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Face processing in children with autism

Effects of stimulus contents and type

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ABSTRACT Recent eye tracking studies of face processing have produced differing accounts of how and whether children with autism differ from their typically developing peers. The two groups' gaze patterns appear to differ for dynamic videos of social scenes, but not for static photos of isolated individuals. The present study replicated and extended previous research by comparing the gaze patterns of individuals with and without autism for four types of stimuli: social dynamic, social static, isolated dynamic, and isolated static. Participants with autism differed from their typically developing peers only for social-dynamic stimuli; fixation durations were decreased for eye regions and increased for body regions. Further, these fixation durations predicted scores on a measure of social responsiveness. These findings reconcile differences in previous reports by identifying the specific social and dynamic task components associated with autism-related face processing impairments.

KEYWORDS *autism; eye tracking; face processing; social responsiveness*

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Children with autism have been reported to show normal recognition for nonsocial stimuli (e.g. buildings, objects), but they do not exhibit the same skills for social stimuli (i.e. faces) as their normally developing peers (Boucher and Louis, 1992; Hauck et al., 1998; Trepagnier et al., 2002). More specifically, children with autism experience difficulty distinguishing between familiar and unfamiliar faces (Boucher and Louis, 1992), particularly when recognition is dependent upon the eyes (Joseph and Tanaka, 2003; Teunisse and deGelder, 1994). In general, they tend to fixate less on the eyes and more on the mouth (Klin et al., 2002) or other nonfeature

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regions of the face (Pelphrey et al., 2002). This autism-related face processing impairment does not appear to be due to problems with visual discrimination (e.g. Chawarska et al., 2003) or overall cognitive abilities (Klin et al., 1999). Instead, some researchers have proposed that individuals with autism may process faces using areas of the brain typically involved in processing objects (Hall et al., 2003; Schultz et al., 2000).

The face processing impairments just described are further complicated when tasks require the identification of emotions or mental states (Baron-Cohen, 1989a; 1989b). This is especially true when stimuli require understanding of the environment and social situation (e.g. surprise, fear: Adolphs et al., 2001; Bormann-Kischkel et al., 1995; Klin, 2000; Macdonald et al., 1989; Pelphrey et al., 2002). For example, Klin et al. (2002) asked participants with and without autism to view video clips from the 1967 film version of Edward Albee's *Who's Afraid of Virginia Woolf?*, a film that portrays four individuals involved in intense social interactions, as well as complex social situations comparable to those that individuals with autism might encounter in their daily lives. Klin et al. used eye tracking technology to record participants' eye fixation durations for four regions in each video clip: eyes, mouth, body, and object. Consistent with previous research (e.g. Pelphrey et al.), individuals with autism fixated less on the eye region, and more on the mouth, body, and object regions than individuals in the comparison group.

However, van der Geest and colleagues have reported no impairments in facial and/or emotional processing in children with autism. For example, van der Geest et al. (2002a) found no differences between the gaze behaviors of children with autism and their age- and IQ-matched typically developing peers when viewing cartoon-like scenes that included a human figure. Similarly, although their stimuli and task were similar to that of Pelphrey et al. (2002), who did report face processing differences in adults with and without autism, van der Geest et al. (2002b) found no differences between the gaze behaviors of children with and without autism for still photos of human faces displaying emotional states. Van der Geest and his colleagues concluded that face processing impairments associated with autism cannot be attributed to the simple presence of facial stimuli, and that they are actually due to other related factors, such as having to process social information.

The differing conclusions of Klin et al. (2002) and van der Geest et al. (2002b) are exacerbated by the fact that they are based on studies with different participants, different eye tracking technologies, and, most important, different stimuli (dynamic social scenes versus static shots of isolated individuals, respectively). This is further complicated by the results of Pelphrey et al. (2002), who used stimuli similar to those of van der Geest et al., but drew conclusions similar to those of Klin et al. The purpose of this study was to replicate and extend previous research by comparing the gaze patterns of autism and comparison groups for four types of stimuli: social dynamic, social static, isolated dynamic, and isolated static. Combining image type (static versus dynamic) with image contents (isolated versus social) allowed us to determine whether face processing impairments in autism are dependent upon the contents of the stimuli (isolated individuals versus social scenes), the type of stimuli (static photos versus dynamic video clips), or a combination of these two variables. Four types of stimuli were created from the film used by Klin et al. (i.e. *Who's Afraid of Virginia Woolf?*): isolated static, isolated dynamic, social static, and social dynamic. That is, we were able to replicate the conditions of both the van der Geest et al. (isolated static: see also Pelphrey et al.) and Klin et al. (social dynamic) studies, and to create two new conditions (isolated dynamic and social static). Eye tracking technology was used to record the fixation durations of participants with and without autism for six regions: eye, mouth, body, object, face/other (e.g. ears, hair, cheek), and 'off'. Based on previous research, it was predicted that individuals with autism are likely to fixate on the eyes less and on other regions more than their comparison group peers. If the autism-associated face processing deficit appears only with very naturalistic (i.e. moving) stimuli, the predicted group differences should be observed only in the isolated-dynamic and social-dynamic conditions. If the deficit is dependent upon social stimuli, group differences should be observed only in the social-static and social-dynamic conditions. Finally, if the deficit is dependent upon stimuli being both naturalistic and social, group differences should only be observed in the social-dynamic condition. Note that each of these hypotheses predicts no group differences in the isolated-static condition; this prediction is consistent with the findings of van der Geest et al., but inconsistent with the findings of Pelphrey et al.

It is also important to understand how face processing impairments relate to more general impairments in social processing. Klin et al. (2002) found that longer fixation durations on the mouth region were associated with increased social competence and lower levels of autistic social impairment, whereas longer fixation durations on objects were associated with decreased social competence and higher levels of autistic social impairment. In this study, correlations were also computed for fixation data and age, IQ, and measures of autistic social impairment – the Autism Diagnostic Interview–Revised (ADI–R: Lord et al., 1994) and the Autism Diagnostic Observation Schedule (ADOS: Lord et al., 1999) – and a recently developed measure of social responsiveness, the Social Responsiveness Scale (SRS: Constantino and Gruber, 2005). The SRS differs from other instruments used to assess symptoms of autism spectrum disorder in that it measures severity of symptoms rather than presence/absence of them, and it can be used with all participants – not only those with autism. It may therefore be sensitive to social impairments across a wider range of functioning than traditional autism screening measures. In addition, to our knowledge, this is the first use of the SRS in combination with eye tracking data. Based on Klin et al.'s findings, higher levels of social responsiveness (indicated by lower scores on the SRS) should be associated with longer fixation durations on the eye region and shorter fixation durations on other regions.

Method

Participants

Twelve male children and adolescents, ages 9 to 18, were recruited through a large, federally funded research project on the neurobiology of autism by the Utah Autism Research Program at the University of Utah. These participants had been diagnosed with DSM-IV autistic disorder by a psychiatrist or licensed psychologist with expertise in autism. Each participant also met criteria for an autism spectrum disorder on the ADOS and/or the ADI–R. Participants under the age of 16 also had IQ testing using the Differential Ability Scale (DAS) or the Wechsler Intelligence Scale for Children (WISC), whereas those over the age of 16 were given the Wechsler Adult Intelligence Scale (WAIS). Previous researchers have found evidence for the convergent validity of these measures (DiCerbo and Barona, 2000; Nichols, 1998). Parents of all participants filled out the SRS at the time of the experiment. Participants were matched for chronological age and verbal intelligence with a comparison group of 12 male children and adolescents recruited from the community. Intelligence profiles for individuals with autism typically show normal performance intelligence but impaired verbal intelligence; thus, difficulties often arise when making matching decisions. Thus, in the current research, groups were matched on both verbal intelligence and performance intelligence. See Table 1 for information regarding the mean age, IQ (verbal and performance), ADOS, ADI, and SRS scores for the two groups. No participants were recruited that had visual acuity deficits that could not be corrected with eyeglasses or contacts.

Stimuli

All participants viewed 20 digitized stimuli from the 1967 film version of Edward Albee's *Who's Afraid of Virginia Woolf?*, which was chosen by Klin et al. (2002) for its portrayal of interactions involving strong emotions. Five of these stimuli were those Klin et al. used in their 2002 study (social-dynamic condition); stimuli were composed of video clips showing highly emotional interactions among two or more characters. Five additional stimuli were

Table 1 **Participant demographic data**

	Autism group (n = 12)	*Comparison group (n = 12)*	*t Value*	*p Value*
Age	13.6 (2.7)	13.3 (2.3)	0.240	0.813
VIQ*	96.3 (15.0)	100.3 (10.1)	0.765	0.452
PIQ*	104.5 (17.66)	108.25 (14.52)	0.498	0.625
SRS	97.6 (26.2)	34.6 (6.9)	8.061	0.000
ADOS+ social	10.4 (2.2)			
ADI social^	16.4 (4.8)			

* Verbal (V) or Performance (P) IQ as derived from the Differential Ability Scale, the Wechsler Intelligence Scale for Children, 3rd edition (WISC-III), or the Wechsler Adult Intelligence Scale, 3rd edition (WAIS-III). These instruments have a mean of 100 and a standard deviation of 15. The VIQ scores for participants in this sample ranged from 80 to 124; the PIQ scores ranged from 79 to 133.
+ The Autism Diagnostic Observation Schedule (ADOS) –3 and ADOS-4 have a cut-off of 6 on the socialization section (maximum is 14).
^ The Autism Diagnostic Interview has a cut-off of 10 on the socialization section (maximum is 30).

dynamic in nature but contained only one individual (isolated-dynamic condition); in all stimuli in this condition, the individual portrayed was speaking either to himself/herself or to another character that was not speaking and was not shown on the screen. Participants also viewed 10 static images, five with two or more individuals (social-static condition) and five with one individual (isolated-static condition). The static stimuli depicted isolated individuals or social scenes that were not included in the dynamic stimuli. In all four conditions, stimuli were chosen to display content that portrayed situations individuals may encounter in their everyday lives. In addition, all conditions portrayed partial or whole-body shots of individuals in natural settings (e.g. house, car, restaurant, outdoors) that contained objects.

Four different stimulus lists were created, with the stimuli appearing in a different order in each list. Participants were randomly assigned to one of the four stimulus sets, with an equal number of participants assigned to each list.

Apparatus

Participants' gaze behaviors were measured with an Applied Sciences Laboratory Model 501 head-mounted eye tracker with a magnetic head tracking device attached. The eye tracker was interfaced and controlled via a Hewlett-Packard (HP) 1.8 GHz computer. Another HP 1.8 GHz computer, with an 18.6 × 13.95 inch LCD monitor and a set of external speakers, was used to control the experiment. Participants had free head and eye movement, and their head movements and orientation were recorded with the ASL EyeHead Integration system. The eye tracker did not touch the participant's eye at any point during the experiment. The eye tracker has an accuracy range of one half to one degree of visual angle. Viewing is binocular, with eye location sampled from the right eye at 60 Hz. Each sample was compared to the previous sample to determine whether the eye was fixated or moving. The room was dark except for a lamp located directly behind the participant to enable the examiner to keep notes. The eye tracker was individually calibrated for each participant.

Procedure

Each individual participant's session lasted approximately 30 minutes. After giving informed consent, participants were seated in a comfortable armchair approximately 25 inches from the monitor, which filled most of the participants' visual field. Participants were then fitted with the eye tracker and the machine was calibrated. The experimenter was seated behind the participant operating the eye tracker; therefore the experimenter was out of the participants' eyesight. The experiment began with a desensitization task, consisting of a short video of the experimenter informing participants that they would see several pictures, both dynamic and static, and that they would be asked questions after viewing all of the images. Once it was determined participants were comfortable (by demeanor and attention to the desensitization task), the 20 stimuli were presented on the computer screen one at a time. A fixation point appeared in the middle of the screen for 5 seconds prior to each stimulus, and it was automatically replaced with the next stimulus. Static stimuli appeared for 10 seconds each, and the dynamic stimuli ranged in length from 21 seconds to 1 minute 9 seconds. After all stimuli were viewed, the eye tracker was removed, and participants were then asked eight memory questions (e.g. 'Was there a picture of someone who was happy?') to ensure that they attended to the stimuli. All participants answered at least two-thirds of the questions correctly, and the two groups did not differ significantly in terms of overall accuracy, $t_{22} = 0.312$, $p = 0.758$.

Results

During each experimental session, the participant's eye tracking data appeared as a point-of-gaze (POG) cursor superimposed over the stimulus on a small black-and-white monitor. These data were videotaped at the standard rate of 30 frames per second and videotapes were later digitized. Two dynamic video clips (one isolated dynamic and one social dynamic) were altered during the digitization process, such that the contents of the video clips were too dark to determine reliably where the POG cursor was located. As a result, these stimuli were dropped from all analyses. Because both the participant's POG cursor and the scene contents changed from frame to frame in the dynamic stimulus conditions, each frame had to be coded in order to determine the region on which the participant was currently fixated. Eight video clips (30 frames per second, totaling an average of 6101 frames per participant) were coded for each participant. Some frames were not coded, due to either a blink or a saccadic shift. Fixation durations (i.e. total viewing time, or sum of all fixation durations) for six critical regions were analyzed: eyes, mouth, body, object, face/other, and off. The object region consisted of any discernible shape or object in the scene. The face/other region consisted of facial features (e.g. hair, forehead, cheek, etc.) unrelated to the eye or mouth regions. Fixations were coded in the off region when participants looked away from the image displayed on the screen. Separate analyses were conducted for each region.

Reliability analyses

In order to ensure reliability in coding of the dynamic stimuli, a second rater coded 25 percent of the data in the dynamic conditions. This rater's codes were then compared to the first rater's codes. Inter-rater reliability was high ($\kappa = 0.947$, $p < 0.001$). In addition, the first rater coded the data for one participant, then recoded the same data after 2 weeks. Internal consistency (test–retest reliability) was also high ($r = 0.957$, $p < 0.001$).

Group differences in fixation durations

Mean fixation durations for both the autism and comparison groups for all regions in each of the four stimulus conditions are presented in Table 2. The largest and most important difference between the autism and comparison

Table 2 **Mean total fixation durations in seconds as a function of stimulus condition, region, and group**

		Eye	*Mouth*	*Face/Other*	*Body*	*Object*	*Off*
Social dynamic	Autism	1.09	0.98	4.57	2.32	1.23	0.53
	Comparison	2.52	1.01	4.92	1.31	0.89	0.27
	Difference	*1.43***	*–0.04*	*–0.35*	*1.01**	*0.34*	*0.26*
Isolated dynamic	Autism	2.48	1.33	7.79	2.03	0.68	1.19
	Comparison	3.71	1.19	6.98	1.31	0.41	0.79
	Difference	*–1.23*	*0.14*	*0.81*	*0.72*	*0.28*	*0.41*
Social static	Autism	1.70	0.63	2.40	2.06	2.80	2.51
	Comparison	2.28	0.70	2.12	1.22	2.82	1.90
	Difference	*–0.57*	*–0.06*	*0.28*	*0.84*	*–0.02*	*0.60*
Isolated static	Autism	2.56	1.21	2.44	0.47	0.59	1.01
	Comparison	3.25	0.76	1.83	0.71	0.75	0.98
	Difference	*–0.70*	*0.45*	*0.61*	*–0.24*	*–0.16*	*0.03*

*p < 0.10; **p < 0.05

participants was in fixation durations on the eye region. The main effect of group was marginal, $F(1, 22) = 3.109$, $MSE = 22.977$, $p = 0.092$, However, planned contrasts revealed that this effect was mainly due to participants with autism spending significantly less time (mean = 1.09 s) than the comparison participants (mean = 2.52 s) fixating on the eye region in the social-dynamic condition, $t_{22} = 2.811$, $p = 0.01$. The two groups did not differ significantly in fixation times on the eye region for any of the other conditions.

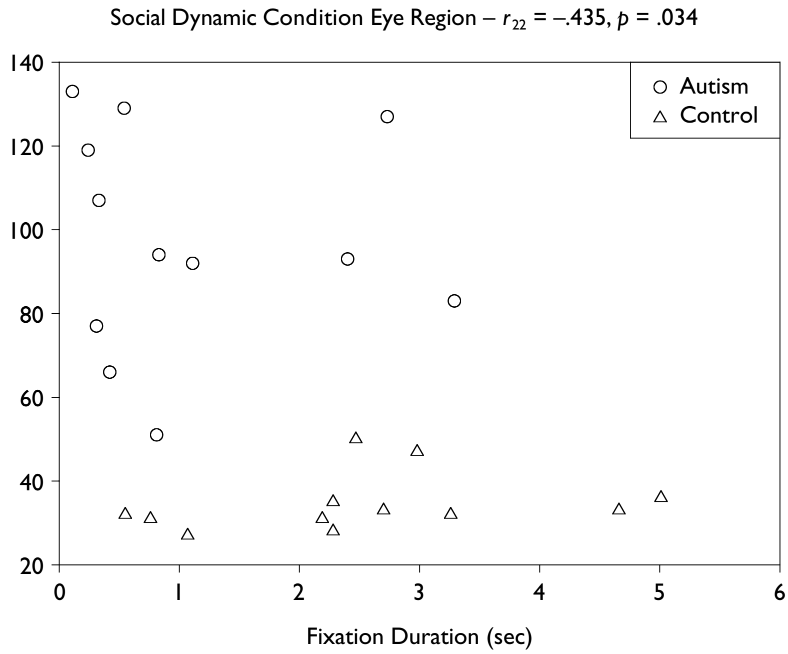
Although the main effect for group did not approach significance for the analysis on the body region, a planned contrast demonstrated that individuals with autism also spent marginally more time looking at the body (mean = 2.32 s) than individuals in the comparison group (mean = 1.31 s), but again, only in the social-dynamic condition, $t_{22} = 1.979$, $p < 0.06$. Contrasts for all other regions (i.e. mouth, face/other, object, and off) between the autism and comparison groups did not approach significance.

The only reliable differences between the two groups were on the eye and body regions in the social-dynamic condition. As a result, Pearson correlations were computed between these fixation durations and measures of age, VIQ, PIQ, and social functioning (i.e. scores on the SRS, ADOS, and ADI–R). Note that the correlation analyses for the SRS, age, VIQ, and PIQ included data for all participants, whereas the ADOS and ADI–R analyses included only the data from the participants with autism. All correlations are reported in Table 3. The SRS significantly predicted the eye region fixation durations, $r_{22} = -0.435$, $p = 0.034$; that is, as social responsiveness decreased (indicated by higher scores on the SRS), fixation durations in the eye region decreased (Figure 1). The correlation between the body region fixation durations and the SRS was marginally significant, $r_{22} = 0.361$, $p = 0.083$; that is, as social responsiveness decreased, fixation durations on the body region tended to increase. The correlations between social-dynamic condition fixation durations in the eye and body regions did not significantly correlate with age, PIQ, VIQ, or the scores on either the ADOS or the ADI–R (all $p > 0.24$).

Table 3 **Correlations for fixation durations for the eye and body regions in the social-dynamic condition with measures of social functioning, age, and IQ**

	SRS (N = 24)	*ADOS (N = 12)*	*ADI (N = 12)*	*AGE (N = 24)*	*VIQ (N = 24)*	*PIQ (N = 24)*
Social-dynamic eye region fixations	–0.435**	0.151	–0.461	0.207	–0.145	0.091
Social-dynamic body region fixations	0.361*	0.103	–0.066	–0.248	0.023	0.069

**p* < 0.10; ***p* < 0.05



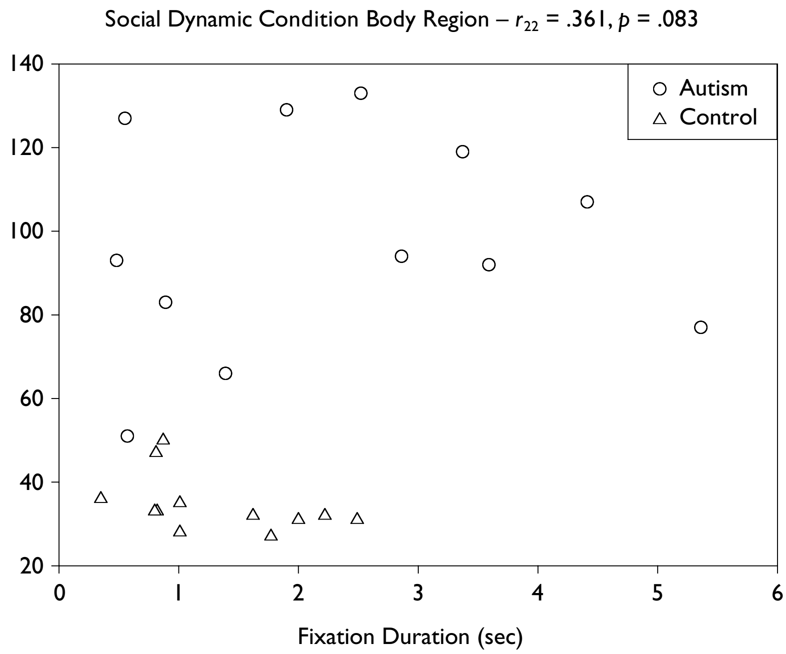


Figure 1 **Scatterplots for correlations between SRS scores and fixation durations in the eye and body regions in the social-dynamic condition**

General discussion

The goal of this study was to extend the research on face processing in individuals with autism by reexamining factors from recent studies in this field. Klin et al. (2002; Pelphrey et al., 2002) and van der Geest et al. (2002b) found very different results when comparing fixation durations for facial stimuli for individuals with and without autism. However, the stimuli used in these studies differed in two ways: image type (static versus dynamic) and image content (isolated versus social). The purpose of this study was to replicate and extend the results of these studies by comparing the gaze patterns of individuals with and without autism for four types of stimuli: social dynamic, social static, isolated dynamic, and isolated static.

The only differences observed between the two groups were in the social-dynamic condition. Individuals with autism spent significantly less time (1.09 s) looking at the eyes than did their typically developing peers (2.52 s). They also spent marginally more time looking at the body (2.32 s) than did individuals in the comparison group (1.31 s). These findings are consistent with the results of Klin et al. (2002) who found that individuals with autism fixated less on eyes and more on mouths, bodies, and objects than comparison group participants when viewing social-dynamic stimuli. The lack of a group difference in the isolated-static condition is also consistent with the results of van der Geest et al. (2002b), who found no differences in gaze behaviors between participants with and without autism when viewing still photos of isolated individuals. The lack of group differences in the isolated-static condition is inconsistent, however, with the findings of Pelphrey et al. (2002). Our findings also extend beyond the results of previous research by demonstrating that the two groups' gaze patterns do not appear to differ for isolated-dynamic or social-static stimuli.

Based on the present findings, and those of Klin et al. (2002) and van der Geest et al. (2002b), the face processing deficit associated with autism appears to be at least partially dependent on stimuli being both realistic (i.e. dynamic or moving) and social in nature. When one of these variables was missing from stimuli in the present study, children with autism performed similarly to individuals in the comparison group. It may be that the emotions and social interactions portrayed in the stimuli were not as difficult for children with autism to process when only a single individual and/or a static shot was presented compared to when multiple interacting individuals were presented in a dynamic scene. This explanation is consistent with the idea that individuals with autism can identify emotions, but that this becomes increasingly difficult when comprehension of the social environment is also required (Adolphs et al., 2001; Bormann-Kischkel et al., 1995; Klin, 2000; Macdonald et al., 1989).

The results also demonstrate that autism-associated deficits in face processing are related to more general impairments in social functioning. As participants' social responsiveness (as measured by the SRS) decreased, they tended to fixate less on the eyes and more on the body. This finding suggests that the amount of time an individual spends fixating on others' eyes in social interactions may reflect the degree to which they are able to process or make sense of social information or facial cues. Such correlations between clinical (SRS) and behavioral (eye tracking) measures of social responsiveness are also important because they serve to further validate clinical measures. The data also help researchers to understand the psychological constructs that may underlie behavioral impairments and to outline the specific circumstances in which these impairments occur.

Although this study yielded promising results, they are based on high-functioning children and adolescents with autism. Further research is needed to determine whether they can be extended to the general population and/or individuals with autism who demonstrate lower cognitive functioning. In addition, the black and white film chosen for use in this study – *Who's Afraid of Virginia Woolf?* – is almost 40 years old, and its content may have reflected more intense emotions and social interactions than those which children in today's society experience on a daily basis. Finally, because existing static and dynamic shots from the film were used in this study, it was not possible to control for the size of the regions across stimuli. However, because the compared groups viewed the same stimuli in each condition, this issue did not impact our analyses.

In summary, individuals with high-functioning autism and their typically developing peers do differ in how they process images of faces, but only when those faces are incorporated into social-dynamic stimuli. These findings help to identify the specific social and dynamic task components associated with autism-related face processing impairments. In addition, the SRS, a new measure of social responsiveness, predicted fixation durations for regions (i.e. eyes, body) that typically contain important emotional and social information. Thus, it may be possible to increase children's social responsiveness by training them to direct their gaze more toward the eyes and less toward the body during social interactions. Future research should continue to explore the nature and extent of social impairments associated with autism, the domains in which these impairments do and do not impact processing, and the factors that may mediate these impairments.

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