Eye-movement patterns are associated with communicative competence in autistic spectrum disorders

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Background: Investigations using eye-tracking have reported reduced fixations to salient social cues such as eyes when participants with autism spectrum disorders (ASD) view social scenes. However, these studies have not distinguished different cognitive phenotypes. Methods: The eye-movements of 28 teenagers with ASD and 18 typically developing peers were recorded as they watched videos of peers interacting in familiar situations. Within ASD, we contrasted the viewing patterns of those with and without language impairments. The proportion of time spent viewing eyes, mouths and other scene details was calculated, as was latency of first fixation to eyes. Finally, the association between viewing patterns and social-communicative competence was measured. Results: Individuals with ASD and age-appropriate language abilities spent significantly less time viewing eyes and were slower to fixate the eyes than typically developing peers. In contrast, there were no differences in viewing patterns between those with language impairments and typically developing peers. Eye-movement patterns were not associated with social outcomes for either language phenotype. However, increased fixations to the mouth were associated with greater communicative competence across the autistic spectrum. Conclusions: Attention to both eyes and mouths is important for language development and communicative competence. Differences in fixation time to eyes may not be sufficient to disrupt social competence in daily interactions. A multiple cognitive deficit model of ASD, incorporating different language phenotypes, is advocated. Keywords: Autism, eye-tracking, language impairment, social attention.

Communication deficits are a key feature of autism spectrum disorders (ASD; American Psychological Association, 1994). While pragmatic deficits are universal to the disorder, there is considerable heterogeneity in structural language profiles leading some investigators to postulate distinct neurocognitive phenotypes within ASD (Tager-Flusberg & Joseph, 2003). Language phenotypes have been identified at the behavioural (Kjelgaard & Tager-Flusberg, 2001), cognitive (Joseph, Tager-Flusberg, & Lord, 2002) and neurobiological levels (De Fosse et al., 2004).

Prominent theories of autism posit that reduced attention to social cues early in development may derail the social learning process (Klin, Jones, Schultz, & Volkmar, 2003). Inattention to social cues such as eyes and faces may have deleterious consequences for language learning because of the special role these cues have in signalling a communicative partner’s intention (Itier et al., 2007) and in disambiguating linguistic messages (Hanna & Brennan, 2007). Given that social impairments characterise ASD, it is puzzling how some individuals manage to attain age-appropriate language skills.

Alternatively, language impairment may adversely affect social development. Non-autistic children with language impairment are known to have difficulties navigating the social world (Durkin & Conti-Ramsden, 2007). Similarly, children with ASD who have disproportionate language impairment, relative to nonverbal ability, experience greater social-communicative impairments than those with a more balanced cognitive profile (Joseph et al., 2002). Such findings suggest that social experience may be influenced by language ability. However, these findings are difficult to interpret because assessments of social understanding place great demands on language skill.

In the current study, we used eye-tracking methods to explicitly compare visual attention to social cues in two phenotypes: those with and those without additional language impairments. Eye-tracking enables investigators to identify elements of social scenes that capture an individual’s attention with no overt task demands or explicit language requirements. Previous eye-tracking studies of ASD have presented cognitively able participants with static images of faces in isolation, with equivocal results. The most consistently reported finding is that individuals with ASD spend a significantly smaller
proportion of viewing time focusing on the eye region of the face (Corden, Chilvers, & Skuse, 2008; Dalton et al., 2005; Neumann, Spezio, Piven, & Adolphs, 2006). However, other investigators using complex social scenes have failed to find group differences in viewing patterns (van der Geest, Kemner, Verbaten, & Van Engeland, 2002; Fletcher-Watson, Leekam, Benson, Frank, & Findlay, 2009). Studies reporting reduced fixations to eyes provide support for theoretical positions linking social and communication deficits in autism to impaired social attention. Nevertheless, it remains unclear how individual differences in eye-movement patterns relate to social and communicative deficits. Moreover, viewing static social images is obviously far removed from real-life experience in which eyes and faces are embedded in a complex environment and are constantly moving and changing (Smiley et al. 2006). Klin, Jones, Schultz, Volkmar, and Cohen (2002) sought to address these issues in a landmark study in which high-functioning adolescents and adults with ASD viewed short film clips, rather than static images. Relative to the typical comparison group, individuals with ASD spent less time fixating on the eye-regions of the film protagonists and a correspondingly greater proportion of time fixating on the mouth.

Importantly, Klin et al. (2002) demonstrated an association between fixation patterns and daily social behaviour. Surprisingly, there was no association between fixation time to eyes and social behaviour; instead, improved outcome was associated with fixation time to mouths. The authors suggested that increased fixation to mouths might represent a compensatory strategy adopted by viewers with ASD to circumvent their poor social understanding by constructing social meaning from the literal linguistic message. It is therefore necessary to establish whether these observations characterise different language phenotypes. For instance, for viewers with poor language comprehension, fixating the mouth may not improve social understanding, resulting in less fixation time to the mouth. Eye-movement data from relevant populations are lacking, but Norrix, Plante, Vance, and Boliek (2007) reported that non-autistic children with specific language impairments were less susceptible to the McGurk effect, demonstrating a reduced influence of visual information on speech perception. This finding suggests that visual attention to the mouth may be reduced in individuals with language impairment.

Alternatively, there is evidence that at different developmental stages and contexts, viewing the mouth supports language development. Typical infants spend roughly equal amounts of time looking at eyes and mouths, with a slight increase in fixation time to mouths during language acquisition (Hunnius & Geuze, 2004). In addition, viewing the mouth is important for bimodal speech perception (Kuhl & Meltzoff, 1982) and may support comprehension when the auditory signal is degraded (Lansing & McConkie, 2003). Thus, individuals with ASD and additional language impairments may increase their viewing time to the mouth for different reasons than non-language impaired peers. If so, we would expect viewing time to mouth to support communication, but not social outcome for individuals with impaired language.

The use of complex dynamic social stimuli by Klin and colleagues represents an important step forward in exploring social attention in autism. Nevertheless, their study has at least two important limitations, both of which are addressed in the current study. First, Klin et al. presented clips from the 1967 black-and-white film, Who’s Afraid of Virginia Woolf?, arguing that the film involves interactions that mirror ‘complicated social situations that individuals with autism may encounter in everyday settings...’ (p. 811). The latter part of this claim is debatable, particularly given that the clips were presented out of context and many of the interactions depicted are out of the realm of normal social experience. It is possible that individuals with ASD spent less time viewing socially relevant aspects of the film simply because they were less motivated to try to piece together a coherent narrative from the isolated segments. Indeed, Klin et al. report that individuals with ASD had significantly more off-screen fixations than did peers, which may be indicative of a lack of attention or motivation. We therefore developed videos that were more socially relevant to our participants.

A second limitation of the Klin et al. study is that it was not designed to investigate individual differences. Like previous research, findings are limited by exclusive sampling of high-functioning populations with mean verbal abilities in the average to above-average range. Given variability of language profiles in ASD, it is important to establish whether atypical viewing patterns are characteristic of the wider ASD population. To address this concern, we tested a larger group of adolescents with ASD, incorporating a broader range of verbal abilities.

In summary, our goal was to replicate and extend the work of Klin et al. (2002) using eye-tracking to investigate viewing patterns to dynamic scenes of social interaction in different ASD language phenotypes. We calculated the time spent fixating the eyes and mouth, and correlated eye-movement patterns with measures of social and communicative competence. Because social impairment characterised all of our participants, we predicted that both groups would demonstrate decreased fixation times to eyes relative to typically developing peers. However, we hypothesised that looking time to mouths and/or the relationship between viewing the mouth and adaptive outcomes may differ between the two language phenotypes. For individuals with ASD and normal range language skill, we anticipated increased fixation time to mouths, associated with improved social and communication functioning in everyday life.
However, the importance of viewing the mouth for individuals with ASD and language impairment is less clear. We hypothesised that viewing the mouth would not be advantageous to this group because of their poor comprehension of the literal as well as social message.

Methods and materials

Participants

Twenty-eight adolescents (27 males) with ASD were recruited from special schools in England: participants and their parents provided informed consent for entry into the study. Clinical diagnoses of ASD were made by multidisciplinary teams according to DSM-IV criteria prior to school entry; these diagnoses were validated for the present study using the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003) and the Autism Diagnostic Observation Schedule (ADOS; Lord, Rutter, DiLavore, & Risi, 1999). Language status was assigned on the basis of a history of language delay, diagnosis of language impairment from a speech-language therapist and current scores of at least −1.25 SD on the Recalling Sentences sub-test of the Clinical Evaluation of Language Fundamentals (CELF-3UK; Semel, Wiig, & Secord, 2000). This measure requires individuals to repeat sentences of increasing length and grammatical complexity. In non-autistic populations it is an excellent clinical marker of language impairment (Bishop, Adams, & Norbury 2006; Conti-Ramsden, Botting, & Faragher 2001) and is one of the core sub-tests of the CELF used to identify language phenotypes in ASD (Tager-Flusberg & Joseph, 2003). Fourteen participants met all criteria for the Autism Language Impairment group (ALI). Remaining participants served as the Autism Language Normal group (ALN, n = 14). A comparison group of 18 typically developing teenaged boys (TD) were matched to participants with ASD for age and non-verbal ability. None had a history of language impairment, psychiatric illness or special educational provision (Table 1). Both groups with ASD had non-verbal abilities within the normal range yet were significantly impaired in social functioning as measured by the Vineland Adaptive Behavior Scales-II (VABS-II; Sparrow, Cicchetti, & Balla, 2005). They did not differ on either measure of autistic symptomatology (SCQ, F(1, 22) = .05, p = .83; ADOS, F(1,26) = 1.18, p = .28), or current social functioning (VABS-social, F(1,23) = 0.2, p = .90). Not surprisingly, the groups differed with respect to verbal ability and functional communication (BPVS, F(2, 42) = 11.05, p < .001; VABS-communication, F(1,23) = 4.67, p = .04). The ALI group had lower verbal ability than both the ALN and TD groups (ALI vs. ALN, p = .01; ALI vs. TD, p < .001). The ALN group did not differ from the TD group with respect to verbal ability (p = .42).

Eye-tracking stimuli

Participants watched five digitised colour-video clips professionally produced for this investigation. Each clip contained a complete story unit in which 2–3 characters were engaged in a social interaction, with spoken dialogue, that prompted a range of emotional responses. The protagonists were similar in age to our participants and film locations and story content reflected their daily experiences (e.g., a noisy library). Each clip lasted between 20 and 36 seconds with a total viewing time of 2 minutes and 34 seconds. Thus the number of video clips analysed and the total duration of viewing time is comparable to Klin et al. (2002); although our clips included emotional responses, these were arguably less intense and less complex than those used by Klin and colleagues. A still from one of the clips is presented in Figure 1.

Eye-movements were acquired at 50Hz using an ASL 504 remote system running series 6000 software. Video clips were presented on a 27cm × 34cm computer monitor situated approximately 80 cm from the participant. The eye-tracking camera was situated under-
neath the computer monitor. Participants were not restrained and were individually calibrated before the onset of each video clip using a custom-made 9-point calibration routine.

Stimuli were presented and analysed using GazeTracker software, with regions of interest (ROI) drawn on each frame of video to ensure continuous motion of the ROIs. A fixation was defined as the amount of continuous time (minimum 100 milliseconds) spent looking within a 40-pixel diameter region. The number and duration of fixations within a given ROI were recorded. We calculated the percentage of time spent fixating the eyes, mouth, body, and other aspects of the scene across all five video clips. This was calculated as the sum of fixation durations within each predefined ROI divided by total fixation time.2

Results

Saccades, eye-blanks and off-screen fixations were not included in analyses. These data accounted for 15.7%, 18.5% and 13.7% of the total viewing time for the ALI, ALN and TD groups respectively, $F(2,

2 There is a lack of consensus in the literature as to how best to analyse eye-movement data. We adopted the approach used by Klin et al. (2002) to facilitate comparison between our study and their earlier work, which attempts to control for individual variation in total fixation time. However, we re-ran the analyses using raw fixation data and the results were identical.

Figure 1a Still frame from one of the social videos in which two girls are disgusted by their café food and discuss sending it back. Figure 1a shows the fixation points (black circles) and saccades (lines) during a 2s period of the video for an ALN viewer, who does not fixate either face during this period. In Figure 1b, an ALI viewer shows a more typical pattern of fixations, focusing on the faces of each girl and a relevant object on the table.

Table 2 Mean (SD) percentage of visual fixation time on pre-defined regions of the social scene.

<table>
<thead>
<tr>
<th>Region</th>
<th>ALI</th>
<th>ALN</th>
<th>TD</th>
<th>F value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyes</td>
<td>28.3 (12.6)</td>
<td>20.6 (11.5)</td>
<td>32.1 (13.9)</td>
<td>3.23</td>
<td>.04</td>
</tr>
<tr>
<td>Mouth</td>
<td>17.6 (9.8)</td>
<td>19.1 (9.6)</td>
<td>17.8 (12.7)</td>
<td>.09</td>
<td>.91</td>
</tr>
<tr>
<td>Body</td>
<td>28.9 (4.4)</td>
<td>32.0 (5.5)</td>
<td>28.1 (4.9)</td>
<td>2.58</td>
<td>.08</td>
</tr>
<tr>
<td>Other</td>
<td>25.21 (8.33)</td>
<td>28.28 (10.24)</td>
<td>21.65 (7.86)</td>
<td>2.20</td>
<td>.12</td>
</tr>
</tbody>
</table>

$F(2, 42) = 1.09, p = .35$. Table 2 reports the mean (SD) percentage of fixation time per ROI for each group. Analysis of variance indicated a main effect of group in time spent fixating the eye region. Overall, the TD group spent a significantly greater proportion of time fixating the eyes than the ALN group, $t(30) = 2.51, p = .02$, Cohen’s $d = .90$. The difference between the ALI and the ALN groups approached significance, but was not reliable, $t(26) = 1.69, p = .10$, Cohen’s $d = .64$. There was no difference between the ALI and TD groups, $t < 1$. There were no other significant group differences.

It is important to note that these data are non-independent; increases in fixation time to one region necessarily result in decreased fixation time to another region, making direct comparison between regions statistically unreliable. However, three observations are notable. First, all groups spend longer viewing eyes than mouths, though this pattern is attenuated in the ALN group. Second, although the ALN group spend less time than peers fixating the eyes, there are no group differences in fixation time to the mouth, indicating that individuals with ALN are not preferentially reallocating attention to the mouth. Finally, there is considerable within-group variation in fixation patterns for all three groups.

These analyses have focused on fixation duration; it is possible that although some participants with
ASD spent the same proportion of time gazing at eyes, they were not captured by this social cue to the same extent as TD peers. To investigate this possibility, latency of first look to eye regions was averaged across all five videos. Mean (SD) latencies were ALI, 2.9s (2.3), ALN, 6.3s (3.8) and TD, 3.1s (3.6). The ALN group was significantly slower to fixate the eye region, $F(2, 42) = 4.77, p = .01$, than both TD ($p = .03$, Cohen’s $d = .87$) and ALI ($p = .03$, Cohen’s $d = 1.08$) peers.

Finally, we explored the association between fixation time to eyes and mouths, background measures, and measures of social and communicative competence (Table 3). Replicating previous investigations, there were no significant associations between gaze behaviour and background measures of non-verbal and verbal ability, for either TD or ASD participants. In addition, time spent viewing eyes was not associated with social competence (cf. Klin et al. 2002), nor was the association between gazing at the mouth and social advantage significant across ASD sub-groups ($rs = .09–.12$). However, there were strong associations between viewing patterns and communicative competence, both for the combined ASD group, and within language sub-groups (Figure 2). In all cases, increased fixation time to the eyes (Panel A) was associated with lower scores on the VABS-II Communication sub-scale, while increased fixation time to the mouth (Panel B) was associated with better communicative competence. When two outliers in the ALN group were removed, the negative association between fixation to eyes and communicative competence remained strong ($r = 0.54, P = 0.005$) while the relationship between fixation to mouth and communicative competence was diminished ($r = 0.39, p = .07$).

**Table 3** Correlations between fixation times to eyes and mouth and measures of social and communicative competence within ASD groups

<table>
<thead>
<tr>
<th></th>
<th>Percentage fixation time to eyes</th>
<th>Percentage fixation time to mouth</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASD combined</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal ability</td>
<td>$-0.04$</td>
<td>$-0.04$</td>
</tr>
<tr>
<td>Non-verbal ability</td>
<td>$-0.13$</td>
<td>$0.08$</td>
</tr>
<tr>
<td>ADOS social</td>
<td>$0.07$</td>
<td>$-0.15$</td>
</tr>
<tr>
<td>VABS: social</td>
<td>$-0.17$</td>
<td>$0.12$</td>
</tr>
<tr>
<td>VABS: communication</td>
<td>$-0.54^{**}$</td>
<td>$0.56^{**}$</td>
</tr>
<tr>
<td>ALI only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal ability</td>
<td>$0.51^*$</td>
<td>$-0.44^*$</td>
</tr>
<tr>
<td>Non-verbal ability</td>
<td>$-0.15$</td>
<td>$0.01$</td>
</tr>
<tr>
<td>ADOS social</td>
<td>$0.19$</td>
<td>$-0.25$</td>
</tr>
<tr>
<td>VABS: social</td>
<td>$-0.32$</td>
<td>$0.15$</td>
</tr>
<tr>
<td>VABS: communication</td>
<td>$-0.40$</td>
<td>$0.68^{**}$</td>
</tr>
<tr>
<td>ALN only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal ability</td>
<td>$-0.46^*$</td>
<td>$0.41$</td>
</tr>
<tr>
<td>Non-verbal ability</td>
<td>$-0.03$</td>
<td>$0.14$</td>
</tr>
<tr>
<td>ADOS social</td>
<td>$0.08$</td>
<td>$-0.09$</td>
</tr>
<tr>
<td>VABS: social</td>
<td>$-0.04$</td>
<td>$0.09$</td>
</tr>
<tr>
<td>VABS: communication</td>
<td>$-0.59^{*}$</td>
<td>$0.62^{*}$</td>
</tr>
<tr>
<td>TD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal ability</td>
<td>$-0.07$</td>
<td>$0.28$</td>
</tr>
<tr>
<td>Non-verbal ability</td>
<td>$-0.09$</td>
<td>$0.03$</td>
</tr>
</tbody>
</table>

$p < .05$, $^{**} p < .01$.

**Figure 2** Correlation of measure of communicative competence and percentage of visual fixation time to eyes (Panel A) and mouths (Panel B) in participants with ASD as a function of language phenotype

$(r = -.45, p = .03)$ while the relationship between fixation to mouth and communicative competence was diminished $(r = .39, p = .07)$.

**Discussion**

We explored viewing patterns to complex, dynamic social scenes in 28 adolescents with ASD. Atypical viewing patterns were broadly aligned with language phenotype and relationships between viewing patterns and communicative competence were evident. These findings highlight the need to consider language phenotypes in studies of autistic cognition.
We hypothesised that as social impairments characterise all individuals with ASD, both groups would show reduced fixations to eyes. However, this was not the case. Consistent with previous research (Klin et al., 2002), we found that verbally able individuals with ASD (ALN group) spent less time viewing the eyes of scene protagonists and were slower to fixate eye regions. A different viewing pattern was observed for individuals with ASD and concomitant language impairment (ALI). This group spent as much time fixating the eyes, and did so just as quickly, as TD peers. These observations are important as they provide the first demonstration of typical viewing patterns in individuals with ASD when observing dynamic social stimuli.

One explanation for these observations might be that groups differ not only in language status, but also in their profile of autistic symptomatology. However, the groups did not differ in overall SCQ orADOS scores; to the extent that these instruments measure symptom severity, differences in viewing pattern do not reflect differences in autistic severity. However, it is possible that the groups differ with respect to symptom profile. We examined the SCQ scores of our participants and found that the ALN group had slightly elevated ratings of restricted and repetitive interests and behaviours relative to the ALI group (3.92 versus 2.00, $t = 2.24$, $p = .04$). This finding is post-hoc and must be treated with caution, but suggests that the approach to social situations may differ because of differences in interests and behaviour, leading some individuals to attend to less social aspects of scenes.

A second possibility is that different viewing patterns in ASD sub-groups reflect underlying cognitive or perceptual differences that co-vary with language status. For example, the two ASD groups may differ with respect to ocular motor control, which could explain why the ALN group were slower to fixate the eyes. Fletcher-Watson et al. (2009) demonstrated that individuals with ASD were not unduly influenced by the low-level perceptual properties of visual stimuli such as contrast, brightness and colour, suggesting that low-level perceptual processes are unlikely to account for viewing preferences.

Unlike Klin et al. (2002), we observed no group differences in time spent fixating the mouth. What might account for these different findings? The film clips used by Klin and colleagues arguably represent an extreme of social-cognitive processing (Luddo, 2004). While our scenes involved emotional responses, the situations were more familiar to our participants than the exchanges that dominate the earlier film. The ease with which these scenes are comprehended might have influenced attention to the mouth. Consistent with this suggestion, studies using static images have also reported typical viewing patterns to the mouth for individuals with ASD (Dalton et al., 2005; Fletcher-Watson et al., 2009; Neumann et al., 2006). We propose that when a scene is easier to comprehend, attention need not be redirected to the mouth in order to construct social meaning.

Nevertheless, looks to mouths did relate to behaviour; in both ASD groups increased fixation time to mouths was associated with better adaptive communication, highlighting the important role of the mouth in socio-communicative development. Interestingly, increased fixation time to the eyes was associated with poor adaptive communication. These findings appear contrary to accepted wisdom that eye contact is essential for good communication, and possibly suggest that for individuals with ASD, the mouth provides more consistent and transparent communicative cues than the eyes.

It is important to note that our findings relate to adolescence only. Given that ASD is a developmental disorder, it is vital that future work adopts a developmental perspective. This is illustrated by considering the prediction that attention to mouths would vary according to language ability. As language delay is a defining characteristic of autism, we might predict that infants with ASD will demonstrate reduced fixation time to mouths, yet a recent study of toddlers with ASD showed increased fixation time to the mouth relative to TD peers (Jones, Carr, & Klin, 2008). However, the difference between participants with ASD and toddlers with developmental delay matched for language and cognitive ability did not reach stringent levels of statistical significance. In addition, the authors note that the underlying reasons for fixating the mouth are unlikely to be similar to the same behaviours observed in adolescent/adult populations, making these findings difficult to interpret. An eye-movement study of infant siblings at high risk for ASD revealed few differences in fixation patterns between high-risk and low-risk infants, although a greater proportion of infants in the high-risk group preferred to look at mouths (Merin et al., 2006). It is uncertain at this point whether these fixation preferences relate to later diagnostic status or language ability. Prospective longitudinal studies incorporating eye-movement paradigms should reveal patterns of development in social attention and identify compensatory mechanisms, clearly demonstrating how the allocation of attention to eyes and mouths relates to later social and language development.

Unlike previous studies, all of our participants were in full-time specialist education, which included a social skills curriculum emphasising the importance of eye contact in social interaction. Thus, the more typical viewing patterns evident in many of our ASD participants may be a consequence of explicit learning (Itier et al., 2007). However, we query whether instruction in eye gaze improves adaptive social skills. In our data, fixating the eyes was not associated with social adaptation, and was negatively associated with adaptive communication. We note also that similarities in viewing patterns

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between ASD and TD peers does not necessarily mean that viewers with ASD derive the same meaning from social stimuli. For instance, Fletcher-Watson et al. (2009) observed that while participants with ASD fixated the eye region of individuals in static images to the same extent that their typical peers did, they did not show the same tendency to look at the object being fixated by the person in the scene. This suggests that individuals with ASD may fail to appreciate the social significance of eye cues. Furthermore, although viewing videos of peer interaction is arguably more naturalistic than viewing static black and white images of faces, it is still a large step removed from the demands of interpersonal social interaction. An important goal for future work is to develop eye-movement paradigms for individuals with ASD as they themselves engage with the social world. However, the lack of association between attention to eyes and social skill reported here and in other studies forces us to question whether the importance of eyes for developing social competence has been over-stated. Indeed, recent work in (non-autistic) adults reveals that people spend considerable time looking away from the eyes (40%) and that the proportion of time spent fixating the eye region varies according to a scene’s social content, and other factors such as the number of protagonists (Birmingham, Bischof, & Kingstone, 2008). Few studies have considered how these factors relate to social attention and understanding in adults and we know of none that have investigated these factors in typical development. This is unfortunate as a satisfactory interpretation of social attention in atypical development requires a much richer understanding of those factors that influence social attention in typically developing children.

Potential limitations of our study serve to highlight important avenues for future work. First, we validated language status using one specific measure, the Recalling Sentences sub-test of the CELF (Semel et al., 2000). Our rationale was that it is a reliable measure that does not overestimate language ability, is unlikely to be confounded by poor social ability and is sensitive to persistent difficulties in adolescence (Conti-Ramsden et al., 2001). Thus, in combination with a diagnosis and history of language impairment, we consider sentence repetition a valid marker of a distinct language phenotype in ASD. Second, although we included large numbers of participants with ASD, the sample size in each phenotypic group is necessarily smaller. While larger groups are clearly desirable, we regard the relative homogeneity of our groups with respect to age and cognitive ability a strength of our investigation. Third, we selected an adolescent population in order to draw comparisons with an earlier study of visual fixation patterns using dynamic stimuli. However, it is apparent that in order to fully understand the relationship between viewing patterns and social and communicative competence, a developmental framework will be necessary to characterise these relationships over time. It is clear that the relationships between fixation patterns and social/communicative competence are not straightforward. Future studies will be enhanced by assessing other variables that may influence social-visual attention in ASD, specifically measures of non-social interests, social anxiety (Corden et al., 2008) or social reward (Dawson et al., 2002). Although our scenes included emotional interactions, these were not highly aversive (i.e., they did not contain fearful emotions), nor did actors look directly to camera at any point; therefore it is unlikely that reduced fixation time to the eyes was due to anxiety. Finally, like previous investigators, our analyses focused primarily on duration of fixations. The implicit assumption has been that ‘more is better’; however, the ability to shift visual attention from people to relevant environmental stimuli is likely to be more socially and communicatively advantageous (Landry & Bryson, 2004). Although participants in the ALI group had equivalent viewing patterns and latencies of first look to eyes, it may be that their ability to coordinate shifts in visual attention over time is aberrant, something we are currently investigating.

Conclusion

Eyes have been accorded privileged status as conveyors of social knowledge. Accordingly, reduced attention to eyes has been posited as a causative factor in maladaptive social development in ASD. However, there is mounting evidence of considerable variation in attention to eyes and at least superficially ‘normal’ fixation patterns to static social scenes (Fletcher-Watson et al., 2009). In addition, few studies have demonstrated a strong relationship between viewing the eyes and social advantage in ASD. Our data demonstrate that differences in viewing patterns are aligned with variations in language ability, and that viewing the mouth is associated with communicative competence. Two important implications follow from these findings. First, they provide additional evidence for different language phenotypes in ASD (Tager-Flusberg & Joseph, 2003). Second, they provide the first demonstration of typical viewing patterns of dynamic social stimuli in a proportion of individuals with ASD. A challenge for future research is to establish how typical viewing patterns relate to the atypical social interactions and understanding that characterise ASD. We propose that small but significant differences in attention to the eyes may not be sufficient to cause difficulties in daily social interactions (Corden et al., 2008). Instead, a range of non-social factors contribute to social outcome, including linguistic capacity, attention modulation and rigidity of behaviour. Future research explicitly comparing different language phenotypes, utilising eye-tracking
methods and adopting a multiple cognitive deficit approach will be necessary to tease apart these relationships.

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Key points

- Previous eye-tracking investigations of social attention in ASD have exclusively sampled participants with high-functioning verbal skills and reported reduced fixation time to eyes.
- The current study is unique in explicitly comparing viewing patterns to social stimuli in different language phenotypes in ASD.
- Individuals with ASD and age-appropriate language abilities spent less time viewing the eyes and were slower to fixate eyes than typical peers. However, individuals with ASD and additional language impairments did not differ from typical peers.
- Eye-movement measures were not associated with social outcomes, but increased viewing time to the mouth was associated with greater communicative competence.
- Clinically, gazing at eyes may not confer social advantage in everyday environments, but integrating cues from the eyes and the mouth may support communication.

References


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