impact in everyday activities may not always be obvious or easily quantified. Since

ASD directly impacts upon an individual's ability to live independently, the National Audit Office has recently called for more research into adults with ASD (Clark, Scharaschkin, & Xu, 2009).

A recent surge in eye-tracking studies has used eye movement measures to differentiate between typically developed (TD) participants and ASD individuals across a range of processing domains. This is unsurprising since eye movement measures provide an excellent online index of cognitive processing for many types of task (Liversedge & Findlay, 2000; Rayner, 1998, 2009), and hence they are potentially a valuable tool to examine how ASD participants differ in their online

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processing abilities compared to TD participants. However, the 60 or so papers published to date on eye movements in ASD (see review by Benson & Fletcher-Watson, 2011) report inconsistencies in the presence and severity of impairments across many processing domains, and it has been proposed that eye movement control in ASD remains poorly understood (Brenner, Turner, & Müller, 2007).

One contemporary model of ASD that can offer an account for some of the current inconsistencies in the eye movement literature on ASD proposes that ASD reflects problems with information processing, rather than acquisition (Minshew & Goldstein, 1998; Minshew, Luna, & Sweeney, 1999). As such, processing demands that are simple or mechanical in nature are intact in ASD, whereas more complex information processing may be impaired within the same cognitive domain. Moreover, the model proposes that complex information-processing deficits transcend multiple cognitive domains and hence should be observed in tasks that require "integration of multiple features rather than reliance on one or two individual features, speed of processing, processing of large amounts of information, or processing of novel materials" (Minshew, Williams, & McFadden, 2009, p. 383).

In theory, these characteristics of the disorder should be observed in patterns of eye movements, and, if this is the case, some of the reported inconsistencies in the eye movement literature to date may simply reflect differences in processing demands of the task at hand. In support of the model, in our eye movement studies, we have found more similarities than differences in eye movement metrics between TD and ASD groups for tasks that have simple processing demands in the attentional (Kuhn et al., 2010) and in the social domains (Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009). Furthermore, in a partial replication of the classic Yarbus study (1967), there was no modulation of patterns of eye movements in ASD for high-level, top down inspection instructions in scene processing. In that study (Benson, Piper, & Fletcher-Watson, 2009), participants were presented with a picture depicting the unexpected return home of a father from a war. Participants were asked to look at the picture and estimate: (a) How wealthy is the

family? and (b) how long has the unexpected visitor been absent? The TD group looked more often and for longer at the people and the heads of the people in the scene during Task b than during Task a, and, conversely, they looked more often and for longer at the objects in the scene for Task a than for Task b. These online sampling differences were absent in ASD. However, since only complex inspection instructions were used in the above study, it was not possible to compare the behaviour of the two groups for simple versus complex processing in this scene inspection task.

A principal goal of the present study was to record volitional eye movements in ASD and TD participants in an attempt to directly test Minshew and Goldstein's (1998) model in the same experiment, which as yet has not been done. To achieve this, we presented the same materials for a simple information-processing "spot the difference" (STD) task and a complex information-processing "which one's weird" (WOW) task. In choosing the complex processing task, we adopted a similar paradigm and materials to those used in a recently reported study (Rayner, Castelhano & Yang, 2009).

For the purposes of this study, we operationally define complex information processing as processing that goes beyond simple perceptual processing and where the task demands require the use of top down knowledge to inform a subjective value judgement. We predicted that the ASD group should show differences in processing, as revealed by specific eye movement measures compared to the TD group in our complex WOW task. Whereas for our simple STD task (e.g., decide which one of a pair of pictures has a detail missing), we operationally defined simple processing as processing that is devoid of higher level cognitive demands, and which is essentially a low-level pattern-matching task, and here we predicted that performance should be equivalent for both groups.

Method

Participants

ASD participants ($n = 14$, age 18–50 years, 10 males), with a formal diagnosis (*DSM–IV*, 1994), were recruited from local charitable organizations

and the adult diagnostic research centre in Southampton. TD participants ($n = 13$, age 19–48 years, 6 males) were volunteers from the local community. All participants were paid, and all had normal or corrected-to-normal vision. Two performance components (Block Design and Matrix Reasoning) and verbal components (Vocabulary and Similarity) of the Wechsler Abbreviated Scale of Intelligence (Psychological Corporation, 1999) were completed on a one-on-one basis prior to eye movement recording, and there were no group differences on all measures. Both groups also completed the Autism Spectrum Quotient (AQ; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), and ASD participants scored significantly higher on the number of self-reported autistic traits (see Table 1 for participant mean IQ and AQ scores and alpha values).

Eye movement recording

Eye movements were sampled at 1,000 Hz using an Eyelink tracker with spatial accuracy of less than 0.25 degrees (S.R. Research Ltd, Osgoode). A chin rest and forehead supports were used to stabilize head position. Viewing was binocular but data were analysed for the right eye only. Individual participants were calibrated using a 9-point matrix that covered the dimensions of the screen ($1,024 \times 768$ pixels), each point being fixated sequentially, followed by a validation procedure to ensure that fixation was within 0.5 degrees of each calibration point. Fixation on a central spot was checked prior to each trial presentation, and recalibration was performed if this was off centre.

Materials

Forty-eight full-colour photographs—24 pairs of scenes for each task (WOW and STD)—were used as stimuli. In the WOW task, each pair had a normal scene and an anomalous scene in which one object (e.g., a baby) replaced another (e.g., a beach ball). A few of these scenes were from a previous study (Rayner et al., 2009). In addition, we collected the other "weird" pictures from the Internet, and then, using Adobe Photoshop, we prepared a control version of each scene in which the unusual object was replaced with either the background elements or with another suitable object. The scenes typically had a focal object or a central group of objects. For the "weird" condition, the weird aspect of the scene was a part of a single object or group that was incompatible with the rest of the scene. Figure 1 shows (a) an example of a pair of scenes for the WOW task, with (b) regions of interest around the target item. The weird scene is the one with the large animal walking down the highway.

In the STD task, each trial was made up of either two "normal" scenes or two "weird" scenes taken from the WOW task, and one of the pictures in each pair was manipulated using Photoshop to remove a "detail". The details removed were designed to make the task quite difficult, rather than easy. Figure 2 shows an example of two pairs of scenes for the STD task—a normal picture pair and a weird picture pair—with regions of interest around the missing detail item and the corresponding area in the counterpart picture. The complete set of picture pairs for both tasks can be obtained from the first author.

Table 1. *Participant descriptives*

Characteristic	TD		ASD		
	Mean	SD	*Mean*	SD	p
Age	26.9	7.83	29.5	10.6	.470
AQ	15.00	5.63	31.82	9.59	<.001
Full-scale IQ	113.15	14.91	110.18	21.09	.691
Verbal IQ	110.31	14.67	109.27	22.97	.895
Performance IQ	112.92	13.19	108.73	17.71	.513

Note: TD = typically developed. ASD = autism spectrum disorder. AQ = Autism Spectrum Quotient.

(a)

(b)
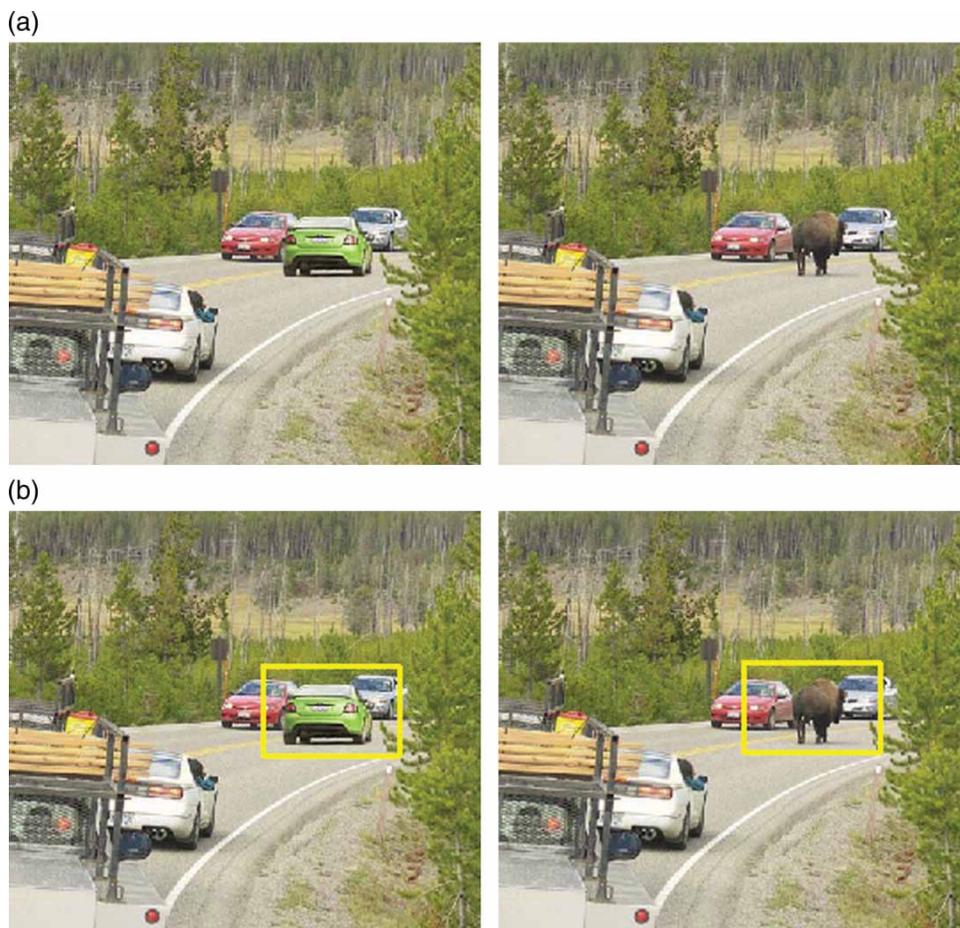
Figure 1. *(a) Stimulus example picture pair for the "which one's weird" (WOW) task. (b) Regions of interest for the "target" areas in the picture pair. To view a colour version of this figure, please see the online issue of the Journal.*

Design

A repeated measures design was employed for each task, with detail absent versus detail present in the STD task and picture type (weird versus normal) in the WOW task as within-participants variables and group as a between-participants variable.

Procedure

We recorded eye movements for a simple (STD) task, and a complex (WOW) task. All participants were shown a hard copy of an example picture pair, prior to completing each task, to ensure comprehension and ability to respond appropriately. The specific instruction was: "Look at the pairs of pictures and use the button controller to indicate which picture is weird, odd or unusual" for the WOW task, or, in the STD task, "which picture has a detail missing?".

For each task, 24 picture pairs were presented randomly side by side on a 21-inch colour monitor (1,024 × 768 pixels), at a distance of 60 cm, for 20 s or until a button press response was made. Prior to a picture pair display, a central fixation spot was presented to ensure that all participants started at the centre of the screen. Each trial was initiated by the experimenter once calibration had been checked. Order of task and whether the weird picture in the WOW task and the detail missing
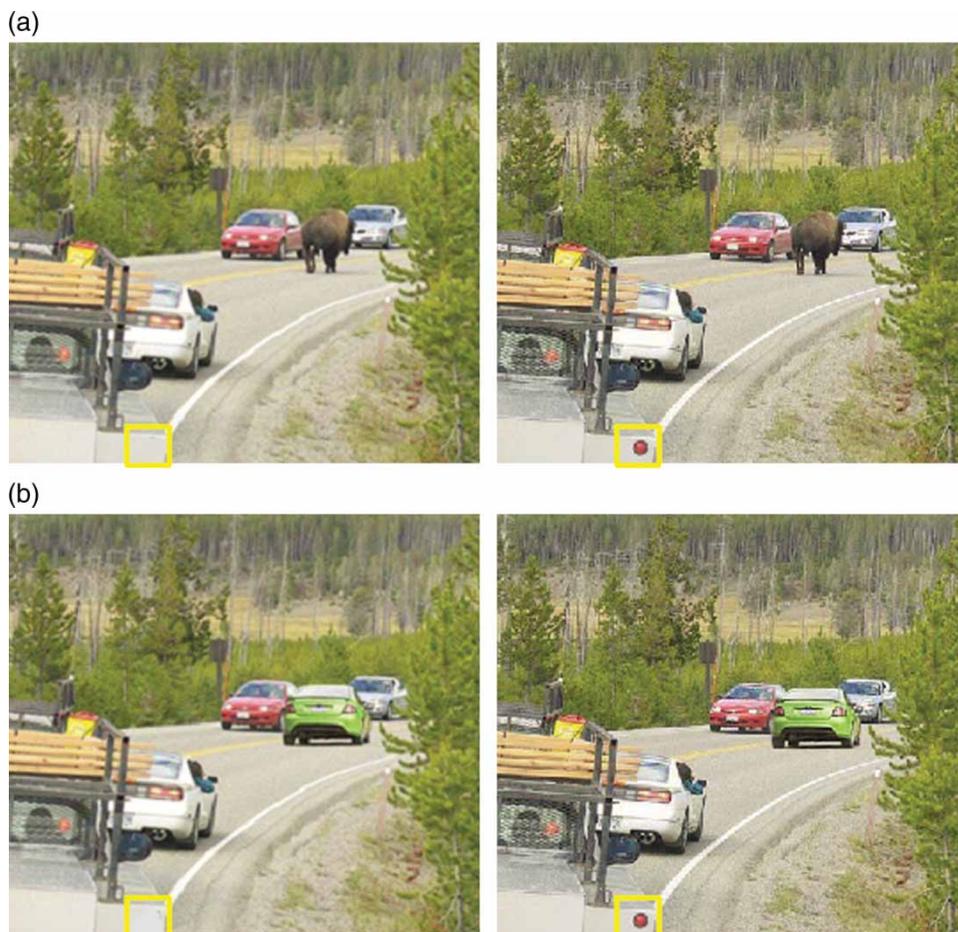
Figure 2. *(a) and (b) The same stimulus example picture pair from the "which one's weird" (WOW) task shown in Figure 1, now as used in the "spot the difference" (STD) task, with regions of interest. To view a colour version of this figure, please see the online issue of the Journal.*

picture in the STD task appeared on the left or the right of the picture pair were counterbalanced across the picture set and across participants. Four practice trials were presented immediately before the experimental trials for each task.

Results

Data preparation and analyses

For each picture pair, we created an interest region around the target item and the corresponding region of the same size in the counterpart picture (Figures 1 and 2b). An in-house semiautomated procedure was used to analyse the eye movement data. Eyelink software was used to detect saccades and fixations using a default velocity criterion, and in-house software was used to calculate the distribution of fixations falling into each of the interest areas. For the principal analyses, we compared manual reaction times and accuracy, the time taken to begin fixating in a given region of interest, the number of fixations it took to get there, the duration of the first fixation when it landed in the target region, and some global eye movement measures such as the mean time spent fixating in the target area. These were calculated using the

Table 2. *Baseline eye movement measures*

		Measure			
		Mean no. fixations		Mean fixation duration (ms)	
Test		M	p	M	p
WOW	TD	10.33 (1.3)		254 (37)	
	ASD	9.37 (1.3)	.145	273 (41)	.306
STD	TD	17.69 (2.8)		241 (27)	
	ASD	17.64 (2.8)	.960	261 (36)	.103

Note: TD = typically developed. ASD = autism spectrum disorder. WOW = which one's weird. STD = spot the difference. Standard deviations in parentheses.

Behavioural data
Accuracy
STD task. There was no significant main effect of picture type (normal or weird), $F(1, 25) = 0.002$, $p = .968$, $\eta_p^2 = .000$, no significant main effect of group (ASD: $M = 59\%$, $SD = 16.6$; TD: $M = 60\%$, $SD = 9.7$), $F(1, 25) = 1$, $p = .761$, $\eta_p^2 = .004$, and no interaction between picture type and group, $F(1, 25) = 1.05$, $p = .316$, $\eta_p^2 = .04$. Both groups found the task to be difficult, as indicated by the low accuracy rates, but this was not modulated by whether or not participants had ASD.

WOW task. For the WOW task, accuracy was high (98%), showing that both ASD and TD participants could successfully carry out the task and that performance, at least in terms of accuracy, was the same for both groups.

Response time (RT)
STD task. There was no significant main effect of picture pair type (normal or weird), $F(1, 25) =$ 0.081, $p = .778$, $\eta_p^2 = .003$; no significant main effect of group (ASD: $M = 8,539$ ms, $SD = 1,186$; TD: $M = 7,769$ ms, $SD = 1,088$), $F(1, 25) = 3.08$, $p = .092$, $\eta_p^2 = .110$, observed power = .393; and no interaction between picture type and group, $F(1, 25) = 0.34$, $p = .565$, $\eta_p^2 = .013$.

WOW task. RTs were significantly longer for the ASD group than for the TD group (ASD: $M = 4,310$ ms, $SD = 746$; TD: $M = 2,846$ ms, $SD = 730$), $F(1, 25) = 26.5$, $p < .001$, $\eta_p^2 = .514$, indicating that more processing time was needed for them to complete this task prior to responding.

Eye movement data
Baseline eye movement measures were calculated from all trials across the two tasks, and our analyses indicated that there were no significant between-group differences in the mean number of fixations (calculated as a proportion of the time taken to respond) and mean fixation durations for both the STD and the WOW tasks (see Table 2 for group means and alpha values). This means that any differences found in the eye movement measures reported in the next section reflects processing, rather than any basic eye movement sampling, differences between the two groups.

Elapsed time to the target region. We compared the time taken from the onset of each trial display to the start of the first fixation on the target region. This measures how long participants

spent exploring and processing other parts of the scene before attending to the task-relevant region.

STD task. For this, and all other reported analyses for the STD task, the data were collapsed over normal and weird picture pairs since there was no evidence to suggest any effect of picture pair type in the behavioural data. There was no significant main effect of group (ASD: $M = 5,343$ ms, $SD = 1,078$; TD: $M = 4,560$ ms, $SD = 1,257$), F $(1, 25) = 3.04$, $p = .094$, $\eta_p^2 = .108$, observed power $= .388$, for the time taken to begin inspecting the target region of the picture with the detail missing.

WOW task. The ASD group took longer ($M = 1,456$ ms, $SD = 419$) to begin inspection of the target region of the weird picture, $F(1, 25) = 5.05$, $p = .034$, $\eta_p^2 = .168$, than did the TD group ($M = 1,167$ ms, $SD = 207$).

Fixation count to target region. We compared the number of fixations made prior to fixating the target region. This gives an indication of any differences in the way the scenes were inspected before the target region captured the attention of the viewer.

STD task. There was no significant main effect of group (ASD: $M = 17.3$, $SD = 3.99$; TD: $M = 15.6$, $SD = 5.01$), $F(1, 25) = 1$, $p = .326$, $\eta_p^2 = .039$, in the number of fixations taken to begin inspecting the target region of the detail-absent picture.

WOW task. For the WOW task, the ASD group made more eye fixations ($M = 4.26$, $SD = 1.33$) than did the TD group ($M = 3.38$, $SD = 0.702$) before inspection of the target region of the weird picture, $F(1, 25) = 4.57$, $p < .043$, $\eta_p^2 = .154$, observed power $= .538$.

The findings so far, for the RT analyses, the elapsed time to the target region, and the number of fixations made before fixating the target region, indicate that the ASD group differed from the TD group on all these measures for the complex WOW task. For the STD task, there were no or marginal differences between the two groups. So,

although accuracy rates were equivalent across group, the ASD took longer to begin fixating the weird target region. Since ASD were slower to respond in the WOW task, we wanted to understand whether there were differences in processing when they did actually fixate the target region in the weird picture.

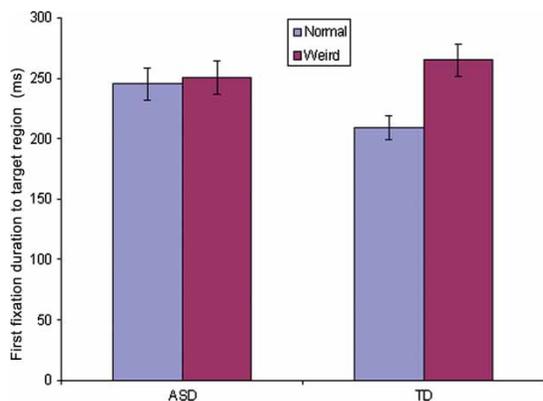**First-fixation duration (FFD) on target region**. The FFD measures whether or not there are any differences in the way the target element of the scene was processed once it was initially fixated by the viewer. For example, in our experiment, a longer first-fixation duration would indicate recognition of the item as the target.

STD task. This analysis was performed on the trials where the FFD on the target region of the picture with a detail missing was immediately preceded by a fixation to the corresponding area in the picture with the detail present. There was no significant group difference (ASD: $M = 288$ ms, $SD = 63.4$; TD: $M = 290$ ms, $SD = 78.0$), $F(1, 25) = 0.005$, $p = .947$, $\eta_p^2 = .000$. Thus, in the STD task, there was no evidence of differences between the two participant groups in the ability to immediately pick up on the missing detail.

WOW task. An analysis of the FFD in the target region revealed a subtle processing deficit for the ASD group. An interaction between picture type and group, $F(1, 25) = 5.76$, $p = .024$, $\eta_p^2 = .187$, indicated that TD participants made longer FFDs to the target region for the weird picture than for the normal picture (weird: $M = 261$ ms, $SD = 45.4$; normal: $M = 209$ ms, $SD = 36.6$), and this was absent in the ASD group (weird: $M = 251$ ms, $SD = 50.0$; normal: $M = 245$ ms, $SD = 50.5$) group (see Figure 3).

Given that the FFD is a measure of early processing (Rayner, 1998, 2009), this finding indicates that the ASD group did not immediately detect that the event or item in the target region was weird in the same way that the TD group did.

Global eye movement measures. These measures were calculated across the whole of the trial

Figure 3. *The first-fixation duration (FFD) in the target region. Error bars denote ±1 SEM. ASD = autism spectrum disorder. TD = typically developed. To view a colour version of this figure, please see the online issue of the Journal.*

period to see whether there were any group differences across the inspection duration period prior to a response being made.

Mean fixation duration in the target region. The mean fixation duration gives a measure of overall processing time. The longer the mean fixation duration was, the more processing had to be done during the task.

STD task. There was no significant main effect of picture type (detail absent or detail present), $F(1, 25) = 0.275$, $p = .605$, $\eta_p^2 = .011$; no significant main effect of group (ASD: $M = 270$ ms, $SD = 33.4$; TD: $M = 267$ ms, $SD = 55.6$), $F(1, 25) = 0.035$, $p = .852$, $\eta_p^2 = .001$; and no interaction between picture type and group, $F(1, 25) = 1.02$, $p = .323$, $\eta_p^2 = .039$.

WOW task. There was a significant main effect of picture type (normal: $M = 264$ ms, $SD = 50.7$; weird: $M = 318$ ms, $SD = 57.6$), $F(1, 25) = 19.6$, $p < .001$, $\eta_p^2 = .439$; no significant main effect of group, $F(1, 25) = 1.53$, $p = .227$, $\eta_p^2 = .058$; and no interaction between picture type and group, $F(1, 25) = 0.718$, $p = .405$, $\eta_p^2 = .028$.

Mean fixation count in the target region. The mean fixation count gives a measure that corresponds to the overall importance of the target area of interest in the scene. More fixations indicate higher importance.

STD task. There was no significant main effect of picture type (detail absent or detail present), $F(1, 25) = 2.37$, $p = .137$, $\eta_p^2 = .086$, no significant main effect of group (ASD: $M = 3.27$, $SD = 0.428$; TD: $M = 3.18$, $SD = 0.714$), $F(1, 25) = 0.175$, $p = .679$, $\eta_p^2 = .007$, and no interaction between picture type and group, $F(1, 25) = 0.057$, $p = .814$, $\eta_p^2 = .002$.

WOW task. There was a significant main effect of picture type (normal: $M = 2.82$, $SD = 0.888$; weird: $M = 3.79$, $SD = 0.977$), $F(1, 25) = 64.87$, $p < .001$, $\eta_p^2 = .722$; a significant main effect of group (ASD: $M = 3.85$, $SD = 0.500$; TD: $M = 2.72$, $SD = 0.817$), $F(1, 25) = 19.40$, $p < .001$, $\eta_p^2 = .437$; and a marginal interaction between picture type and group, $F(1, 25) = 3.42$, $p = .076$, $\eta_p^2 = .120$. This interaction indicates a difference in magnitude (ASD: normal, 3.08; weird, 4.44; TD: normal, 2.35; weird, 3.27) whereby both groups fixate more on the weird target region than on the normal corresponding region prior to making a manual response. The difference between the fixation count in the normal and weird target regions in the picture pairs was greater for the ASD group than for the TD group, and this finding supports those reported earlier, in that, compared to the TD group, the ASD group had to make reliably more fixations to the weird target area before making their decision.

Mean total time in the target region. Mean total time is again related to the significance of the area being inspected. Higher total times means that more attention to and processing of information in that region were carried out overall.

STD task. There was no significant main effect of picture type (detail absent or detail present), $F(1, 25) = 0.716$, $p = .405$, $\eta_p^2 = .028$; no significant

main effect of group (ASD: $M = 868$ ms, $SD = 93.2$; TD: $M = 807$ ms, $SD = 190$), $F(1, 25) = 1.17$, $p = .291$, $\eta_p^2 = .045$; and no interaction between picture type and group, $F(1, 25) = 0.475$, $p = .497$, $\eta_p^2 = 019$.

WOW task. There was a significant main effect of picture type (normal: $M = 748$ ms, $SD = 304$; weird: $M = 1{,}142$ ms, $SD = 338$), $F(1, 25) = .143$, $p < .001$, $\eta_p^2 = .851$; a significant main effect of group (ASD: $M = 1{,}145$ ms, $SD = 208$; TD: $M = 745$ ms, $SD = 259$), $F(1, 25) = 19.72$, $p < .001$, $\eta_p^2 = .441$; and an interaction between picture type and group, $F(1, 25) = 7.24$, $p = .013$, $\eta_p^2 = .225$, which also shows a magnitude effect (ASD: normal, 904 ms; weird, 1,387 ms; TD: normal, 592 ms; weird, 898 ms). As above, this finding reflects the greater number of fixations made by the ASD group to the weird target region prior to making their decision as to which picture was weird.

In summary, for the simple STD task, no between-group differences were found for all eye movement measures including the number of fixations made, the time taken to begin inspecting the target region where the detail was missing, and all global measures. For the WOW task, the global eye movement measures complement those reported earlier, such as RT, number of fixations made, and the time taken to begin inspecting the target region, and they provide further evidence that the reason the ASD take longer to make the decision as to which picture is "weird" is because it takes them longer to process the relevant information. This longer time to process the information is also reflected in the finding that when the ASD group initially fixate in the weird target region, unlike the TD group, they fail to immediately pick up that this is the weird item.

Because it is well known that ASD individuals often interact socially in ways that are inappropriate and/or ineffective, an obvious question following on from our findings is whether the observed effects were modulated by the social content of the picture pairs? Although our materials were not specifically set up to address this question, one metric of the degree to which a picture conveys "social" information is whether a person appears within it. We were able to divide the picture pairs from the WOW task into those that had people in them (social $n = 12$) and those that did not (nonsocial $n = 12$), and so we took this opportunity to compare the RT and the FFD measures using this very broad social categorization.

Response time (RT). A repeated measures analysis of variance (ANOVA) with social content versus no social content as a within-participants variable and group as a between-participants variable was computed for the RT measure. A main effect was observed for social content, $F(1, 25) = 18.96$, $p < .001$, $\eta_p^2 = .431$, and group, $F(1, 25) = 26.82$, $p < .001$, $\eta_p^2 = .518$. This was qualified by an interaction between social content and group, $F(1, 25) = 8.10$, $p = .009$, $\eta_p^2 = .245$.

For the TD group, social content did not modulate RT, $t(12) = -1.76$, $p = .105$, whereas, and in contrast, the ASD group took significantly longer to respond for the social ($M = 4{,}884$ ms, $SD = 1{,}125$) than for the nonsocial picture pairs ($M = 3{,}751$ ms, $SD = 624$), $t(13) = -4.12$, $p = .001$ (see Figure 4a).

First-fixation duration (FFD) on target region. A repeated measures ANOVA with social content versus no social content and normal versus weird as within-participants variables and group as a between-participants variable was computed for the FFD measure. There was no main effect for social content, $F < 1$. There was a main effect of picture type, $F(1, 25) = 8.51$, $p = .007$, $\eta_p^2 = .254$, and no main effect of group, $F < 1$. Importantly, there was a three-way interaction between social content, picture type, and group, $F(1, 25) = 6.02$, $p = .021$, $\eta_p^2 = .194$.

In the FFD analyses, the TD group showed the same immediate "pick up" effect regardless of the content of the picture pairs—nonsocial, $t(12) = -3.46$, $p = .005$ (normal $M = 200$ ms, $SD = 32.2$; weird $M = 253$ ms, $SD = 50.2$); social, $t(12) = -2.73$, $p = .018$ (normal $M = 212$ ms, $SD = 38.7$; weird $M = 262$ ms, $SD = 54.2$)—whereas the ASD group did not. The ASD group showed a longer FFD to the normal target region ($M =$
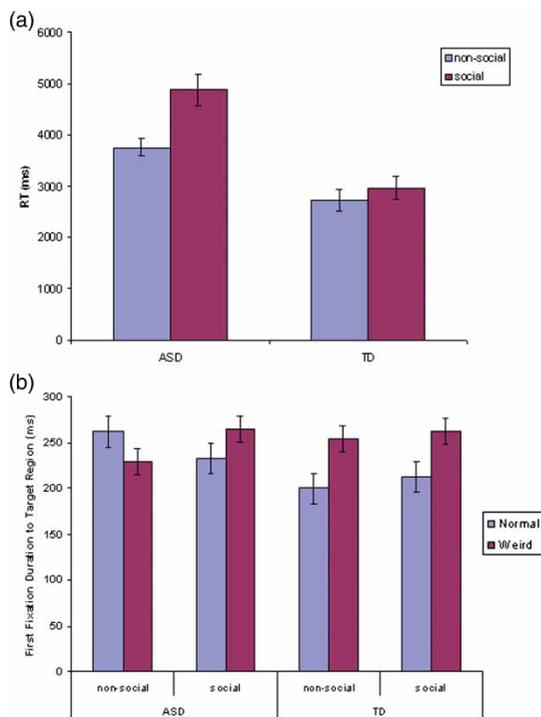
Figure 4. *(a) The mean response time (RT) for autism spectrum disorder (ASD; left) and typically developed (TD; right) participants, for the picture pairs divided into those with social content (dark bars or red online) and those with no social content (light bars or blue online). (b) The mean first-fixation duration (FFD) to the target region for ASD (left) and TD (right) participants, for the picture pairs divided into those with social content and those with no social content for the normal pictures (light bars or blue online) and the weird pictures (dark bars or red online). To view a colour version of this figure, please see the online issue of the Journal.*

262 ms, $SD = 80.5$) than to the weird target region ($M = 229$ ms, $SD = 58.1$) for the picture pairs with no social content, $t(13) = 2.48$, $p = .027$, and for those with social content there was no (or a marginal) difference between the normal ($M = 232$ ms, $SD = 44.9$) and weird ($M = 265$, $SD = 66.4$) picture, $t(13) = -1.95$, $p = .07$. This interaction is presented in Figure 4b.

We speculate that any modulation of social content could stem from the possibility that, to decode social information, more complex cognitive judgements are involved. This, though, remains to be tested empirically in a future study, as the social content of our stimuli and their complexity were

not systematically manipulated a priori in the present study. However, it is known that individuals with ASD have difficulties with various social cognitive tasks, such as judging the sincerity of smiles (Boraston, Corden, Miles, Skuse, & Blakemore, 2008) and understanding other people's preferences through nonverbal cues (David et al., 2010).

Discussion

The aim of this investigation was to compare behavioural and eye movement measures between ASD and TD participants for a simple versus a complex processing task using the same materials. Our findings revealed roughly equivalent performance (and no significant differences) in all measures between the two groups for our simple STD task. We deliberately made the missing details hard to spot in the STD task to allow us to test for any perceptual processing advantage (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Keehn et al., 2009) and for biased attention to detail in the ASD group (Frith & Happe, 1994), but no evidence was found to support either of these. As cognitive abilities increase, so perceptual processing advantages decrease (Minshew et al., 2009); hence this could explain why no perceptual processing advantage was observed in our STD task for our ASD sample. As predicted, and for all eye movement measures, we found no evidence of processing differences between our two sample groups for the simple information-processing STD task.

We did observe processing differences between ASD and TD participants for a task where they had to decide which one of a pair of pictures was "weird" (Rayner et al., 2009). Although accuracy rates were equivalent and almost at ceiling for both groups, the ASD group took longer to respond, and this was reflected in the eye movement data, where they took more time scanning the scenes prior to fixating the target region. This slower processing of the information for the complex task fits with Minshew and Goldstein's (1998) model of ASD as one of complex processing deficits: "where impairments in ASD are observed, relative to age

and IQ when either integration of multiple features, speed of processing, processing of large amounts of information, or processing novel material is required" (Minshew et al. (2009), pp. 383), as in our WOW task reported here.

Of particular significance was the finding that when the weird target region was first fixated, the duration of that first fixation was greater for the weird target region than for the counterpart normal picture target region exclusively for the TD participants. In other words, the ASD group did not immediately pick up on the weird target item when they first looked at it. This finding in itself may have significance for problems experienced in social interactions in this high-functioning population. Our post hoc analyses of social versus nonsocial picture pairs revealed that the TD group showed the same fast "pick up" of the weird target item, regardless of social content, whereas the ASD group were slower to respond in the social content condition, and they did not show the expected pattern for the FFD analyses. However, a cautionary approach needs to be adopted when interpreting these post hoc analyses, and it remains an empirical question as to whether any failure to be able to quickly and accurately spot subtle social cues in ASD results in an inability to react or respond appropriately to such cues.

Further support for our finding of impaired complex information processing with intact simple information processing in ASD comes from a sequence analysis performed on the eye movement data from the experiment reported in this paper (Au-Yeung, Benson, Castelhano, & Rayner, 2011). The sequence analysis technique as devised by Cristino, Mathôt, Theeuwes, and Gilchrist (2010) gives a numerical index of how similar two sequences of eye movements are. These analyses revealed that the eye movement sequence over the whole trial period significantly differed between ASD and TD individuals for the complex WOW task but not the simple STD task.

In conclusion, our findings show performance deficits on several measures for a complex, but not a simple, information-processing task in ASD when viewing the same materials. We believe these data to be important to the understanding of how cognitive processing is reflected in oculomotor control measures in ASD. The eye movement data also revealed a subtle processing difference between the two groups—namely, that there was no immediate "which one's weird" (WOW) effect in ASD. Future work will examine whether our findings reported here are systematically modulated by social content of the materials.

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