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Gaze patterns during scene processing in typical adults and adults with autism spectrum disorders

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ABSTRACT

Background: Little is known about how adults with autism spectrum disorder (ASD) process dynamic social scenes.
Method: We studied gaze behavior in 16 adults with ASD without intellectual impairment and 16 sex- and age-matched controls during passive scene processing.
Results: Adding more characters to a scene resulted in a drop in time spent looking at *faces*, and an increase in time spent looking at *bodies* (static trials) or *off-person* (dynamic trials) [Scene Type × AOI × Mode: $F(2, 60) = 3.54$, $p = .04$, $\eta^2_p = .11$]. Unlike controls, adults with ASD showed only a small drop in the number of fixations made [Mode × Group: $F(1, 30) = 11.30$, $p = .002$, $\eta^2_p = .27$] and no increase in the duration of face fixations [Mode × AOI × Group: $F(2, 60) = 3.50$, $p = .04$, $\eta^2_p = .11$] when dynamic cues were added. Thus, particularly during dynamic trials, adults with ASD spent less time looking at faces and slightly more time looking off-person than did controls [Mode × AOI × Group: $F(2, 60) = 3.10$ $p = .05$, $\eta^2_p = .09$]. Exhibiting more autistic traits and being less empathic were both associated with spending less time fixating on faces [$.34 < |r| < .55$, $p < .05$].
Conclusions: These results suggest that adults with ASD may be less sensitive to, or have more difficulty processing, dynamic cues—particularly those conveyed in faces. The findings demonstrate the importance of using dynamic displays in studies involving this clinical population.

1. Introduction

Autism spectrum disorder (ASD) is a condition characterized by deficits in social communication and interaction, and by restricted and repetitive interests or behaviors (American Psychiatric Association, 2013). Some of the social difficulties experienced by people with ASD have been suggested to arise, in part, from deficits in face processing (e.g., Baron-Cohen, 1995; Remington, Campbell, & Swettenham, 2011; Senju, 2013). It is important to note, however, that most of the existing research exploring face processing – both in typical viewers (see O'Toole, Roark, & Abdi, 2002 for a review) and in viewers on the autism spectrum (e.g., Riby, Doherty-Sneddon, & Bruce, 2009) – has involved the use of static stimuli. In order to gain an accurate picture of the factors that contribute to social deficits in ASD, it is essential to extend this work with studies that incorporate naturalistic facial stimuli, particularly in light of recent behavioral evidence suggesting that people process

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moving and static faces differently (e.g., Chiller-Glaus, Schwaninger, Hofer, Kleiner, & Knappmeyer, 2011; Hill and Johnston, 2001; Pilz, Thornton, & Bülthoff, 2006; Stoesz & Jakobson, 2013, 2014).

In recent years, researchers have used eye-tracking technology to explore differences in how viewers attend to faces presented in static and dynamic scenes. The results of these studies have generally suggested that typical individuals are biased to attend to *faces* rather than to other aspects of static displays (e.g., Remington et al., 2011), but that adding motion (e.g., O'Toole et al., 2011) or adding more characters to a scene (Stoesz and Jakobson, 2014) causes them to shift their attention from faces to bodies, or off-screen. Stoesz and Jakobson (2014) showed that the effect of the latter manipulation was more dramatic in children than in adults. They also showed that children made fewer fixations on dynamic faces than adults did, and showed a larger increase in mean fixation duration after the addition of dynamic cues. This is of interest as adjustments such as these can reflect more effortful processing (Holmqvist et al., 2011). Together, these observations are consistent with the idea that children generally find the processing of faces in dynamic and/or socially complex scenes more challenging than adults do.

Several recent observations suggest that adding naturalistic facial motion and increasing the social complexity of scenes affects the gaze behaviors of children with ASD even *more* than the gaze behaviors of typical children. For example, Riby and Hancock (2009) observed that children with ASD spent more time than controls looking at backgrounds than at faces when viewing dynamic human action sequences, but not when viewing cartoon pictures. These authors concluded that group differences in gaze behaviors are most apparent in realistic viewing conditions, and that the increased complexity of dynamic displays functions to either distract or overload attention in individuals with ASD. Rice, Moriuchi, Jones, and Klin (2012) found that, compared to typical controls, children with ASD spent more time looking at bodies and inanimate objects, and made fewer fixations on faces, when they were viewing dynamic social scenes passively. Others have reported that children with ASD spend less time fixating on the eyes and more time fixating on bodies than controls when viewing dynamic multiple-character scenes, but not when viewing static single-character scenes (Speer, Cook, McMahon, & Clark, 2007).

The first purpose of the present study was to determine if some of the findings reported above could be replicated in adults with ASD. To that end, we tracked the eye movements of adults with ASD and of typical controls as they passively viewed static and dynamic, single- and multiple-character scenes. We expected that introducing movement and additional characters to a scene would affect the gaze behaviors of both groups, but that adults with ASD might show a pattern of gaze behaviors similar to that described in children with this disorder. Specifically, we hypothesized that viewers with ASD would spend less time looking at faces and more time fixating on bodies than controls, particularly when viewing dynamic multiple-character scenes. This pattern of results would support the view that problems in attending to salient social cues persist into adulthood in people with ASD. We extended earlier work by determining whether such group differences, if present, reflected changes in the number and/or the duration of fixations made on faces, which would allow us to characterize changes in gaze behavior more fully.

ASD is a spectrum disorder. If problems with social perception (including those affecting attention to facial cues) contribute to symptom severity, these problems may be most evident in those who display the largest number of autistic traits. In support of this hypothesis, Ingersoll (2010) showed that, in a large sample of university students, participants who endorsed more autistic traits made more errors on a face recognition task. Another study examining autistic characteristics in the general population found that traits associated with the broad autism phenotype were related to impairment in social cognition (Sasson, Nowlin, & Pinkham, 2012). Given these findings, the second major goal of the present study was to assess the strength of associations between attentiveness to faces during passive scene perception and the autistic traits of participants in our full sample.

Finally, we wanted to study the relationship between attentiveness to faces and self-reported levels of empathy. The link between social perception and empathy is interesting, given that people with ASD exhibit difficulties with cognitive empathy (the ability to take another's perspective or understand the reasons for their behavior) (Dziobek et al., 2008; Lockwood, Bird, Bridge, & Viding, 2013) [note that results for affective empathy, the ability to feel another's emotions, are more mixed (Dziobek et al., 2008; Mazza et al., 2014)]. Recently, it has been reported that individual differences in face-specific event-related potentials are related to both the number of autistic features and the level of empathy that typical viewers display (Lazar, Evans, Myers, Moreno-De Luca, & Moore, 2014). Moreover, empathizing with emotive faces by appraising the emotions expressed activates social networks in the brain (Schülte-Ruther, Markowitsch, Fink, & Piefke, 2007). In typical viewers, there is also a relationship between empathy and the ability to detect faces quickly, and those who exhibit higher affective empathy make more and longer fixations in particular areas of static faces, depending on the emotion displayed (Balconi and Canavesio, 2014). In the present investigation, we anticipated that viewers who self-reported higher levels of empathy would also be more attentive to faces during passive scene processing.

2. Methods

2.1. Participants

We tested 16 adults with ASD (11 men, 5 women), all of whom had received a formal diagnosis of ASD or Asperger's disorder from a physician, psychologist, or psychiatrist, which was validated prior to participation by a qualified, independent practitioner. Each individual with ASD was matched to a typical participant of the same sex and age (±2 years).

All participants scored in the normal or above-normal range in intelligence as measured by the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The WASI is internally consistent [α = .98 for Full-Scale IQ (FSIQ) for average adults], and shows excellent test-retest reliability (r = .92 for adult FSIQ). Verbal IQ (VIQ), Performance IQ (PIQ), and FSIQ scores from the WASI are correlated with corresponding scores obtained using the Wechsler Adult Intelligence Scale-III (WAIS-III; Wechsler, 1997) (r = .88, .84, and .92, respectively) (see Wechsler, 1999). In the present sample, the groups were well matched in terms of VIQ, but the typical group scored slightly higher than the ASD sample in terms of estimated FSIQ (see Table 1). Despite this, the mean difference in FSIQ scores between members of a given pair of participants was only 7.1 points. All participants had normal or corrected-to-normal vision. Typical participants had normal developmental histories.

2.2. Materials

2.2.1. Autism spectrum quotient (AQ)

The AQ was used to quantify behavioral traits characteristic of individuals on the autism spectrum (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001); it can reliably estimate variation in autistic symptomology in the general population (i.e., in typical samples that may include adults falling within the broad autism phenotype) (Broadbent, Galic, & Stokes, 2013). The AQ self-report measure assesses behaviors in five core domains; each domain is assessed using 10 items: (1) social skills, (2) communication skills, (3) imagination, (4) attention to detail, and (5) attention switching/tolerance of change. Participants answer each item on a 4-point scale ranging from “definitely agree” to “definitely disagree,” and points are awarded for responses indicative of atypical behavior. AQ total scores can range from 0 to 50; higher scores are indicative of greater symptom severity.

2.2.2. Empathy quotient (EQ)

Participants completed the EQ, a 40-item self-report measure designed to assess individual differences in empathy in adults of normal intelligence (Baron-Cohen and Wheelwright, 2004). EQ scores can range from 0 to 80; low scores are indicative of weaker empathizing skills. The authors of the EQ do not differentiate between cognitive and affective forms of empathy, but other researchers have reported that the EQ items primarily tap into cognitive empathy, emotional reactivity, and social skills (Lawrence, Shaw, Baker, Baron-Cohen, & David, 2004; Muncer and Ling, 2006).

2.2.3. Eye-tracking experiment

Stimuli for this task included 12 four-second movie clips and 12 still-frame images from several episodes of the *Andy Griffith Show*, a television series that aired on CBS from 1960 to 1968 (for a detailed description of the stimuli, see Stoesz and Jakobson, 2014). No soundtrack was presented. Half of the scenes involved a single character and half involved two or three characters. Therefore, there were four conditions for this task: single-character/static, single-character/dynamic, multiple-character/static, and multiple-character/dynamic. Each clip depicted the face and body of one or more characters, and other objects. Display size was standardized at 640 pixels (23.8° of visual angle) wide and 480 pixels (18.0° of visual angle) high. Photographs had a resolution of 72 pixels per inch and the videos were presented at 29 frames per second.

The scenes chosen depicted naturalistic situations that were relatively neutral in emotional valence, but which still conveyed important information that (*if attended to*) could be extracted through the application of higher-order perceptual and cognitive processes (e.g., nonverbal linguistic and/or paralinguistic information conveyed through facial movement and gesture, and information about the very fact that the interactions were *not* emotionally charged). In short, they depicted situations like those we experience every day, namely conversations between a person and one or more (on- or off-screen) characters.

Stimuli were presented on a Tobii 1750 non-invasive, binocular corneal-reflection eye-tracker (0.5° precision, 17 in., 50 Hz sample rate, 1280 × 1024 pixels resolution; Tobii Technology Inc., Fall Church, VA). Participants' heads were unrestrained because this eye-tracking system compensates for large and rapid head movements. Tobii Studio 1.2 Enterprise experimental software controlled the stimulus presentation and recorded the eye-movements.

Table 1
Age, estimated IQ, and autistic symptomology.

	Adults with ASD (n = 16)		Typical adults (n = 16)		$F(1, 30)$	p	η^2_p
	M	SD	M	SD			
Age (years)	27.8	7.8	27.3	7.5	.03	.86	.001
WASI							
Verbal IQ	107.8	13.9	110.7	9.5	.48	.49	.02
Performance IQ	103.9	15.7	113.3	11.4	3.70	.06	.11
Full-scale IQ	106.3	10.8	113.4	8.7	4.16	.05	.12
AQ total score	28.9	8.4	15.3	7.6	21.91	<.001	.42
EQ total score	27.1	11.4	47.0	11.9	23.41	<.001	.44

AQ = autism quotient; ASD = autism spectrum disorder; EQ = empathy quotient; WASI = Wechsler Abbreviated Scale of Intelligence.

2.3. Procedures

The Psychology/Sociology Research Ethics Board at the University of Manitoba approved the testing protocol. All participants provided written informed consent prior to taking part in the study. We tested participants individually in a quiet room. Participants completed a demographic questionnaire, the WASI, the AQ, and the EQ (randomly ordered) before completing the eye-tracking experiment. During the eye-tracking experiment, participants sat approximately 57 cm from the screen.

Before starting the experiment, participants completed a nine-point calibration trial in which they tracked a white dot on a black background as its size changed and it moved to various locations on the screen. Immediately following the calibration trial, the Tobii Studio 1.2 software provided the examiner with feedback regarding calibration quality. If the eye-tracker could not detect the participant's eye movements accurately, the calibration trial was repeated. After a successful calibration, the participant proceeded to view the series of 24 experimental trials, presented in random order. Each trial consisted of a 2-s central white fixation point presented on a black background, followed by the presentation of a 4-s scene, which participants were instructed to view passively (see Fig. 1). The experiment took about 2.4 min to complete.

2.4. Analysis of eye-tracking data

We examined participants' gaze behaviors within three non-overlapping areas of interest (AOIs) – the face (or faces), body (or bodies), and off-person – for all scenes. Because the characters did not move across the screen during dynamic scenes, the location of each AOI remained relatively constant, making a complete frame-by-frame analysis unnecessary. Due to differences in camera viewing angles, however, individual face and body AOIs were smaller, and off-person AOIs were larger, in multiple- than in single-character scenes. However, because we were not interested in examining attention to each individual depicted in a scene, we calculated the combined area (expressed as a percentage of the total display area) of all face AOIs and of all body AOIs in multiple-character scenes, and compared these to the size of face and body AOIs in single-character scenes using a 2 (Scene Type: single-character or multiple-character) × 2 (Mode: static, dynamic) × 3 (AOI: faces, bodies, off-person) Analysis of Variance (ANOVA). The sizes of particular AOIs were comparable across static and dynamic conditions ($p > .29$ for the main effect and all interactions involving Mode). Not surprisingly, the (combined) face AOI was consistently smaller than the (combined) body AOI, which was smaller than the off-person areas of the display [$F(2,10) = 199.5$, $p < .001$, $\eta^2 = .978$], with faces occupying 4.1%, bodies 23.7%, and off-person regions 72.2% of the total viewing area, overall. However, there was a significant Scene Type × AOI interaction [$F(1,5) = 8.29$, $p = .008$, $\eta^2 = .624$]. Follow-up tests on this interaction confirmed that the (combined) face AOIs in multiple-and single-character scenes were comparable in size ($p = .19$), but that the (*combined)* body AOIs were larger, and the off-person AOIs were correspondingly smaller, in multiple- than in single-character scenes ($p \leq .02$ for each comparison).

We used the default settings of the Tobii Fixation filter (i.e., distance threshold equal to 35 pixels; Tobii Studio 1.2 User Manual. Version 1.0., 2008) to extract two measures of gaze behavior (see below). This standard fixation filter does not set upper and lower boundaries for fixation durations; rather, it interpolates across short segments (<100 ms) of missing data (caused by blinks, for example), and uses velocity thresholding to determine when a fixation has occurred. Previous research examining this standard fixation filter suggests that data quality from adult viewers is relatively high (Wass, Smith, &

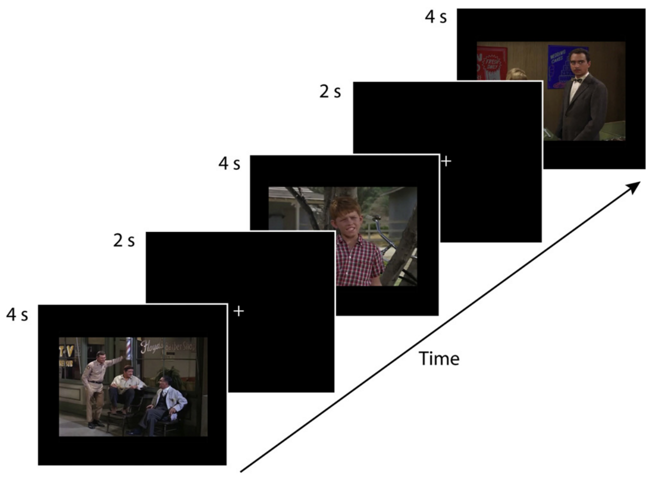

Fig. 1. Participants viewed pictures and movies on a screen passively while their gaze was tracked. The stimuli displayed a single character or multiple characters interacting. There were six trials for each of the four conditions. Each trial began with a white fixation point on a black background, followed by the presentation of a stimulus for four seconds. This figure depicts three static trials and is reproduced with permission from Stoesz and Jakobson (2014).

Johnson, 2013). Overall, the average duration of a single fixation ranged from 200–720 ms in the static condition, and from 220–750 ms in the dynamic condition.

We extracted both the *total duration of all fixations* within a given AOI (in seconds) and the *number of individual fixations* made within that AOI, for each trial. We then computed the *average duration of an individual fixation* within each AOI on a given trial by dividing the total duration of all fixations by the number of fixations. Finally, we found the mean value (per trial) for each variable, in each of the four experimental conditions. We used these mean values, which were normally distributed, in subsequent analyses.

2.5. Statistical design and preliminary analyses

We analyzed the data using SPSS 22 (SPSS Inc., Chicago, IL, USA). Data for each of the three dependent variables were submitted to a separate 2 (Group: Typical, ASD) × 2 (Scene Type) × 2 (Mode) × 3 (AOI) ANOVA, with repeated measures on the last three factors. We used Levene's test of equality of variances for all comparisons; within-group effects were evaluated with Greenhouse-Geisser corrections where violations of sphericity were found. Fisher's LSD tests were used for follow-up multiple comparisons tests on significant interactions. Before running the ANOVAs, we confirmed that estimated FSIQ scores were not strongly correlated with any of the eye-tracking variables in the full sample ($-.19 < r < .24$, $p > .19$), or in either group (Typical adults: $-.21 < r < .34$, $p > .21$; adults with ASD: $-.36 < r < .43$, $p > .10$). This step provided some assurance that any individual differences in intellectual ability were not making a large contribution to observed group differences in the experimental effects.

We also computed the average "on-screen" gaze time per trial by summing the total duration of fixations in face, body and off-person AOIs per trial (note that this does not include time spent making saccades). This variable was entered into a 2 (Group) × 2 (Scene Type) × 2 (Mode) ANOVA. There was no main effect of Group, and there were no significant interactions involving Group [$F(1, 30) < 2.1$, $p > .15$]. Similarly, the total "on-screen" gaze time across all 24 trials that comprised the experiment did not differ between the two groups [$M_{ASD} = 81.2$ s (SD 3.3) vs. $M_{Control} = 81.5$ s (SD = 1.9), $F(1, 32) = .103$, $p = .751$, $\eta_p^2 = .003$], and accounted for 84.6–84.9% of the total valid viewing time. These results provide some assurance that both groups were equally engaged in the task.

3. Results

3.1. Mean total fixation duration per trial

Although face AOIs were smaller than other AOIs (see Section 2.4), they demanded most of our viewers' attention. Thus, participants spent more time looking at faces and less time looking at bodies than looking off-person [main effect of AOI: $F(2, 60) = 17.66$, $p < .001$, $\eta^2_p = .37$], overall. We also observed significant main effects of Mode and Scene Type [$F(1, 30) \geq 41.32$, $p < .001$, $\eta^2_p \geq .58$] and significant two-way [$F(1, 30) \geq 8.24$, $p \leq .001$, $\eta^2_p \geq .22$] and three-way [$F(2, 60) = 3.54$, $p = .04$, $\eta^2_p = .11$] interactions involving all combinations of AOI, Mode, and Scene Type. Follow-up tests performed on the three way interaction (depicted in Fig. 2) showed that the main effect of AOI held in each of the four conditions [$F(2, 62) \geq 4.66$, $p \leq .01$, $\eta^2_p \geq .13$]. Additional contrasts confirmed that adding more characters to a scene led to a drop in the time viewers spent looking at both moving and static *faces* [$t(31) > 2.56$, $p \leq .02$, $d' \geq .50$]. This drop was associated with a significant increase in time spent looking at *bodies* during static trials [$t(31) = 3.80$, $p = .001$, $d' = .84$], and with a significant increase in time spent looking *off-person* during dynamic trials [$t(31) = 6.05$, $p < .001$, $d' = .73$].

Although the general pattern of responses described above is interesting, significant differences in how participants with and without ASD viewed the scenes were also evident (see Fig. 3). Follow-up tests on the significant AOI × Group interaction [$F(2, 60) = 4.06$, $p = .02$, $\eta^2_p = .12$] revealed that, compared to typical controls, individuals with ASD spent less time looking at faces [$t(30) = 2.27$, $p = .03$, $d' = .82$] and showed a trend to spend more time looking off-person [$t(30) = 1.99$, $p = .06$, $d' = .70$] than did typical controls. The latter effect was most apparent during viewing of dynamic scenes [AOI × Group × Mode: $F(2, 60) = 3.10$ $p = .05$, $\eta^2_p = .09$]. Taken together, these results are consistent with the view that face processing poses a particular challenge for those on the autism spectrum (leading them to "disengage" from faces), and/or that their attention is not as strongly drawn to faces as is typically the case.

In order to gain more insight into how these changes in total fixation duration came about, we undertook a more detailed examination of viewers' fixation behaviors. Specifically, in Sections 3.2 and 3.3 (respectively) we document changes in the average number and duration of individual fixations made per trial in response to our experimental manipulations.

3.2. Mean number of fixations per trial

When examining the number of fixations participants made per trial, we observed significant main effects of Scene Type and AOI [$F \geq 6.62$, $p \leq .004$, $\eta^2_p \geq .18$], and a significant Scene Type x AOI interaction [$F(1, 30) = 7.78$, $p = .002$, $\eta^2_p = .21$]. Adding more characters had little effect on the number of fixations viewers made in face AOIs, but resulted in increases in the number of fixations made on bodies and off-person (see Fig. 4; $p \leq .02$ for all contrasts).

Post-hoc tests performed on the Mode × AOI interaction [$F(2, 60) = 11.25$, $p < .001$, $\eta^2_p = .27$] showed that adding motion cues led to a small (but significant) drop in the number of fixations made on faces and bodies, but to a dramatic drop in the

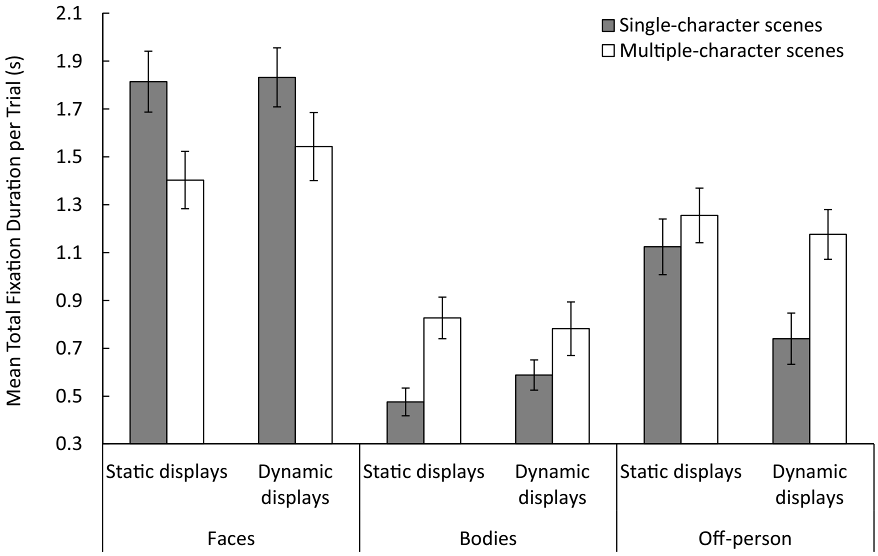

Fig. 2. The mean total fixation duration per trial (in seconds) for each area of interest (AOI: faces, bodies, off-person) in each condition. Adding characters led to a drop in the time viewers spent looking at (static or dynamic) faces, and to corresponding increases in time spent looking at bodies (static displays) or off-person (dynamic displays). All contrasts noted were significant ($p \leq .02$).

number of off-person fixations (see Fig. 5; $p \leq .03$ for all contrasts). Interestingly, we also observed a significant Mode × Group interaction [$F(1, 30) = 11.30$, $p = .002$, $\eta^2_p = .27$; see Fig. 6]. Post hoc tests on this interaction revealed that, while both groups made fewer fixations when viewing dynamic than static scenes, this effect was smaller in the ASD group ($p \leq .002$ for all contrasts)—as one might expect if the clinical group was less sensitive to information conveyed by dynamic cues.

3.3. Mean duration of individual fixations per trial

In the analysis of these data, we observed significant main effects of AOI and Scene type [$F(1, 30) \geq 38.36$, $p < .001$, $\eta^2_p \geq .56$] and a significant AOI × Scene Type interaction [$F(2, 60) = 26.23$, $p < .001$, $\eta^2_p = .47$; see Fig. 7]. Post-hoc tests showed that, although adding more characters to a scene had little effect on the *number* of face fixations that viewers made (see Section 3.2), it resulted in a dramatic drop in the mean *duration* of face fixations [$t(31) = 6.50$, $p < .001$, $d' = .11$], without affecting the mean duration of fixations made on bodies or in off-person areas [$t(31) < 1.10$, $p > .20$].

Overall, the average duration of a single fixation was longer when participants viewed dynamic compared to static displays [$F(1, 30) = 14.26$, $p = .001$, $\eta^2_p = .32$], but this effect interacted with both AOI and Group [Mode × AOI: $F(2, 60) = 3.66$,

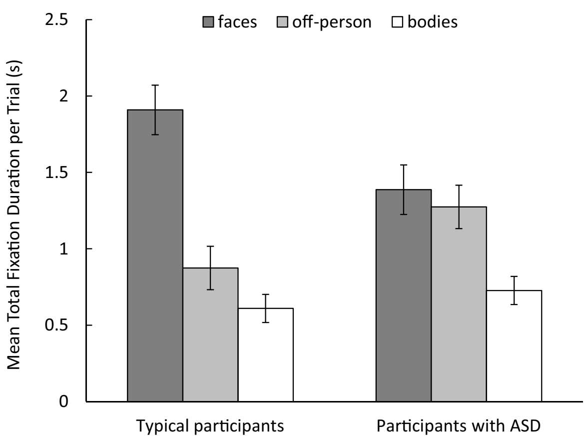

Fig. 3. Group differences in mean total fixation duration per trial (in seconds) in each area of interest (AOI: faces, bodies, off-person). Although the main effect of AOI was significant in each group, the key finding was that typical participants spent more time looking at faces than did participants with autism spectrum disorder (ASD).

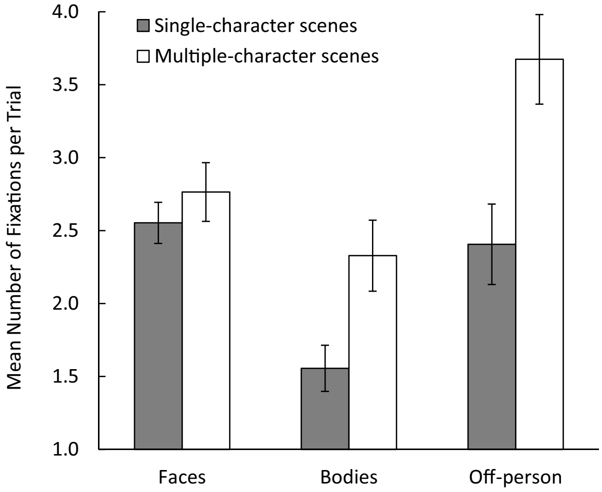

Fig. 4. The mean number of fixations per trial in each area of interest (AOI: faces, bodies, off-person) while participants viewed single- and multiple-character scenes. Adding characters resulted in more fixations being made in off-person and body AOIs [$t(31) \geq 2.40$, $p \leq .02$, $d' \geq .33$], but not in face AOIs.

$p = .03$, $\eta^2_p = .11$; Mode × AOI × Group: $F(2, 60) = 3.50$, $p = .04$, $\eta^2_p = .11$]. Follow-up tests performed on the three-way interaction (depicted in Fig. 8) confirmed that group differences were most apparent in face AOIs. Here, typical participants responded to the addition of motion cues by increasing the average duration of their face fixations [$t(15) = 3.09$, $p = .008$, $d' = .45$], whereas participants with ASD did not [$t(15) = .55$, $p = .59$].

3.4. Relationships between gaze behaviors in face AOIs and autistic symptomology

As expected, the ASD group endorsed more autistic traits and fewer signs of empathy than the typical group (see Table 1) and scores on the AQ and the EQ were strongly negatively correlated with one another in the full sample [$r(30) = -.83$, $p < .001$]. As the number of autistic traits viewers endorsed on the AQ increased, there were corresponding reductions in the mean time spent looking at faces (in all conditions), and in the mean number and duration of individual face fixations made while participants viewed multiple-character scenes (whether static or dynamic) [$-.54 < r(30) < -.35$, $p < .05$ in all cases]. Similarly, viewers who endorsed fewer signs of empathy on the EQ spent less time looking at faces (in all conditions), produced fewer face fixations while viewing dynamic multiple-character scenes, and produced shorter face fixations while viewing single-character dynamic displays [$.34 < r(30) < .46$, $p < .05$ in all cases]. Illustrative scatterplots showing the

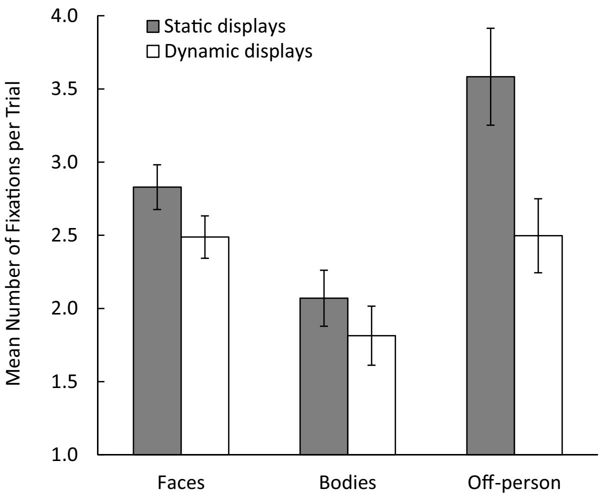

Fig. 5. The mean number of fixations per trial for each area of interest (AOI: faces, bodies, off-person) while participants viewed static and dynamic displays. Introducing motion led to a drop in the total number of fixations in all AOIs ($p < .03$ for all three comparisons), but size of this drop was largest in off-person areas ($p = .001$).

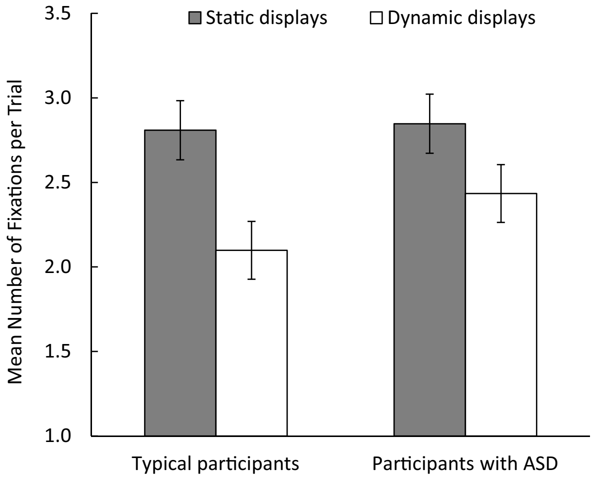

Fig. 6. The mean number of fixations per trial made by each group during the viewing of static and dynamic displays. Both groups made fewer fixations on dynamic than static scenes, but this effect was smaller in the ASD group ($p \leq .002$, for all contrasts).

relationships between measures of autistic symptomology and gaze behaviors within face AOIs as participants viewed dynamic, multiple-character scenes are provided in Fig. 9.

4. Discussion

This study was designed to extend research exploring how typical adults and adults with ASD without accompanying intellectual impairment attend to faces by comparing their gaze behaviors as they viewed various types of scenes passively. As expected based on past research (Boraston and Blakemore, 2007; Campatelli, Federico, Apicella, Sicca, & Muratori, 2013; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Riby and Hancock, 2009; Senju, 2013; Spezio, Adolphs, Hurley, & Piven, 2007), adults with ASD spent less time fixating on faces than did typical participants, overall. But we had expected that gaze behaviors exhibited by the ASD group would not only differ from those of typical adults (Stoesz and Jakobson, 2014) but also, perhaps, that they would resemble those of children with ASD—who are more likely than age-matched controls to shift their

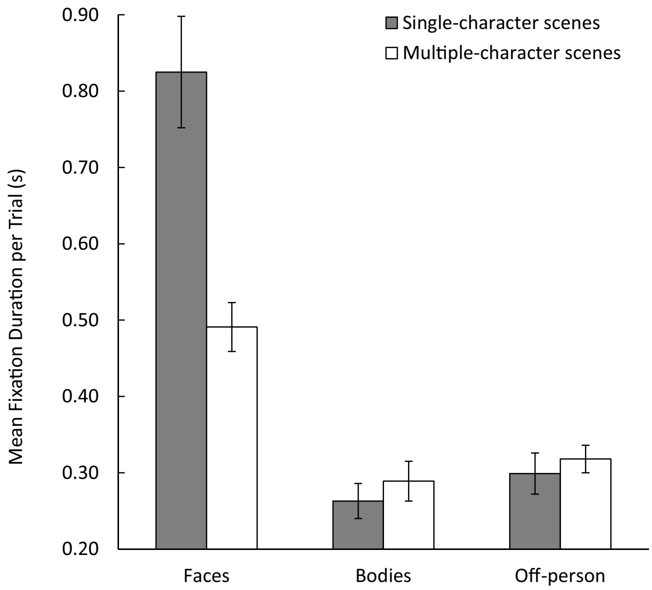

Fig. 7. The average fixation duration per trial (in seconds) for each area of interest (AOI: faces, bodies, off-person) while participants viewed single- and multiple-character scenes.

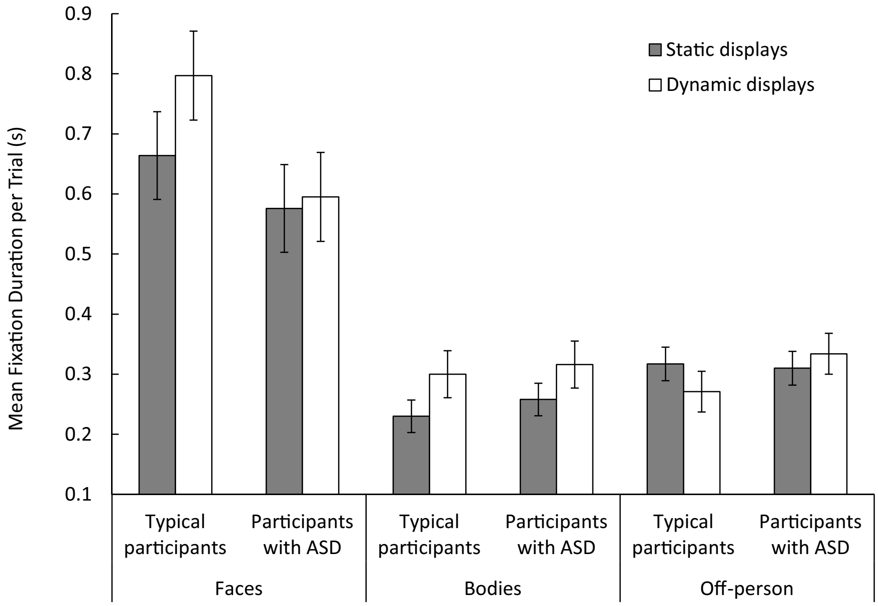

Fig. 8. The mean fixation duration per trial (in seconds) for each area of interest (AOI: faces, bodies, off-person) while typical participants and participants with ASD viewed static and dynamic displays.

gaze off faces and onto bodies, objects, or backgrounds when viewing dynamic social scenes (Riby and Hancock, 2009; Rice et al., 2012; Speer et al., 2007). Such a result would support the view that unusual gaze behaviors remain a feature of ASD into adulthood. This hypothesis was largely confirmed; thus, we found that, *particularly during dynamic trials*, adults with ASD spent less time looking at faces and slightly more time looking off-person than controls did. Unlike in Speer et al. (2007), however, in the present study this effect was not more pronounced during viewing of multiple-character (compared to single-character) scenes. Our results complement recent findings from Chevallier et al. (2015), who found that differences in visual attention to faces between adults with ASD and typical controls are more evident during viewing of naturalistic, dynamic scenes than during viewing of arrays depicting isolated people and objects (moving or stationary).

Adding characters to a scene led viewers in both groups to shift their attention from *faces* to *bodies* (during static trials) or to *off-person* regions (during dynamic trials). This was achieved by reducing the average *duration* (but not the number) of face fixations, and by increasing the *number* (but not the duration) of fixations made on bodies or off-person regions. It is possible that the effect seen during static scene viewing was simply due to the fact that body AOIs were larger in multiple- than in single-character scenes (see Section 2.4), making them more salient. However, this difference in relative size also held during dynamic trials, and here attention was drawn from faces to off-person regions, which occupied a *smaller* area in multiple- than in single-character scenes. We suggest that viewers shifted their attention from faces to bodies in static displays because they found it challenging to process multiple (static) faces, and that they shifted to off-person regions when movement was introduced because they found it challenging to process animate activity (i.e., movements of faces and bodies) when more than one person was present in a scene. It will be important to continue exploring how our attention to bodies changes with varying task demands in future work, given that bodies (particularly those in motion) communicate important social information (O'Toole et al., 2011).

Compared to typical adults, viewers with ASD showed only a small drop in face fixation *number* and no corresponding increase in face fixation *duration* when dynamic cues were added. If we accept that making fewer but longer fixations is a behavioral response that allows typical viewers to deal with increased processing demands (Holmqvist et al., 2011), these observations are consistent with the view that adults with ASD have reduced sensitivity to, or a reduced ability to process, facial motion, compared to their peers. Support for this interpretation comes from the observation that, unlike controls, they find it harder to judge sad expressions that are depicted in dynamic than in static displays (Enticott et al., 2014). This may be related to the finding that people with ASD do not change the way they scan faces when dynamic cues are introduced, whereas typical controls do (Horlin et al., 2013). Problems processing moving faces may also be related to atypical activation in the right fusiform gyrus (including the fusiform face area), which occurs when adults with ASD view dynamic social stimuli, but not static images (Weisberg et al., 2014).

Further support for the idea that facial movement may overload the attentional/processing capacity of people with ASD comes from studies examining gaze behaviors exhibited during naturalistic interactions. In one such study, children with ASD were more likely than typical controls to look away from an interviewer's face when listening to arithmetic questions, but not when formulating their answers (Doherty-Sneddon, Riby, & Whittle, 2012). Interestingly, others report that, whereas

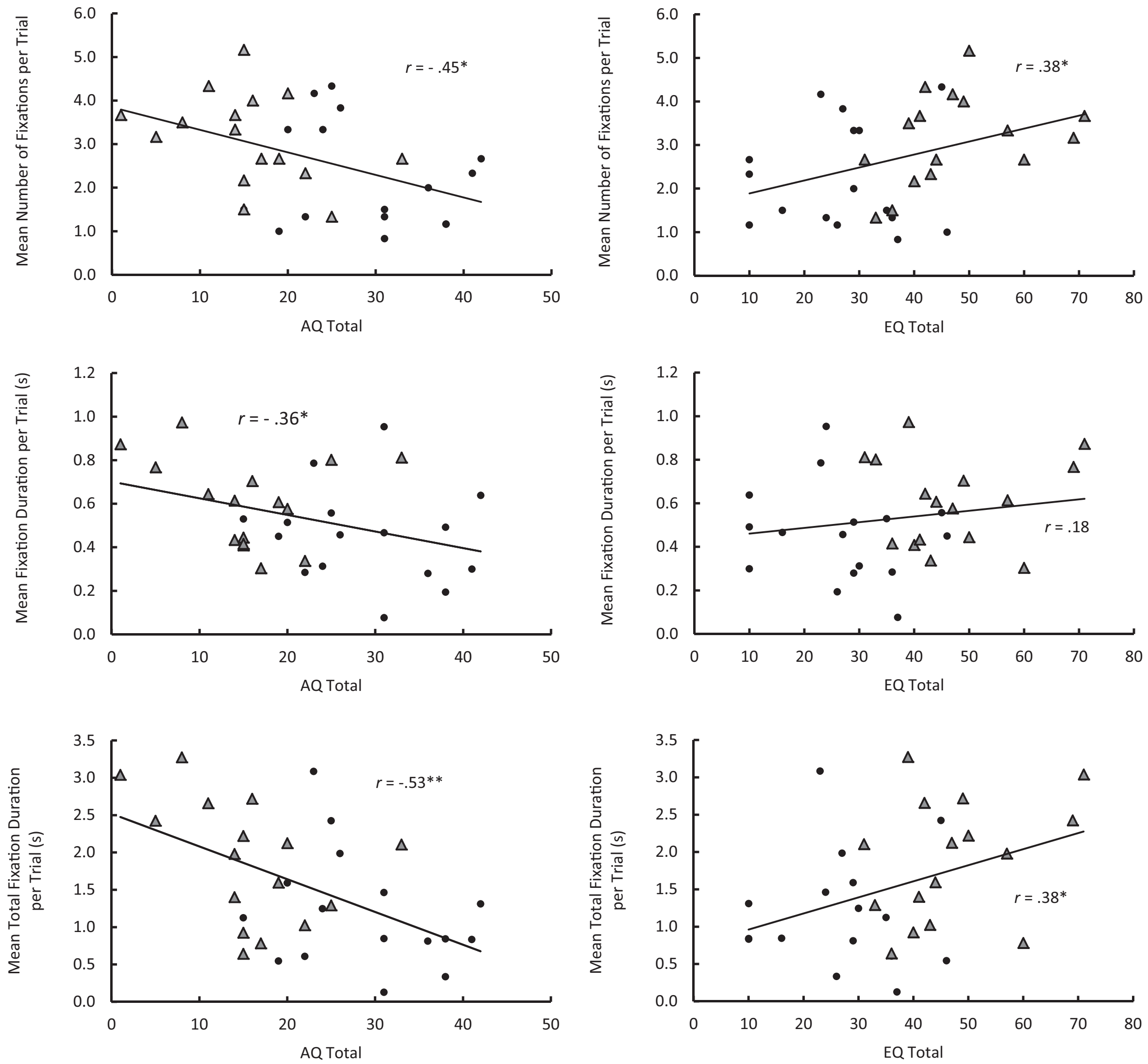

Fig. 9. Scatterplots showing relationships between gaze behaviors and scores on the autism quotient (AQ) and the empathy quotient (EQ) in the full sample as participants viewed dynamic, multiple-character scenes. Triangles represent participants in the typical group; circles represent participants in the ASD group. AQ scores were negatively correlated with the number and duration of fixations made on faces, and with the time spent fixating faces. EQ scores were positively correlated with these variables. $^{*}p < .05$, $^{**}p < .01$.

the performance of typical children improves when the examiner directs his/her gaze toward them when posing questions, this benefit is not observed in children on the spectrum (Falck-Ytter, Carlström, & Johansson, 2015). Children with ASD also look less at an examiner's face during other kinds of dyadic interactions (Noris, Nadel, Barker, Hadjikhani, & Billard, 2012; Riby, Doherty-Sneddon, & Whittle, 2012), and find it more challenging than their peers to maintain eye contact with an examiner (Riby et al., 2012). Together, these results support the conclusion that attending to (naturally moving) faces interferes with cognitive performance more in children with ASD than in their peers.

Some have argued that people on the autism spectrum look less at faces than their peers because they do not find them interesting or compelling (Campatelli et al., 2013), or because they find doing so aversive (Dalton et al., 2005). It is also possible that people with ASD are simply less *motivated* to use the rich information provided by facial movement to help them understand or make inferences regarding the unfolding storyline. Support for this idea comes from Grynszpan and Nadel (2015). Participants in this study viewed videos of social scenes and then described the interactions depicted. When *instructed* to focus on the characters' facial expressions, participants with ASD who made longer face fixations showed a better understanding of the social interactions than those who made shorter face fixations. In contrast, typical controls were able to interpret the social scenes accurately whether or not they were instructed to attend to faces. The authors suggested that individuals with ASD lack the motivation to look at faces when watching social interactions (see also Nomi and Uddin, 2015 for a review).

We observed that individuals who made fewer and shorter face fixations also endorsed more autistic and fewer empathic traits. Similar relationships have been described in other studies involving clinical and non-clinical samples. For example, Klin et al. (2002) presented videos depicting social scenes to boys with autism and found that the best predictor of ASD group membership was reduced time looking at the eyes. In children with ASD, increased focus on the mouth was associated with better social adjustment, whereas spending more time looking at objects was associated with worse social adjustment. In related work, Matsumoto, Takahashi, Murai, and Takahashi (2015) observed that individuals with schizophrenia who exhibited lower levels of affective empathy made fewer fixations and performed more poorly on a task requiring biological motion perception than those who exhibited higher levels of affective empathy. Finally, in a study that involved a non-clinical (university student) sample, Vabalas and Freeth (2015) found that the number of autistic traits that young adults endorsed predicted their gaze behaviors during live, face-to-face interactions. Specifically, students exhibiting many autistic traits made smaller and less frequent saccades than those exhibiting few autistic traits, despite being just as likely to look at their conversational partner's face. In contrast to the findings described above, in their sample of 60 children and adolescents with ASD and 50 typical controls, Parish-Morris et al. (2013) found no association between time viewers spent looking at dynamic faces and autistic symptomology as measured by the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003; Rutter, Le Couteur, & Lord, 2003). As these authors note, however, the SCQ was not specifically designed to assess social motivation, which may be one of the more important aspects of autistic symptomology linked to social attention.

The correlational nature of the studies discussed above do not allow us to draw causal inferences, but the results do suggest that it may be worthwhile to explore the impact of incorporating gaze training into programs designed to enhance the social skills of people with ASD. Utilizing training materials that depict spontaneous as opposed to staged interactions (see Hanley, McPhillips, Mulhern, & Riby, 2012), and situations varying in social complexity, will also be important. Finally, in the interest of improving the success of generalization training, it would be prudent to incorporate naturalistic, dynamic stimuli into such programs. Given the atypical responses to dynamic cues exhibited by adults with ASD in the present study, further research should explore when and how best to accomplish this while keeping the cognitive load within comfortable limits.

A limitation of the present study was that we did not measure participant's *scene comprehension*, or whether (in the ASD group) comprehension was related to the time spent fixating on faces. This was not done because we were interested primarily in how people allocate attention when viewing naturalistic social interactions (i.e., conversations), as opposed to how they use nonverbal cues to make higher-level social inferences. Despite this, we did find interesting relationships between attention to faces and measures of autistic and empathic traits. Future research might extend our work, and the work of Grynszpan and Nadel (2015) described above, by employing displays depicting simple and more complex/nuanced social interactions, and by exploring whether the amount of attention people with ASD pay to faces relates to their scene comprehension in either condition.

Two additional limitations of the current research are the small sample sizes, and our focus on individuals with ASD who were functioning in the normal range intellectually. Although we found that FSIQ was not strongly related to task performance in our sample, further work is needed to determine whether the findings of this study would generalize to people with ASD who have an intellectual impairment. We elected not to include viewers with low IQ scores in order to remove this as a confound, however, doing so necessarily limits the conclusions one can draw. An additional, potential limitation of our study was that our groups were matched with regard to VIQ, but not with regard to FSIQ. However, as has been eloquently argued elsewhere (Burack, Hodapp, & Zigler, 1998; Dennis et al., 2009; Jarrold & Brock, 2004), there is no "ideal" way to match a group with a neurodevelopmental disorder to a control sample. Jarrold and Brock (2004) have argued that the best approach might not be to match on the basis of IQ, but rather to attempt to equate performance on carefully designed control tasks. This was achieved (unintentionally) to a certain extent in the present work, as we found that the most *striking* group differences emerged only when dynamic cues were added to our displays. As the static displays were still images extracted from the film clips that served as dynamic stimuli, movement of the character(s) was the main feature that distinguished the two types of stimuli in the present study. Our findings nicely complement those of Chevallier et al. (2015), and lend support to the argument that future research exploring social attention and motivation in ASD should incorporate naturalistic, ecologically relevant stimuli.

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