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Abstract

Background: Autism and Williams syndrome (WS) are neuro-developmental disorders associated with distinct social phenotypes. Whilst individuals with autism show a lack of interest in socially important cues, individuals with WS often show increased interest in socially relevant information. **Methods:** The current eye-tracking study explores how individuals with WS and autism preferentially attend to social scenes and movie extracts containing human actors and cartoon characters. The proportion of gaze time spent fixating on faces, bodies and the scene background was investigated. **Results**: Whilst individuals with autism preferentially attended to characters' faces for less time than was typical, individuals with WS attended to the same regions for longer than typical. For individuals with autism atypical gaze behaviours extended across human actor and cartoon images or movies but for WS atypicalities were restricted to human actors. **Conclusions:** The reported gaze behaviours provide experimental evidence of the divergent social interests associated with autism and WS.

Keywords: Eye-tracking, Williams syndrome, autism, social cognition

Disorders of development may impact upon social communication in several ways. The most prominent example of atypical social skills is evident in the spectral neuro-developmental disorder of autism (Frith, 1989). Social deficits of communication, interactions and imagination contribute to the diagnostic criteria for autistic spectrum disorders (Wing, 1976; DSM IV, American Psychiatric Association, 1994). However, the effect of atypical development on social skills may be bi-directional, as evident by comparing individuals with autism and the genetic disorder of Williams syndrome (WS). This disorder provides an example of heightened sociability; with individuals typically described as hyper-sociable (Jones et al., 2000; Doyle, Bellugi, Korenberg, & Graham, 2004), having a 'pro-social drive' (Frigerio et al., 2006), intense 'looking' towards unfamiliar people (Mervis et al., 2003), and an inability to inhibit social information (Porter, Coltheart, & Langdon, 2007). Thus, autism and WS are both associated with characteristic deficits of social functioning although the effect appears very different (Brock, Einav & Riby, 2008) and when studied together the groups can make important contributions to the field of social neuroscience (Tager-Flusberg, Plesa Skwerer, & Joseph, 2006). The current exploration uses eye-tracking methodology to explore the social attention preferences of individuals with autism and WS.

A wealth of research has used eye-tracking to identify how individuals with autism view socially relevant information. Exploring gaze behaviour can reveal components of the attentional system (Henderson, 2003) as well as social interests (Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003) and studying where individuals look to gain information can provide insights into the difficulties shown in everyday social interactions (Boraston & Blakemore, 2007). In the first study of its kind, Klin and colleagues (Klin, Jones, Schultz, Volkmar, & Cohen, 2002b) recorded the gaze behaviour of individuals with high-functioning autism whilst viewing short video extracts from Edward Albee's '*Who's Afraid of Virginia Woolf?*'. When watching this black-&-white movie participants with autism exhibited grossly different visual fixations to those of a typically developing comparison group. Rather than fixating on socially salient information (e.g. actors' faces and body movements) participants with autism tended to look at irrelevant inanimate details. The researchers, and many since, have concluded that individuals with autism fail to process socially important information from their environment. Reduced fixations towards character's faces may indicate less opportunity to perceive and interpret social cues (e.g. gaze or expressions) conveyed by that character. Therefore the way that individuals view such information can link directly to socio-cognitive skills; such as widely reported face processing deficits (Gepner, de Gelder, & de Schonen, 1996; Riby, Doherty-Sneddon, & Bruce, 2008b).

Since the original research by Klin and colleagues, numerous eye-tracking studies have been conducted with participants who have autism, involving a range of stimuli and producing varying results. The only other study to involve movie extracts (rather than still images) was conducted by Speer, Cook, McMahon and Clark (2007). The research used static and movie extracts with twelve individuals who had high-functioning autism. Utilising movie stimuli taken from Klin et al. (2002b), Speer and colleagues also used frame-shots from the movie to show that individuals with autism only exhibited atypicalities when viewing moving and not static images. However, the fact that the stimuli were those used by Klin and colleagues may imply that the gaze behaviour patterns are stimuli-specific rather than associated more generally with autism.

Research exploring gaze behaviour when individuals with autism attend to static images has been more varied and used characters within scenes as well as isolated face images. Van der Geest, Kemner, Camfferman, Verbaten, and van Engeland (2002a) found no gaze atypicalities when individuals viewed cartoon-like images containing people. However, atypicalities are reported in a number of other studies, particularly when participants attend to human faces (Dalton et al., 2005; Pelphrey et al., 2002; Sasson et al., 2007) and people within social scenes (Riby & Hancock, 2008a). There is a general consensus of decreased eye region fixations (Dalton et al., 2005; Klin et al., 2002; Pelphrey et al., 2002; Speer et al., 2007; Riby & Hancock, 2008a) which may be implicated in eye gaze processing difficulties (Riby et al., 2008b) or theory of mind deficits (Baron-Cohen, 1995). Using social scene pictures Riby and Hancock (2008a) report that individuals with autism show reduced face gaze and eye fixations and the current study makes an important extension to that research by using the same participants but varying the nature of stimuli; thus reducing extraneous variables of individual differences across studies. Cartoon drawings will be used in an attempt to explore differences of gaze behaviour reported by van der Geest et al. (2002a) and Klin et al. (2002b).

Tracking eye movements has proven particularly useful for determining the nature of atypical social gaze in autism and this methodology can be extended to the exploration of other groups such as WS. Alongside evidence of hyper-sociability and a pro-social drive (Jones et al., 2000; Frigerio et al., 2006), individuals with WS show relative strengths at processing facial identity compared to other nonverbal stimuli (Bellugi, Lichtenberg, Jones, Lai, & St. George, 2000). However, that is not to say that faces are encoded in a 'typical' manner (e.g. Karmiloff-Smith et al., 2004; Riby, Doherty-Sneddon & Bruce, 2008a). Looking at faces is critical to interpreting facial cues and gaze behaviour can provide insights into face-related skills associated with WS. Riby and Hancock (2008a) report that individuals with WS exhibit prolonged face gaze towards human actors (particularly the eye region) when viewing photographic social scenes. Prolonged face gaze dramatically contrasts that of individuals with autism under the same task conditions. It has been claimed that atypicalities in *perceiving* social information are closely related to the social interaction profiles in autism (Joseph & Tager-Flusberg, 2004) and we propose that the same applies to WS.

The overall aim of the current research is to explore gaze behaviour towards socially relevant information in autism and WS within one study, utilising various stimuli with the same participants. The current research considers the relevance of using realistic social information in the study of social attention and notes the importance of ecologically valid stimuli (cf. Smilek, Birmingham, Cameron, Bischof, & Kingstone, 2006; Birmingham, Bischof & Kingstone, 2007). The use of human actors in pictures or movies represents increased ecological validity when compared to the use of cartoon characters. Cartoon stimuli are aimed at closely representing real people whilst removing some of the socially demanding factors associated with human interactions and for this aim we use stimuli from the cartoon animation '*The Adventures of TinTin*'© (Anchor Bay Entertainment). The cartoon conditions are central to understanding the impact of stimuli characteristics on gaze behaviour and although they do not represent ecologically valid information they may emphasise the impact of utilising different types of image. Movies should have greater ecological validity than still images, for both cartoons and natural images. We therefore use both still and moving stimuli from cartoons and moving images of human actors to link to previously reported atypicalities of gaze towards static pictures with the same participants (Riby & Hancock, 2008a).

It is predicted that individuals with autism and WS will exhibit atypicalities of gaze behaviour towards characters in scenes, which vary in strength with the nature of stimuli. We explicitly predict that exaggerated face gaze will be evident in WS but reduced face gaze will be evident in autism, to varying degrees across stimulus categories.

Method

Participants

Eighteen participants with Williams syndrome were recruited through the Williams syndrome Foundation. All participants were diagnosed phenotypically by clinicians and 14 participants had their diagnosis confirmed by *fluorescent in situ hybridization* (FISH) testing; thus detecting the deletion of one copy of the elastin gene on chromosome 7. Of these 18 participants, 2 were excluded due to calibration difficulties, thus the final sample comprised 16 participants with WS between 8 years 9 months and 28 years 0 months (mean 17 years 6 months; full details provided in Table 1). Participants with WS were individually matched to two typically developing individuals, one of comparable chronological age to account for life experience, and one of comparable nonverbal ability due to the nonverbal nature of the eye-tracking task. The chronological age matched group ranged between 8 years 10 months and 28 years 0 months (mean 17 years 6 months; difference between groups on chronological age p=.98). The nonverbal ability group was matched using scores on the Ravens Coloured Progressive Matrices task (RCPM; Raven, Court, & Raven, 1990; max score 36). The group with WS scored between 8 and 24 (mean 16) and the typically developing group scored between 8 and 25 (mean 17, difference between groups on RCPM score p=.78). To comply with our inclusion criteria, all typically developing participants scored within the 'normal' range when teachers completed the Strengths and Difficulties Questionnaire (Goodman, 2001).

Twenty-six participants with autism were recruited through mainstream and special needs schools. All participants had previously satisfied the diagnostic criteria for autism according to the DSM-IV (APA, 1994) and when completed by teachers the Childhood Autism Rating Scale (CARS; Schopler, Reichler, & Rocher Renner, 1988) classified 15 children as mild-moderately autistic, and 11 children as severely autistic. To comply with the inclusion criteria, all participants scored within the autistic range (scores ranged between 32 and 54). Due to task compliance difficulties and eye-tracking calibration requirements 6 participants were excluded (on CARS: 1 mild-moderately autistic, 5 severely autistic) and the final sample comprised 20 individuals between 6 years 4 months and 18 years 4 months (mean 13 years 4 months; see Table 1). Participants with autism were individually matched to typically developing individuals of comparable chronological age and nonverbal ability. The chronological age matched group ranged 6 years 2 months to 18 years 8 months (mean 13 years 3 months; difference between groups p=.89). For nonverbal ability, using the RCPM, the group with autism scored between 7 and 20 (mean 13) and the typically developing group also scored between 7 and 20 (mean 13, difference between groups p=.59). Informed consent and ethical approval were received prior to the research.

Table 1: Participant demographic data (standard deviation in parenthesis)

Group	N	Gender M:F[1]	CA[2]	RCPM Score[3]
WS	16	11:5	17:06 (76m)	16 (5)
CA match	16	10:6	17:06 (75m)	29 (4)
NV match	16	11:5	7:06 (48m)	17 (6)
Autism	20	15:5	13:04 (48m)	13 (4)
CA match	20	14:6	13:03 (48m)	25 (6)
NV match	20	13:7	5:03 (17m)	13 (3)

1. Number of males: number of females in the group
2. Chronological age (CA) in years: months (sd in full months)
3. Ravens coloured progressive matrices (RCPM) raw score with sd in brackets (max. 36)

Stimuli

Static images

Frame-shots were taken from '*The Adventures of TinTin'*© (Anchor Bay Entertainment). The TinTin© animation was chosen due to the realistic nature of character representations, alongside a reduction in ecological validity / social realism. Images were standardised to 640 by 480 pixels using Adobe Photoshop CS.

The colour static scenes were presented for 5 seconds and separated by a white screen lasting 1 second. Participants saw 20 scenes (in randomised order) containing characters and 5 randomly presented filler scenes containing no characters (e.g. a desert with a palm tree). The nature of scenes varied to show a range of situations; for example a group sat in a train carriage, two characters walking in a forest, characters sat at a desk using a telephone and characters discussing documents. The position and number of characters (between 1 and 4) varied across items. Participants were told 'please look at the pictures while they are on the screen' and no further instruction was provided.

Movie extracts

Movie stimuli were short colour extracts containing human actors or cartoon characters from '*The Adventures of TinTin'*©. For movies involving human actors, the natural interaction between individuals was recorded using a Sony digital video camera. The three clips showed a group of four adults discussing information on a piece of paper, two males chatting over coffee and a man stealing from another person's bag. Each extract lasted approximately 30 seconds. For the cartoon movies, suitable 30 second extracts from TinTin© were captured using Adobe Premiere Elements. The cartoon extracts depicted four characters taking a train journey together, two males chatting whilst sharing a bottle of wine and two males chatting whilst walking in a forest. The order in which the six movies were viewed was randomised across participants.

Apparatus

The research utilised a Tobii 1750 eye-tracker run using ClearView 2.5.1 for the presentation of stimuli and recording eye movements. The eye-tracker was controlled via a Dell Latitude D820 laptop computer. The system is completely non-invasive, with little indication that eye movements are tracked and no need to artificially constrain head or body movements. The system is portable and was moved to the testing location of each individual. The Tobii 1750 system tracks both eyes, to a rated accuracy of 0.5 degrees, sampled at 50Hz and was calibrated for each participant using a 9-point calibration of each eye.

ClearView 2.5.1 provides a 'definition tool' to identify areas of interest (AOI) for analyses. For static scenes AOI were designated to faces, bodies and the background. To further investigate fixations to the face region, AOI were designated to the eyes and mouth. The face AOI was marked with an oval shape covering the face region with a hairline boundary. The body was defined by the outline of the body excluding the face. Background was calculated by marking the outline of the complete picture and measuring fixations to the whole image, then at the point of analysis removing the fixation data towards any characters. Finally, AOI for the eyes and mouth were defined using rectangular definition tools to mark regions covering these features.

For the analysis of gaze behaviour towards movie extracts, a bespoke program was designed using Matlab that allowed analysis on a frame-by-frame basis for each extract. AOI were defined for each frame to the pre-specified regions of face, with sub-areas for eyes and mouth regions, body and background. The face was marked by following the contour of the face and body by following the outline of the character (excluding the face). Background was calculated by marking the outline of the complete frame and measuring fixations to the whole images. Across the six movie extracts (3 showing human actors and 3 showing cartoon characters) the total number of frames varied from 280 (one of the cartoons was only 10 frames per second) to 740 (mean 587 frames).

Procedure

Participants were tested individually at home or school. As well as the stimuli presented here participants viewed static images containing human actors (Riby & Hancock, 2008a). The whole session lasted 15-20 minutes. Participants were seated approximately 50 centimetres from the eye-tracking screen with the experimenter sat to one side to control the computer but not interfere with viewing behaviour. The participant was told they would see different types of pictures and movies during the session and the first eye-tracking task involved calibration of the eye tracker. For this purpose the participant followed a blue bouncing ball around the screen to 9 locations. If the calibration process failed or the participant was unable to comply with task demands they were removed from the study (6 participants with autism, 2 participants with WS and 5 participants who were developing typically). Following calibration, participants viewed the stimuli in a random order across conditions. Once all the conditions were complete the experimenter debriefed the participant and showed them an example of their recorded gaze behaviour.

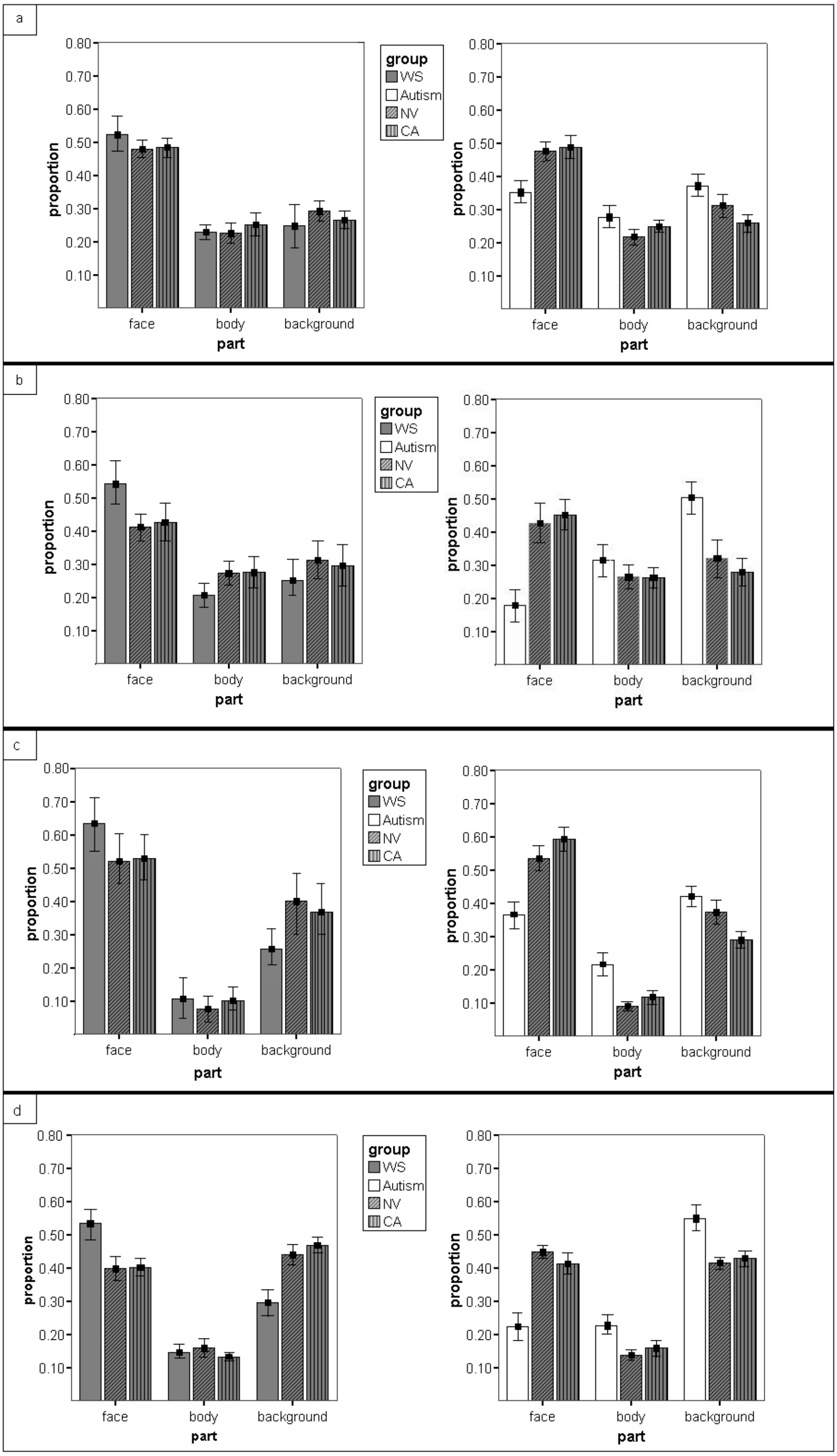

Figure 1: Gaze duration proportions for each area of interest for movie extracts a) cartoon characters b) human actors and for still images of c) cartoon characters and d) human actors (from Riby & Hancock, 2008a). The graphs on the left compare participants with WS to their matched comparison groups, whilst those on the right compare individuals with autism to their typical comparison groups. Error bars represent standard error of the mean.

Results

Figure 1 shows the proportions of gaze time to face, body and image background for each of the three stimuli types (Figure 1a,b,c). In addition to these conditions we provide the proportion data from our previous research using still images of human actors for comparison (Figure 1d). Full statistical analysis follows; here we summarize the key findings. The general pattern is that, across all stimuli types, individuals with autism spend relatively less time looking at faces and more time looking at the background or body areas. Those with WS spend relatively more time looking at faces and less at the background, but the effect is significant only for still cartoons (where it manifests as a decrease in time looking at background) and human movies. Further analysis of the face region of all the stimuli showed that individuals with autism spent less time than their controls looking at the eyes for cartoon pictures and human movies. For those with WS there was an effect only for still cartoons, where they observed the eye region more than their CA controls.

The following two sections report the full analysis of the gaze data, for WS and autism in turn. We then analyse the relationship between participant characteristics (e.g. chronological age, nonverbal ability and where appropriate level of functioning) and length of face gaze (in milliseconds).

Williams syndrome

Participants with WS did not differ from their typically developing comparison groups in the amount of time they spent attending to the cartoon pictures (p=.24), cartoon movies (p=.82) or movies of human actors (p=.82). A 2-way mixed ANOVA with the repeated factor AOI (background, face, body) and independent factor Group[1] (WS, NV, CA) examined gaze behaviour for each type of stimuli. There was a significant effect of AOI for cartoon pictures (F(2,90)=88.8, MSE=2.62, η_p^2=.66, p<.001), movies of human actors (F(2,90)=39.00, MSE=.60, η_p^2=.46, p<.001) and cartoon movies (F(2,90)=124.9, MSE=1.01, η_p^2=.74, p<.001). Importantly, there were significant interactions between AOI and Group for viewing cartoon pictures (F(4,90)=2.77, MSE=.08, η_p^2=.11, p<.05) and movies of human actors (F(4,90)=4.01, MSE=.06, η_p^2=.15, p<.01) but not for cartoon movies (p=.30).

Following up the significant interactions evident for cartoon pictures and human movie viewing revealed a number of ways in which the gaze behaviour of individuals with WS appeared atypical. For the cartoon pictures simple main effect analyses were conducted for each AOI revealing no difference in the proportion of time spent fixating on characters' bodies (p=.42) or faces (p=.14) but a significant effect for background (F(2,47)=4.29, MSE=.09, p<.05). Participants with WS spent a significantly smaller proportion of time looking at the scene background than the NV group (t(15)=4.00, p<.01, see Figure 1) and marginally less time than the CA group (t(15)=1.97, p=.06).

When viewing movies of human actors, there were other subtle atypicalities of gaze behaviour shown by significant Group effects for bodies (F(2,47)=4.35, MSE=02, $p<.05$) and faces of actors (F(2,47)=6.90, MSE=.08, p<.01), but this time not for the movie background (p=.29; see Figure 1a). When viewing faces, individuals with WS fixated for longer than those in the NV group (t(15)=3.77, p<.05; WS 0.54, NV 0.41) and the CA group (t(15)=3.08, p<.05; CA 0.42). When viewing character

[1] Due to the use of proportional gaze length to each AOI there will be no significant effect of group membership. The proportion of gaze length to each AOI will equal 1 for all participants.

bodies the WS group fixated proportionally less time than both comparison groups (WS-NV t(15)=2.77, *p*<.05; WS-CA t(15)=2.44, *p*<.05; WS 0.21, NV 0.28, CA 0.27).

Areas of interest were designated to the eye and mouth regions of characters' faces for each type of stimuli. The proportion of time spent looking at communicative Features (eyes, mouth) was investigated as a proportion of the overall time spent looking at the face across Groups[2] (WS, NV, CA). For cartoon pictures and movies of human actors ANOVA with factors Group (WS, NV, CA) and Feature (eye, mouth) revealed significant effects of facial Feature (cartoon pictures F(1,45)=171.2, MSE=2.16, η_p^2=.79, *p*<.001; human actor movies F(1,45)=11.20, MSE=.19, η_p^2=.20, *p*<.01) and a varying effect of Group (cartoon pictures minimal trend F(2,45)=2.53, MSE=.04, η_p^2=.10, *p*=.09; human actor movies F(2,45)=3.95, MSE=.14, η_p^2=.15, *p*<.05). Cartoon movie viewing showed no effect of Feature (*p*=.22; eye 0.19, mouth 0.17) or Group (*p*=.39; WS 0.16, NV 0.16, CA 0.22). There was significant interaction between Group and Feature for viewing cartoon pictures (F(2,45)=6.48 MSE=.08, η_p^2=.22, *p*<.01) but not movies of human actors (*p*=.41) or cartoon characters (p=.48).

When attending to pictures of cartoon characters there was no difference between groups when viewing the mouth region (*p*=.48; WS 0.08, NV 0.08, CA 0.11) but there was a significant difference in the proportion of face gaze directed to the eyes (F(2,47)=5.20, MSE=.12, *p*<.01; WS 0.46, NV 0.41, CA 0.29). Participants with WS fixated on the eye region for significantly longer than the CA group (t(15)=0.31, *p*<.01) but not the NV group (*p*=.42; see Figure 1).

Autism

Participants with autism did not differ from their typically developing comparison groups in the amount of time they spent attending to the cartoon pictures (*p*=.59) but they did differ in the amount of time they attended to the human actor movies (F(2,59)=15.21, *p*<.001; mean autism 20sec, NV 24sec, CA 25sec) and the cartoon movies (F(2,59)=11.1, *p*<.01; mean autism 19sec, NV 28sec, CA 27sec). The use of proportional data is therefore critical. A 2-way mixed ANOVA with the repeated factor AOI (background, face, body) and independent factor Group (Autism, NV, CA) examined gaze behaviour for each type of stimuli. There was a significant effect of AOI for all types of stimuli (cartoon pictures F(2,114)=64.3, MSE=1.93, η_p^2=.53, *p*<.001; human actor movies F(2,114)=8.11, MSE=.12, η_p^2=.13, *p*<.01; cartoon movies F(2,114)=72.2, MSE=.15, η_p^2=.56, *p*<.001). Importantly there was also a significant interaction between Group and AOI for all types of stimuli (cartoon pictures F(4,114)=7.59,MSE=.23, η_p^2=.21, *p*<.001; human actor movies F(4,114)=24.1, MSE=.38, η_p^2=.46, *p*<.001; cartoon movies F(6,171)=12.3, MSE=.10, η_p^2=.30, *p*<.001).

Investigating the significant interaction between AOI and Group for each stimuli category revealed one aspect of gaze behaviour where participants with autism consistently differed from the typically developing individuals. For all types of stimuli individuals with autism spent a significantly smaller proportion of their time fixating on the face region than both the NV and CA groups (cartoon pictures F(2,59)=9.89, MSE=.28, *p*<.001; human actor movies F(2,59)=31.2, MSE=.45, *p*<.001; cartoon movies F(2,59)=20.6, MSE=.02, *p*<.001, see Figure 1). The behaviour of the autism group in comparison to the typically developing groups differed less systematically

[2] It is possible for there to be an effect of Group for calculations within the face region as this analysis does not consider gaze to the full face but only to the two main communicative facial regions.

across stimuli for the other areas of interest. Group effects for the Background (cartoon pictures F(2,59)=4.56, MSE=.09, *p*<.05; human actor movies F(2,59)=21.7, MSE=.28, *p*<.001; cartoon movies F(2,59)=9.24, MSE=.06, *p*<.001) were due to participants with autism spending a significantly larger proportion of their time fixating in this region than the CA group (cartoon pictures t(19)=3.18, *p*<.01; human actor movies t(19)=5.95, *p*<.001; cartoon movies t(19)=5.42, *p*<.001). Although participants with autism spent the same amount of time viewing the background of cartoon pictures compared to their NV matches (*p*=.46) they spent significantly longer compared to the NV group for human actor movies (t(19)=4.26, *p*<.001) and cartoon movies (t(19)=2.14, *p*=.05).

Across stimuli the groups showed a significant difference in the way attention was allocated to characters bodies (cartoon pictures F(2,59)=6.95, MSE=.09, *p*<.01; human actor movies F(2,59)=2.92, MSE=.02, *p*=.06; cartoon movies F(2,59)=4.99, MSE=.12, *p*<.05). For cartoon pictures participants with autism spent a larger proportion of their time viewing this region than either comparison group (A-NV t(19)=4.10, *p*<.01; A-CA t(19)=2.23, *p*<.05). For movies of human actors the group with autism showed no difference in the amount of time fixating on the body compared to the NV group (*p*=.09) but fixated for proportionally longer than the CA group (t(19)=2.22, *p*<.05). Finally, for cartoon movies, compared to individuals of comparable nonverbal ability the group with autism spent significantly more time looking at bodies (t(19)=3.17, *p*<.01) although compared to those of comparable age there was no difference (*p*=.23).

The proportion of time spent looking at communicative Features (eyes, mouth) was investigated as a proportion of the overall time spent looking at the face across Groups (Autism, NV, CA). There was a significant effect of Feature for cartoon pictures (F(1,57)=40.5, MSE=1.12, η_p^2=.42, *p*<.001; mean eyes 0.29, mouth 0.10) and human movies (F(1, 57)=3.34, MSE=.14, η_p^2=.06, *p*=.07; mean eyes 0.26, mouth 0.21) but not for cartoon movies (*p*=49; eyes 0.23, mouth 0.21). The effect of Group was marginal for cartoon pictures (F(2,57)=2.95, MSE=.06, η_p^2=.09, *p*=.06) and significant for both types of movie (human actor F(2,57)=13.29, MSE=.58, η_p^2=.33, *p*<.001; cartoon F(2,57)=4.74, *p*<.05). For cartoon movies there was no significant interaction between factors (*p*=.26) but this was significant for human movies (F(2,57)=3.31, MSE=.13, η_p^2=.10, *p*<.001) and cartoon pictures (F(2,57)=3.67, MSE=.10, η_p^2=.11, *p*<.05).

Following up the significant interactions, there was a difference between groups for fixations to the eyes for cartoon pictures (F(2,59)=4.26, MSE=.16, *p*<.05; autism 0.19, NV 0.39, CA 0.31) and human movies (F(2,57)=12.93, MSE=.62; *p*<.001; autism 0.06, NV 0.24, CA 0.41). Participants with autism spent a smaller proportion of time than both comparison groups fixating on the eye region when viewing cartoon pictures (A-NV t(19)=4.19, *p*<.001; A-CA t(19)=3.78, *p*<.01) and human movies (A-NV t(19)=3.01, *p*<.01; A-CA group t(19)=5.11, *p*<.001). For the mouth region, there was no effect of Group for viewing cartoon pictures (*p*=.78; autism 0.11, NV 0.08, CA 0.10). For movies of human actors there was no difference between the autism and NV groups (*p*=.65; Autism 0.12, NV 0.14) but there was a trend for the group with autism to spend a significantly smaller proportion of time than the CA group (t(19)=1.92, *p*=.07; CA 0.24).

a)

b)

Figure 2: Example differences of visual fixation points for a) individuals with WS and b) autism towards one frame of a movie showing human actors.

Participant characteristics and face gaze

Pearson correlation was used to investigate the relationship between the amount of time spent looking at the faces of actors / cartoon characters and participant characteristics (chronological age, nonverbal ability and where appropriate level of functioning on the autistic spectrum). For all groups (participants with autism, those with WS and their typically developing matched comparisons) there were no significant correlations between the amount of time spent fixating on the face region and either chronological age or nonverbal ability, irrespective of stimuli type. However, participants with autism showed a significant negative correlation between level of functioning according to the CARS and amount of time looking at faces for static cartoon pictures ($r=-.69$, $p=.06$), movies of human actors ($r=-.81$, $p<.001$), and cartoon movies ($r=-.72$, $p<.05$). In all cases, longer face gaze was associated with higher functioning on the autistic spectrum (lower CARS score).

Discussion

Previous research has used eye-tracking to emphasise the atypical nature of social interests associated with autism (Klin et al., 2002; Speer et al., 2007) and the current study indicates that atypicalities of gaze behaviour extend to WS. The evidence suggests that the social phenotypes and socio-cognitive skills typically associated with autism and WS are linked to the gaze behaviours shown by each group when attending (or not attending) to socially relevant information. Extending our previous research (Riby & Hancock, 2008a), the movie extracts and still images showed social interactions between characters (human or cartoon) and analysis of fixation durations reveals atypical gaze behaviour in both autism and WS.

Previous discrepancies in the autism literature indicated the need to vary stimuli characteristics with the same participants; providing the impetus for including cartoon stimuli. The current results suggest that atypicalities of gaze behaviours remain when the ecological validity of character depictions is reduced (using cartoons) for individuals with autism, but are significantly affected for individuals with WS. The differential impact of social realism (or ecological validity) suggests the atypicalities of social gaze evident in autism and WS are related to a different underlying causation, possibly relating to differences in socio-cognitive skills. However, the underlying nature of any atypicality cannot be deciphered by the current study and future research using eye-tracking methods alongside socio-cognitive tasks, across a range of stimuli and individuals, is necessary for that aim.

The type of 'comparison' group that is employed is often controversial in research involving participants with disorders of development (cf. Jarrod & Brock, 2004). The nature of group differences across various stimuli in the current study emphasizes the need for comparing performance against typically developing individuals to explore the typicality of gaze behaviour. Although we considered that gaze behaviour to social relevant stimuli would be related to life experience of interacting in a social environment, chronological age was not related to gaze towards socially salient information (the face region). This finding may related to fact that there is no significant correlation between chronological age and various face perception skills for individuals with WS and Autism (Riby et al., 2008b).

When viewing human actors in social situations individuals with WS exhibit prolonged face gaze for movie extracts that mirror those found for still images (Riby & Hancock, 2008a) and in face-search procedures (Riby & Hancock, 2008b) and demonstrate the opposite pattern to individuals with autism. However, our WS group differs from the autism group in that atypicalities of gaze behaviour are reduced or even eliminated when viewing movies of cartoon characters. The inclusion of human actors is therefore central to the observed atypicalities of social gaze in WS when observing moving stimuli and this provides experimental evidence of the nature of prolonged face gaze exhibited by toddlers (Mervis et al., 2003) and shown by adolescents and adults during interviews (Doherty-Sneddon, Riby, Calderwood, &

Ainsworth, submitted). Prolonged face fixations may mean that individuals with WS are less aroused by holding face gaze (Doherty-Sneddon et al., submitted) and therefore do not need to disengage as rapidly as typically developing individuals or those with autism. Alternatively attention mechanisms may play an important role in face disengagement (cf. Riby & Hancock, 2008b). Future research needs to disentangle the relative contribution of these two arguments.

A peculiarity of the current data, together with those in Riby and Hancock (2008a), is the lack of an effect for cartoon movies in those with WS, despite there being one for cartoon stills. An argument based on social realism would predict a greater effect for movies. One possibility is the deficit in motion processing that is characteristic of WS. While biological form processing is relatively good in WS (Reiss, Hoffman & Landau, 2005), it is possible that the impoverished representations of people in cartoons are insufficient to overcome motion processing deficits. Although gaze patterns to cartoon movies resemble those of typically developing controls, further work would be required to ascertain whether those with WS are able to understand the action as well. This might have implications for the design of social skills training materials that use moving or static representations.

One aim of this work was to resolve the discrepancy between Klin et al (2002b), who reported atypicalities of gaze behaviour to movies with human actors and van der Geest et al. (2002a) who found no such effect for drawn images of people. These previous studies were central to the use of human actors and cartoon character stimuli with the same participants in the current study. We suspected that the reduced ecological validity of the drawings might have accounted for a lack of effect found by van der Geest and colleagues; however our autism group differed from their controls on all types of stimuli (including static photographs, reported in Riby & Hancock, 2008a). The use of cartoon drawings did not remove the atypicalities of gaze behavior. There remain two likely sources for the difference: different groups of participants in the two earlier studies, where ours were the same across stimuli; and differing levels of ecological validity in the cartoon drawings between our stimuli and those of van der Geest et al. Our cartoons showed relatively realistic interpretations of characters within social scenes whilst those used previously were disproportionate two-dimensional images of a single person within a picture (van der Geest et al., 2002a). While our cartoon movies were sufficiently non-lifelike to affect the behaviour of the WS group (although some atypicalities do remain for static images), there is evidently sufficient socially relevant information (e.g. people interacting) to influence gaze behaviour in autism. The lack of correlation between chronological age and gaze behavior for both groups with disorders of development implies that any difference across groups is unlikely to be due to participants with WS being older than those with autism. Based on these facts, the inclusion of cartoon stimuli as well those involving human actors reveal important differences between groups with disorders of development.

Speer et al. (2007) found that individuals with autism only showed atypicalities of gaze behaviour for movies containing more than one character. While the current study does replicate atypicalities of fixations for this type of stimuli, the atypicalities extend to other stimuli. The studies differ in participant groups (level of functioning on the autistic spectrum) and the nature of stimuli; either or both may account for the different results. The fact that the participants in the current study showed a significant negative correlation between level of autistic functioning and face gaze length emphasizes the important role played by participant characteristics. Additionally, Speer et al (2007) report fixation length without noting whether overall gaze time differed between groups (the impetus for using proportion of gaze time). In the current study, movie stimuli did not attract the attention of participants with autism in the same way as typically developing participants or those with WS; evidenced by reduced overall gaze time. This reduced attention to movies was not related to participant age. Reduced attention capture by the movies reveals that participants with autism may be less engaged by moving and complex information with sound and language (compared to static images). Research by Speer and colleagues suggests that this may be particularly evident by atypicalities of gaze behaviour when two or more characters interact. If stimuli of this nature do not capture attention then children with autism are likely to have less opportunity to learn important cues. We propose that the complexity of the movie information in some way 'distracts' or 'overloads' the attention of participants with autism in a way that is not possible for static images. This finding has important implications for the design of teaching materials and implies that children with autism may be more engaged by pictures than by 'moving' or 'complex' information.

When fixations in the face region occur for movie stimuli future research would benefit from explorations of the time course of face gaze for individuals with disorders of development known to impact upon social communication. For example, is the timing of face gaze critical to the exaggerated or reduced fixation of individuals with WS and autism respectively? Face gaze is not typical in either group but there may be much more subtle atypicality that relates to the timing of gaze. This may correspond with the way individuals use gaze in natural interactions (e.g. Doherty-Sneddon et al., submitted; Willemsen-Swinkels, Buitelaar, Weijnen, & van Engeland, 1998). Designing tasks that can explore the time course of face gaze would be particularly beneficial.

The gaze behavior to the eye and mouth regions reveals that for movies of human actors participants with autism exhibit reduced fixations to the eye region, but not to the mouth region. Interestingly, although participants with WS show a 'typical' pattern with more attention to the eye than mouth region for these human actor movies, this group spends a larger proportion of face gaze attending to these facial regions than their comparison groups. This may imply a subtly atypical allocation of attention within the face for individuals with WS. These atypicalities are removed by the use of cartoon stimuli for participants with WS, but not for participants with autism who continue to exhibit atypical facial region fixations. In summary the results replicate suggestions by Klin and colleagues (2002b) that gaze behaviour (specifically face gaze) is related to level of functioning on the autistic spectrum. Importantly, some care is needed when interpreting eye and mouth region fixations for movie stimuli. Only a portion of movie frames were used due to the nature of the stimuli; wide angle shots provide sufficient background information to appear realistic but inherently mean that the eye and mouth regions are small in relation to the complete movie frame. Stimuli used by Klin and colleagues were chosen to provide clips where the character's head was greater than 5° of the participants' visual field of view. The characters in the movie extracts used by Klin and colleagues were presented in order to show intense interactions between individuals and provide very little background or 'non-essential objects' that may cause distraction. In the current research we were particularly interested in whether the presence of non-social information did attract attention away from the characters' face or body. In order to achieve this aim the movie stimuli showed a range of natural situations and the stimuli were not constrained (see Figure 2).

From the current evidence, it should be assumed that if an individual with autism is looking at a picture containing a person they will be doing so in a non-typical manner, even if the image is non-photographic. The most natural stimuli here, colour movie extracts with sounds and speech between characters, should provide the best indication of behaviour in natural social interactions. In this condition, individuals with both WS and autism show characteristically atypical gaze behaviours that relate to their respective social phenotypes and socio-cognitive abilities.

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