Gaze Aversion during Social Style Interactions in Autism Spectrum Disorder and Williams syndrome

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Abstract

During face-to-face interactions typically developing individuals use gaze aversion (GA), away from their questioner, when thinking. GA is also used when individuals with Autism (ASD) and Williams syndrome (WS) are thinking during question-answer interactions. We investigated GA strategies during face-to-face social style interactions with familiar and unfamiliar interlocutors. Participants with WS and ASD used overall typical amounts / patterns of GA with all participants looking away most while thinking and remembering (in contrast to listening and speaking). However there were a couple of specific disorder related differences: participants with WS looked away less when thinking and interacting with unfamiliar interlocutors; in typical development and WS familiarity was associated with reduced gaze aversion, however no such difference was evident in ASD. Results inform typical / atypical social and cognitive phenotypes. We conclude that gaze aversion serves some common functions in typical and atypical development in terms of managing the cognitive and social load of interactions. There are some specific idiosyncracies associated with managing familiarity in ASD and WS with elevated sociability with unfamiliar others in WS and a lack of differentiation to interlocutor familiarity in ASD. Regardless of the familiarity of the interlocutor, GA is associated with thinking for typically developing as well as atypically developing groups. Social skills training must take this into account.

Keywords: Eye contact; Gaze; Williams syndrome; Gaze Aversion; Autism Spectrum Disorder.

Abbreviations: GA - gaze aversion

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1. Introduction

Eye gaze serves many functions; ranging from social and emotional to intellectual. Furthermore, gaze behaviour plays an important role in many aspects of child development. Measures of gaze provide insights into typical and atypical social, emotional and cognitive development. For example, there are developmental changes in how infants respond to observed head and eye gaze shifts over the first 36 months of life (Moore & Corkum, 1998; Doherty, Anderson & Howieson, 2008) linked to the maturation of socio-cognitive systems.

1.1 Gaze Aversion and Cognition

Typically, we spontaneously and consistently look away from the face of an interlocutor during cognitively-demanding activity by engaging in the overt behavioural response of ‘gaze aversion’ (GA; Doherty-Sneddon et al., 2002; Glenberg et al., 1998). While GA occurs very little when people are listening to another person speak (Doherty-Sneddon et al., 2002; Glenberg et al., 1998), it predominantly occurs while thinking and (albeit to a lesser extent) while speaking. So, the occurrence of GA potentially reflects the need to concentrate on drawing information from memory and / or engage in on-line cognitive processing, such as speech-planning or computation (Doherty-Sneddon et al., 2002; Glenberg et al., 1998). Conversely, given that under normal circumstances speech perception may be facilitated by the processing of visual information from a speakers face (McGurk & MacDonald, 1976), having access to relevant visual cues is most beneficial while listening to a speaker. In other words, we attend to visual cues when they are most useful to us, but when we need to concentrate on internal cognitive processing we ‘ignore’ them by averting our gaze away from the person with whom we are interacting - the ‘cognitive load hypothesis’ of gaze aversion. Consistent with this interpretation is the finding that GA also occurs in response to objects other than faces, including video-cameras (e.g. Ehrlichman, Weiner, & Baker, 1974).

1.2 Gaze Aversion in Typical Development

Empirical work suggests that children start to use GA whilst thinking (and, to a lesser extent, speaking) from around 5 years of age (e.g. Doherty-Sneddon et al., 2002; Phelps, Doherty-Sneddon & Warnock, 2006). Indeed, it has been argued that a significant developmental surge in the use of GA behaviours during thought occurs between 5 and 6 years of age (Phelps et al., 2006); a behaviour which continues to develop (less markedly) throughout the next two years. So, by the time children have reached 8 years of age they use GA like adults to help them manage cognitive load (Doherty-Sneddon & Phelps, 2005; Doherty-Sneddon et al., 2002). In contrast, 5-year-old children have been shown to use GA to a much lesser extent (about half the proportion of thinking time as older children and adults), and also fail to consistently increase their looking away in response to increasingly difficult questions although some evidence for this does occur (Doherty-Sneddon et al., 2002; Phelps et al., 2006).

1.3 Neuro-Developmental Disorders and Eye Gaze

Williams syndrome (WS) and Autism Spectrum Disorders (ASD) are neuro-developmental disorders associated with atypical patterns of gaze behaviour, atypicalities of social functioning and intellectual impairment. In the current studies we provide novel analyses of GA during social interactions by participants in these groups, contrasting GA while listening, thinking and speaking with familiar and unfamiliar interlocutors. These measures provide innovative new ways of addressing the cognitive and social phenotypes of the groups, revealing possible syndrome-specific effects of atypical development on social interaction styles and informing typical developmental theory (for the importance of these disorders for informing typical developmental theory see Asada & Itakura, 2012). In addition these two disorders afford new insights into the implications of gaze behaviour for information processing during face-to-face interaction.

1.3.1 Williams syndrome

Williams syndrome (WS) is a relatively rare neuro-developmental disorder (estimated prevalence 1:20,000, Morris & Mervis, 2000; but see Strømme, Bjørnstad, & Ramstad, 2002) caused by the microdeletion of approximately 25-28 genes on chromosome 7 (7q11.23; Donnai & Karmiloff-Smith, 2000). This developmental disorder is associated with mild to moderate intellectual impairment (Searcy et al., 2004) that occurs alongside unique cognitive and socio-behavioural phenotypes. The social characteristics are very different from those associated with the autism spectrum (Brock, Einav, & Riby, 2007; for discussion of the benefit of direct comparison between these disorders see Asada & Itakura, 2012). Individuals with WS often show outgoing social behaviours that have been referred to as ‘hypersocial’ (e.g. Jones et al., 2000; Frigerio et al., 2006), they may treat everyone as their friend irrespective of familiarity (Gosch & Pankau, 1997), and during social engagement they may use intense eye contact (Mervis et al., 2003) and atypical social interaction styles (e.g. Asada, Tomiwa, Okada, & Itakura, 2010). Williams syndrome has been described as being at the 'opposite end of the spectrum' to autism and hence why they are an interesting comparison group in studies of socio-cognitive profiles.

Modulating attention, a skill highly related to eye gaze behaviour, may be problematic for individuals with WS (Cornish, Scerif, &Karmiloff-Smith, 2007) and may be entwined with problems shifting gaze towards and away from faces (Riby et al., 2011). Research has suggested that frontal lobe dysfunction and executive functioning deficits may contribute to aspects of the WS behavioural and social phenotypes (Rhodes, Riby, Park, Fraser, & Campbell, 2010) and contribute to atypical gaze behaviours (Porter, Coltheart, & Langdon, 2007). It is further proposed that individuals with WS have problems that are specific to attention disengagement (rather than engagement) and that these problems are especially clear when disengaging from faces (Riby et al., 2011; Riby & Hancock, 2009b). Therefore, attentional deficits have been provided as possible contributors to atypical social behaviours (such as increased attention to faces) in WS, with the alternative being the role of abnormal amygdala structure and function (e.g. Haas et al., 2009). How and when individuals with WS look away during an interaction is therefore of considerable interest.

1.3.2 Autism Spectrum Disorders

Autism spectrum disorders (ASDs) cover a range of pervasive developmental impairments that have a particular effect upon the way an individual functions and interacts socially. Autism is characterised by severe impairments of social functioning, a lack of interest in social interactions, and abnormal eye contact (e.g. Frith, 1989). Indeed many of the classic descriptions of the disorder focus on a lack of interest in others and the atypical use of gaze (e.g. Lord et al., 2000). Indeed there is now considerable eye tracking evidence to emphasise a lack of attention to face, especially the eye region for individuals with ASD compared to those developing typically (e.g. Klin et al., 2002; Riby & Hancock, 2008). This evidence is also extrapolated to real-life interactions, Willemsen-Swinkels, Buitelaar, Weijnen and van Engeland (1998) explored gaze and social behaviours of children with pervasive developmental disorder (PDD; 11 out of 19 had autism) in parent – child interactions. They found that several aspects of gaze behaviour were very similar for the high functioning PDD and controls e.g. the overall amount of mutual gaze. However, the high functioning children with PDD did show atypicalities in the timing of gaze. For example, they were less likely to precede their declarative pointing with a gaze towards the parent than matched children with specific language delay or typically developing children.

It has been proposed that some of the core social deficits associated with autism can be interpreted in terms of deviant cognitive processing; namely executive dysfunction (e.g. Russell, 1997). Part of the problem may be an inability to disengage from salient objects or inhibit responses that are inappropriate. Problems with the executive control of attention would predict atypicalities in the modulation of gaze during social interactions in a similar manner as that suggested for WS. Furthermore, the neural mechanisms / structures that have been implicated in the atypical social phenotype of ASD and inattention to faces are similar to those associated with WS. Dalton et al., (2005) note that activation of both the amygdala and fusiform gyrus regions were positively associated with time spent looking at the eye region of faces by individuals with an ASD. They suggest a heightened emotional response associated with gaze fixation in ASD that may be associated with active avoidance of face contact. In contrast, Senju and Johnson (2009a, b) propose that in autism atypical gaze is associated with a failure to respond to social cues, rather than an active avoidance of them. Whichever model is correct, the pattern of fixation to and away from faces in relation to cognitive and social load, is of interest. Throughout the current manuscript we use the term gaze aversion to mean 'reduced gaze fixation to interlocutor's face'. This averting gaze behavior may be the result of aversion to faces, but may equally reflect a preference to look at other things in the visual environment over faces. The term 'gaze aversion' does not imply here and 'aversion to faces' on the part of the averter. We are particularly interested to see whether GA is modulated across different interactional demands (specifically: listening; thinking; and speaking) in social interactions.

1.3.3 WS and ASD and the use of gaze aversion

A crucial point to make here is that the literature on atypicality in gaze behaviour in both WS and ASDs relates primarily to explaining atypical perception of gaze and its impact on behaviour. In contrast, we focus on how cognitive activity and interlocutor familiarity in both these populations may or may not modulate face contact (with implications for eye contact). In terms of WS, Doherty-Sneddon, Riby, Calderwood and Ainsworth (2009) and Doherty-Sneddon, Riby and Whittle (2012) have reported typical increases of GA accompanying increases in cognitive load when completing question and answer sessions involving mathematics questions. These studies also report higher levels of GA when thinking than when listening or speaking, replicating a typical pattern. In terms of ASD, Doherty-Sneddon et al. (2012) report increases of GA once again in terms of cognitive load (question difficulty increases) and highest levels of GA when thinking. However, individuals with ASD also showed atypically increased levels of GA while listening to questions (but not while thinking about or making their responses), suggesting that they sometimes fail to see the relevance of attending to visual cues rather than actively avoid them. These patterns seem counter-intuitive given the vast amount of documentation of atypical patterns of gaze behavior in both these populations. It is therefore timely to investigate GA with these groups in more socially-mediated encounters where the cognitive demands of the interaction are minimal.

For the current study it is also important to look at the relative impact that familiarity of an interlocutor may have on gaze behavior. We know in typical adults and children that amount of eye contact is in part determined by the closeness of the social relationship (and familiarity is part of this) with, for example, more looking between close friends than strangers (Argyle & Dean, 1965; Rubin). In contrast Sterling, Dawson, Webb, Murias, Munson, Panagiotides and Aylward (2010) report that typically developing adults actually spent less time fixating on familiar faces than unfamiliar faces. One interpretation of this is that participants had to spend more time processing the unfamiliar information in the unfamiliar faces. However, their study was an eye tracking study where participants were looking at static black and white images. This may explain the apparent anomaly with the earlier social studies of interpersonal eye gaze.

To date there are no studies investigating the relative effect that familiarity has on the live face-to-face gaze behavior of people with WS or ASD. Research on face perception has consistently shown that the way we view and process faces is affected by familiarity. For example, typically developing individuals (adults and older children) modify the type of information they use for recognizing familiar versus unfamiliar people (e.g. using internal or external regions of a face; Young, Hay, & McWeeney, 1985). Individuals with WS may show atypical strategies for unfamiliar face perception that are more typically related to familiar faces (e.g. Riby, Doherty-Sneddon & Bruce, 2009). For example, Riby et al. (2009) report an ‘internal feature advantage’ for unfamiliar faces in individuals with WS that is typically evidenced only for familiar face recognition. Given evidence of increased approach to unfamiliar people and an interest in looking at faces irrespective of familiarity (e.g. Mervis et al., 2003, Riby & Hancock, 2008) there is a need for further research to be conducted exploring the effect of familiarity on face gaze associated with WS. This is especially important using personally familiar faces and real life interactions.

The story is slightly different in terms of ASD. Previous research has suggested atypical activation of neural mechanisms when viewing unfamiliar faces (e.g. Critchley et al. 2000) but relatively typical activation when viewing familiar faces (e.g. Pierce et al. 2004). Dalton and colleagues (2005) report that greater activation of the fusiform gyrus and occipital cortex for personally familiar compared to unfamiliar faces is only found in typically developing individuals and is not seen in individuals with autism. Sterling et al (2010) used eye tracking and reported that individuals with ASD did not differ their eye movements according to familiarity of faces, a pattern seen in typical development. Therefore it is suggested that these two types of face stimuli induce similar patterns of brain activation for individuals with autism but not for typically developing individuals (Dawson et al., 2002; Dalton et al., 2005).

In Experiment 1, we investigate whether children with ASD show typical patterns of GA over the listening, thinking and speaking phases of a face-to-face social style interaction with both familiar and unfamiliar interlocutors. The familiar person was someone who was personally highly familiar to the participant (e.g. a parent) while the unfamiliar person was the experimenter. Due to the literature reported so far, it may be evident that individuals with ASD show a lack of difference between their levels of looking at (and away from) familiar and unfamiliar people. In Experiment 2, we investigate GA in face-to-face interactions in WS. Given the evidence of increased approach to unfamiliar people and an interest in looking at faces reported so far, gaze behavior of individuals with WS may be less affected by familiarity than in typical development.

The protocol used is not an entirely natural social interaction. Participants are asked to watch a video clip and then discuss it with either a familiar or unfamiliar other. It was necessary to constrain the topic and give some structure in order to ensure that roughly the same sort of conversation was had by all participants- in terms of style and content. In addition while there is a structure to the conversation (it is about a video clip and the questions asked are scripted) the questions used were designed to elicit free narrative (question 1) or to be open ended (questions 2 and 3). These sorts of questions are constructed in order to elicit spontaneous free flow of conversation (e.g. Doherty-Sneddon & McAuley, 2000). Therefore while the procedure does not allow for an entirely natural social conversation, it approaches this as far as possible.

It is hypothesized that:

1. Based on previous research looking at gaze aversion in problem-solving interactions (e.g. Doherty-Sneddon et al. 2002) and based on previous gaze aversion research with these populations (Doherty-Sneddon et al., 2012) we predict that GA will modulate across phases of the interaction in the current social interactions in all groups- occurring primarily during the thinking phase of the interactions, followed by the speaking phase, and very little during listening.
2. Familiarity of interlocutor will influence the amount of GA (Argyle & Dean, 1965; Rubin, 1970; and cf Sterling et al. 2010) for typically developing children. We predict no difference associated with familiarity in children with ASD (Sterling et al, 2010); and that individuals with WS will use less GA wheninteracting with unfamiliar

interlocutors compared with typically developing participants due to their ‘hypersociability’ towards strangers (e.g. Gosch & Pankau, 1997). This will be most evident during the thinking phase of the interaction as this is where most GA has been found in previous studies.

3. Based on our earlier work (Doherty-Sneddon et al 2012) we predict that individuals with ASD will show atypically higher levels of GA during the listening phase of the interactions than the other groups.

2. EXPERIMENT 1: Gaze Aversion in Autism Spectrum Disorder

2.1 Method

2.1.1 Participants

Eleven participants with ASD (9 males, 2 females) ranged from 12 years 4 months to 15 years 9 months, mean 13 years 7 months from a special education unit of a mainstream secondary school and from schools for pupils with additional educational needs took part. All parents confirmed that their child had previously been diagnosed with an Autism Spectrum Disorder by a clinician and provided informed and written consent for their child to participate. Teachers completed the Social Communication Questionnaire - Current (SCQ; Rutter, Bailey, & Lord, 2003) for each child. The SCQ - current is a questionnaire that provides a quick and easy confirmation of functioning on the autism spectrum for any individual over 4 years of age. The questionnaire looks at the child's behaviour over the most recent 3 month period. The SCQ is considered a valid measure for confirmation of functioning on the autism sepctrum and is regularly used in research for this purpose (see

Chandler et al., 2007). The mean score on SCQ was 25 (range 17-37). The clinical cut off for ASD is 15. The sample therefore is all above this clinical threshold and in addition represents functioning across the spectrum.

Each individual in the ASD group was matched to a typically developing child (5 males, 6 females mean chronological age 11 years 3 months, ranging from 7 years 3 months to 15 years 10 months) on the basis of verbal ability using raw scores on the British Picture Vocabulary Scale II (BPVS II, Dunn, Dunn, Whetton, & Burley, 1997). An independent t-test showed that there was no significant difference between groups on BPVS scores (p > .05) although the ASD group was significantly older than the TD group t(20)=2.61, p<.05 (see Table 1). Due to the difference between verbal ability and chronological age in the ASD group it would be expected that the typically developing matches would be chronologically younger than the ASD group. Verbal ability was used as the matching criteria for this study because the participants would be engaged in a verbal interaction with the experimenter, this also allows direct comparison to our previous research which has used verbal ability (specifically BPVS raw scores) as group matching criteria (Doherty-Sneddon et al., 2012). All participants had normal or corrected-to-normal vision.

Demographic data for participants in Experiments 1 and 2 are given in Table 1.

2.1.2 Materials and Design

Participants were video recorded while they answered questions about 2 short (1 minute) animated video clips they had watched. The clips showed two cartoon animal characters engaged in a chasing game or a play interaction and the clip was full of action to hold the attention of the individuals watching the clip. The interlocutor was either someone familiar to them (e.g. a parent; teacher; sibling) or unfamiliar (the researcher). The familiar interlocutors in the ASD group consisted of 9 parents and 2 teachers. The familiars in the matched controls were 11 parents and 1 sibling. The order in which participants viewed each of the video clips was counterbalanced across the group as the order in which they interacted with their familiar / unfamiliar partner.

2.1.3 Procedure

The session included 3 questions (always asked in the same order):

- Tell me everything you can remember about the video clip.
- What is your favorite character and why?
- What is your favorite part and why?

The first question is a very open question designed to elicit free narrative. The second 2 questions were more specific.

Before the task, the familiar person was given instructions about how to perform the task and during the task they were given a sheet with the questions to be asked, prompts, and were reminded not to interrupt the participant during their answers. The questioner was instructed to prompt (Can you tell me a bit more?) the participant when the participant didn't fully answer the questions or they felt the participant could describe more. During the Unfamiliar Condition the familiar person waited outside of the room or out of view. During the Familiar Condition the researcher waited outside of the room or out of view.

The experimenter/familiar other and the participant sat across from each other at a table (approximately 1 to 1.5 meters apart). A video recorder was set up behind the experimenter to monitor the eye gaze behaviour of the participant. Gaze aversion was defined as occurring whenever direction of eye gaze was diverted away from the face of the interlocutor. Gaze aversion was coded during “listening”, ‘‘thinking’’ and “speaking” time. Listening time was defined as the period of time during which the experimenter was asking the question. Thinking time was from when the experimenter finishing asking a question to when the participant began their answer. Speaking time was the period of time during which the participant spoke their response. These 3 phases of interaction reflected the natural progression of the question-answer interaction between participants and were not explicitly distinguished during the questioning. Each of these phases was analysed as a percentage of time spent averting gaze during that phase. For example total time spent averting gaze during the thinking period divided by the total time used for thinking (for further details see Doherty-Sneddon et al., 2002 or Doherty-Sneddon et al., 2012). The video records were viewed and reviewed as necessary in order to determine amount of time spent in GA.

Inter-judge reliability was calculated for a random sample of the gaze aversion measurements from the video recordings (the same coders coded the video records from experiments 1 and 2 and hence the reliability measurement here is for both studies).This calculation included all of the listening, thinking, and speaking aversion scores for each of the question types for 10% of the children in the sample (10% is a typical sample for interjudge reliability assessment e.g. Doherty-Sneddon et al, 2002). In total, 126 episodes were coded by two judges. One judge was aware of the hypotheses of the study, the other was naive. The informed judge was trained by the principle investigator of the project (author 1) and in turn this judge trained the second naive judge. The judges agreed on 96% of the classifications as GA present or absent. This is an excellent level of reliability (see Krippendorff , 1980 for discussion- 80% is considered good). Furthermore, the coders' scoring for the duration of gaze aversion correlated significantly, r (126) = 0.96, p <.001.

2.2 Statistical analyses

A 3-way mixed ANOVA was used to analyze the gaze aversion data with Group (ASD; typical development) a between-participant variable, and Familiarity (familiar; unfamiliar), and Phase of Interaction (listening; thinking; speaking) within-participant variables. The percentage of time participants spent averting their gaze was the dependent variable.

2.2.1 Pre-analysis checks

Pre-analysis checks for normality within the datasets revealed that one condition (unfamiliar listening) in the gaze aversion data did not meet normality criteria (Kolmogorov-Smirnov (11) = .277, p <.05; (11) = .285, p <.05 ASD and Typical development respectively). A square-route ARCSIN transformation was therefore applied to all the gaze aversion data for the ANOVA. Following this all data was normally distributed (Kolmogorov-Smirnov > .05).

In addition, to check that familiar and unfamiliar persons in each group carried our instructions in an equivalent way and elicited similar quantities of interactions, an analysis was carried out on the amount of time spent in dialogue around question 1 (the main point of elicitation of information). A 3-way mixed ANOVA was carried out on the length of time data with factors Group (ASD; typical development), Familiarity (familiar; unfamiliar), and Phase of Interaction (listening; thinking; speaking). There were no significant main effects or interactions: Group F (1,20) = 3.12, p = .09, η_p^2 = .134 (mean ASD pairs = 16.5 secs; mean TD = 20.5 secs); Familiarity F(1,20) = .552, p > .05, η_p^2 = =.027. Interaction between Familiarity and Group was not significant, F (1,20) = .718, p > .05, η_p^2 = .035. It therefore appears that familiar and unfamiliar partners elicited equivalent amounts of dialogue in both TD and ASD groups.

2.3 Results

A 3-way mixed ANOVA was carried out on the gaze aversion data with Group (ASD; typical development) a between-participant variable, and Familiarity (familiar; unfamiliar), and Phase of Interaction (listening; thinking; speaking) within-participant variables. The percentage of time participants spent averting their gaze was the dependent variable. Phase of interaction had a significant effect (supporting hypothesis 1), with most GA when participants were thinking about their responses in contrast with listening or speaking, F (2,40) = 62.91, $p < .001$, η_p^2 = 0.76 (mean listening = 19%; thinking = 59%; speaking = 48%, see Table 1). Post hoc within-subjects t-tests showed that each level differed from the others: during the thinking phase GA was significantly greater than both listening and speaking phases (t(21) = 10.00, p <.001; t(21) = 3.44 , p < .01 respectively); GA was higher during speaking than listening (t(21) = 7.72, p <.001).

Neither Familiarity nor Group had a significant effect (hypotheses 2 and 3) on the amount that participants averted their gaze although the interaction between Familiarity and Phase of Interaction was significant, F(2,40) = 3.30, p < .05, η_p^2 = .142. Means are given in Table 1. Simple effects analysis revealed that the effect of Phase of Interaction was significant for both familiar and unfamiliar interactions: familiar (F(2,42) = = 27.36, p < .001, η_p^2 = .57;

unfamiliar $F(2,42) = 54.63$, $p < .001$, $\eta_p^2 = .72$). Familiarity did not have a significant effect on gaze aversion at any phase of the interaction. Hypothesis 2 predicted that typically developing and ASD participants would avert their gaze more when interacting with unfamiliar interlocutors. Planned comparisons t-tests showed that this was the case during the thinking phase for the typically developing participants only, $t(10) = 2.11$, $p < .05$ (mean familiar GA = 52% thinking time; mean unfamiliar GA = 71% thinking time. No other comparisons were significant in either the TD or ASD groups ($p>.05$).

Hypothesis 3 predicted that ASD participants would show relatively elevated levels of GA during listening in comparison to typical. A planned comparison t-test showed no significant effect $t(20) = 1.24$, $p = .11$ although mean gaze aversion was marginally higher for the ASD group (mean ASD = 24%; mean TD = 15%). There were no group differences during thinking or speaking phases ($t (20) = .26$, $p = .80$; $t(20) = 0.07$, $p = .95$ respectively). So while ASD participants looked away from their interlocutors nearly twice as much as typical controls while listening, their gaze towards interlocutors was very similar to controls while they were thinking and speaking. Furthermore there was a trend for listening time GA to correlate with SCQ score, $r(11) = .45$, $p = .08$.

2.4 Brief Discussion

In general all participants, typically and atypically developing, engaged in less GA in the current social interactions than we have generally found in previous work focusing more on problem solving question-answer interactions. Some comparison data from the hardest level of problem-solving questions used by Doherty-Sneddon et al (2012) is given in table 2. This illustrates that less GA was used during listening and thinking in the current social interactions. In contrast relatively more GA was found during the speaking phase in the current study. The current elevation in speaking time GA probably reflects the higher cognitive demand of more extended spoken responses. In the earlier work spoken responses were generally shorter and we only initiated once participants ‘had the answer in mind’. However, this cross-study comparison shows differences in the amount of reported GA between a problem-solving paradigm and the current social interactions, the overall patterns of most GA occurring during thinking, followed by speaking and then listening is found as in previous studies (hypothesis 1 is therefore supported).

Hypothesis 2 is supported for TD participants who used more GA when interacting with unfamiliar interlocutors than familiar ones but only during the thinking phase of interaction. In contrast, and as predicted, there was no difference or the participants with ASD in the amount that they looked away from familiar versus unfamiliar interlocutors.

Furthermore children with ASD did not avert their gaze overall more than controls. This is consistent with our earlier work in problem-solving interactions (Doherty-Sneddon et al, 2012). As in our earlier study (Doherty-Sneddon et al, 2012) there was marginal evidence that they averted more while listening however in the current study this was not significant. This is in large part due to the considerable individual differences in gaze aversion while listening. Higher SCQ scores were associated with higher levels of listening time looking away (although caution is required for this correlation due to the small sample size of the ASD group). This tentatively suggests that increased looking away during listening is linked with poorer socio-communicative functioning in this group.

[Insert Table 1]

3 EXPERIMENT 2: Gaze Aversion in Williams Syndrome

3.1 Method

3.1.1 Participants

Thirteen participants with Williams syndrome (WS; 7 males, 6 females) ranged from 10 years 10 months to 35 years 6 months, mean 21 years 11 months. All individuals were recruited through existing links with the Williams syndrome Foundation. All participants had previously been clinically diagnosed and had previously had their diagnosis confirmed with positive fluorescent in situ hybridization (FISH) testing to detect the deletion of the ELN gene in the long arm of chromosome 7. All participants were reported to have normal or corrected-to-normal vision.

Each individual with WS was matched to a typically developing child (5 males, 8 females; mean chronological age 10 years 6 months, ranging from 7 years 3 months to 15 years 10 months) on the basis of verbal ability using raw score on the British Picture Vocabulary Scale II (BPVS II, Dunn, Dunn, Whetton, & Burley, 1997). These typically developing children had not taken part in experiment 1. An independent t-test showed that there was no significant difference between groups ($p > .05$) for verbal ability although the WS group was chronologically older than the TD group ($t(24)= 4.39$, $p<.001$). All participants had normal or corrected-to-normal vision.

All methods, stimuli and procedures replicate those used in Experiment 1. See Table 1 for participant demographics and refer to the previous footnotes.

3.2 Statistical analysis

A 3-way mixed ANOVA was used to analyze the gaze aversion data with Group (ASD; typical development) a between-participant variable, and Familiarity (familiar; unfamiliar), and Phase of Interaction (listening; thinking; speaking) within-participant variables. The percentage of time participants spent averting their gaze was the dependent variable.

3.2.1 Pre-analysis checks

Pre-analysis checks for normality within the datasets revealed that 2 conditions (unfamiliar listening and unfamiliar thinking) in the gaze aversion data did not meet normality criteria (Kolmogorov-Smirnov (13) = .253, $p < .05$; (13) = .246, $p < .05$ Typical development only). A square-route ARCSIN transformation was therefore applied to all the gaze aversion data for the ANOVA. Following this all data was normally distributed (Kolmogorov-Smirnov > .05).

In addition, to check that familiar and unfamiliar persons in each group carried our instructions in an equivalent way and elicited similar quantity of interactions, an analysis was carried out on the amount of time spent in dialogue around question 1. A 3-way mixed ANOVA was carried out on the length of time data with factors Group (WS; typical development), Familiarity (familiar; unfamiliar), and Phase of Interaction (listening; thinking; speaking). This showed that there were no differences across groups ($F(1,24) = 1.83$, $p > .05$, η_p^2 = =.071) nor between familiar and unfamiliar pairs in terms of the time spent interacting

($F(1,24) = 1.303$, $p > .05$, $\eta_p^2 = =.051$). Furthermore the interaction between Familiarity and Group was not significant, $F(1,24) = .010$, $p > .05$, $\eta_p^2 = .000$. It therefore appears that familiar and unfamiliar partners elicited equivalent amounts of dialogue in both TD and WS groups.

3.3 Results

The amount that participants averted their gaze away from the face of the experimenter was significantly influenced by the phase of the interaction . A 3-way mixed design ANOVA was conducted using the gaze aversion data. Group was a between participant variable (WS; typical development) and Phase of Interaction (listening; thinking; speaking) and Familiarity (familiar; unfamiliar) were within participant variables. In support of hypothesis 1 phase of interaction had a significant effect on the percentage of time spent averting gaze with most GA occurring while participants were thinking about their response $F(2,48) = 130.67$, $p < .001$, $\eta_p^2 = 0.85$ (mean listening = 18%; thinking = 66%; speaking = 49%). Post hoc within-subjects t-tests showed that GA during thinking (hypothesis 1) was significantly greater than during both listening or speaking phases ($t(25) = 15.49$, $p <.001$; $t(25) = 6.43$, $p < .001$ respectively). In addition participants averted their gaze more while speaking than listening, $t(25) = 9.55$, $p <.001$.

In support of hypothesis 2, the effect of Familiarity approached significance $F(1, 24) = 3.23$, $p = .09$, $\eta_p^2 = 0.119$ with more GA occurring when participants interacted with someone unfamiliar to them (mean GA during familiar interaction = 40%; unfamiliar interactions = 48%).

Finally there was a significant interaction between Familiarity and Phase of Interaction, F(2,48) = 3.55, p <.05, $\eta_p^2 = .13$. Phase of interaction was significant during both familiar and unfamiliar interactions (F(2,50) = 48.25, p <.001, $\eta_p^2 = .66$; F(2,50) = 87.73, p < .001, $\eta_p^2 = .78$ respectively). Post-hoc within-subjects t-tests revealed that participants averted their gaze significantly less while interacting with familiar partners than unfamiliar during both thinking and speaking phases (thinking: t(25) = 2.29, p <.05, mean familiar 58% GA, mean unfamiliar 73% GA; speaking t(25) = 2.01 , p< .05, mean familiar 44% GA, mean unfamiliar 54% GA).

No further significant effects or interactions were found. However as stated in hypothesis 3 we predicted that WS participants would avert their gaze less from unfamiliar interlocutors than typically developing participants during the thinking phase. Planned comparisons between-subjects t-tests were therefore done comparing GA during unfamiliar encounters across groups. These showed that WS participants did indeed avert their gaze less than typical controls while interacting with unfamiliar partners although the difference was only significant during the thinking phase of interactions t(24) = 1.88, p <.05. This group difference did not occur during listening or speaking and did not occur when participants communicated with familiar interlocutors (p>.05 on all other contrasts).

3.4 Brief Discussion

Participants with WS averted their gaze to a similar degree as their typically developing counterparts and replicated the typical pattern, with more GA while thinking than listening or speaking[1]. Hypothesis 2 (that interactions with familiar interlocutors would result in less GA than those with unfamiliar partners) is supported although the difference is only evident during the thinking and speaking phases of the interactions.

This typical and consistent modulation of GA across the whole interaction is important as WS has previously been associated with a global tendency to over-gaze at interlocutors (e.g. Doyle et al., 2004). Here we find no overall evidence of 'over-gazing' or 'sticky' fixation on faces and primarily typical patterns of GA (supporting Doherty-Sneddon et al., 2012). However, WS participants did engage in less GA during thinking when interacting with unfamiliar partners than did their controls. This may suggest less social inhibition to the unfamiliar interlocutors. However it must be noted that there were 4 participants in the WS group who had mental ages of less than 8 years, while there were only 2 children in the typical controls who fell into this category. We have previously reported that GA levels stabilize around 8 years of age (Doherty-Sneddon et al, 2002). It is therefore possible that while these groups were matched on mental age that the WS group were at a slight 'disadvantage'.

4 General Discussion

Neuro-developmental disorders such as WS and ASD are often associated with atypicalities of gaze behaviour. Important theoretical distinctions have been made suggesting a range of explanations for these atypicalities; from aversion to social stimuli (e.g. active avoidance in autism, Dalton et al., 2005) to a failure to learn the social rules or significance of social cues

[1] In earlier work we have shown consistently that in typical development GA plateaus by 8 years of age (e.g. Phelps et al 2006), therefore the lack of difference between WS group and their controls is not an artifact of the chronological age of the controls.

(passive avoidance in autism and over-gazing in WS, Senju & Johnson, 2009b; Mervis et al., 2003 respectively). The current experiments help us distinguish between these possibilities.

In both experiments hypothesis 1 is strongly supported with large effects of phase of interaction on gaze aversion behaviours. All participants primarily avert their gaze while thinking, followed by speaking, with the least amount of GA occurring during listening. This has relevance for the neuro-developmental disorders investigated. In a recent study (Doherty-Sneddon et al, 2012) we showed that in question-answer interactions with an unfamiliar experimenter, where the topic was problem-solving based (primarily mental arithmetic) that GA levels, for participants with both ASD and WS were primarily 'typical' especially in relation to the cognitive load of questions. Atypicality of gaze behavior (for the parameters assessed) was evident in the listening phase (more GA in ASD) and the thinking phase (less GA in ASD) of the interaction. It is likely that it is during the listening phase that an interlocutor (at that time a speaker) would notice reduced face gaze and hence why functioning on the autism spectrum is associated with reduced eye contact (Lord et al., 2000). The pattern of results allowed us to draw an important speculative conclusion; that children with an ASD fail to recognize the significance of visual social cues while listening to questions rather than actively avoid them due to hyper-arousal or aversion to social stimulation. If their GA was driven by hyper-arousal or aversion to social stimuli we would expect elevated levels of GA across all phases of the interaction (and not the pattern observed). The current work provides an important addition to this by investigating GA in ASD and WS while participants are engaged in a far more social interaction - a conversation about a cartoon clip. Here we see that even in a social interactions (compared with the earlier problem-solving ones) that gaze aversion is modulated across the different phases of interactions. This further supports that in autism looking away from an interlocutor is not driven by active avoidance of all visual contact.

As predicted by hypothesis 2, typically developing participants averted their gaze less when interacting with familiar than unfamiliar others. This was the case in both experiments 1 and 2. The amount of eye contact (the converse to gaze aversion) that individuals engage in is a good indicator of the emotional closeness of a relationship (e.g. Argyle & Dean, 1965; Rubin, 1970) and the current results are consistent with these earlier assertions. Importantly this was also the case for participants with WS but not those with ASD. The fact that the ASD participants were the only group who did not show evidence of GA modulation across familiarity makes sense in terms of earlier work on face perception in autism. For example, these two types of face stimuli induce similar patterns of brain activation for individuals with autism but not for typically developing individuals (Dawson et al., 2002). Current results show an analogous lack of differentiation of familiarity in autism in real-time face-to-face interactions.

Furthermore, WS participants showed very similar overall levels and patterns of GA across interactions to their typical controls (hypothesis 1). This is consistent with our previous study looking at GA during problem-solving encounters in WS (Doherty-Sneddon et al, 2012). In that paper very typical amounts and patterns of GA in WS were also found. The current experiment shows that even in more social encounters participants with WS actually engage in generally typical patterns and levels of face contact and look more at people that are familiar to them than those who are unfamiliar. The one point where the WS participants diverge from typically developing individuals is in their level of GA while thinking about their responses to unfamiliar interlocutors as this was lower than that exhibited by typical controls (hypothesis 2). The current results are therefore only in part consistent with previously reported hypersociability account of WS. The baseline levels and typical modulation of GA across the interaction as well as across familiarity by the participants with WS is important given that WS has previously been associated with a global tendency to over-gaze at faces (Mervis et al., 2003; Riby & Hancock, 2008). In addition, there are accounts of a lack of differential between people who are familiar and unfamiliar in WS with hyper-sociability to strangers often reported. Research has suggested that individuals with WS rate unfamiliar people with increased approach (e.g. Jones et al., 2000; Frigerio et al., 2006) and if this is combined with an increased / prolonged attention to a person's face (e.g. Mervis et al., 2003) this can be particularly problematic. The current results suggest that WS participants avert their gaze more to unfamiliar people but only at certain points within interactions (i.e. thinking). This is the only evidence in the current data for over-gazing to unfamiliar others in WS. However it is worthy of further investigation given that the thinking phase is where most GA occurs (with the caveat that there was a slightly reduced mental age profile in the WS compared to the controls that may have caused a slight reduction in GA). Hypersociability may well only be evident under certain circumstances and will be subject to extreme individual variability.

Hypothesis 3 predicted that participants with ASD would avert their gaze more while listening than typical controls. While participants with ASD averted their gaze 56% more while listening than typical controls this difference was not significant (cf Doherty-Sneddon et al, 2012). One reason this effect did not reach significance in the current study is that there was considerable individual difference in this behavior and a relatively small sample size. The individual difference certainly seems in part due to level of functioning as SCQ scores correlated with levels of listening phase GA- with participants with poorer socio-communicative functioning/ greater impairment averting their gaze more during listening than those with less impairment (although we note that future work with a larger sample size is required to consolidate this suggestion).

The current studies have some limitations. First it is possible that the familiar interlocutors differed in terms of their behavior. For example it may be that parents/partners of participants with autism differ in their interactional style to those of participants with WS or typically developing children. However the GA behavior of participants was generally similar across all groups during the familiar interactions. The exception to this was the elevated GA during listening in ASD compared with TD, but this trend was found in both familiar and unfamiliar interactions. Furthermore length of dialogue was similar in both familiar and unfamiliar interactions and this was not influenced by Group membership. This suggests roughly similar approaches by all interlocutors interacting with participants.

A further limitation of the current work is that participant groups were matched on a measure of single word vocabulary, yet the interactive task used includes more complex language. It is therefore possible that the language measure used here does not fully capture the language skills that are contributing to the task being conducted. There is therefore a need for further work exploring in more detail the role of a comprehensive battery of language skills in this type of dialogue task with a larger sample of individuals (which is important to both increase statistical power and explore individual variability within disorder groups). For example, a verbal IQ measure would provide a more detailed insight into language skills and not just receptive vocabulary as assessed in the current study. We used this measure for consistency across our experiments (e.g. Doherty-Sneddon et al., 2012). In addition this measure has the advantage of: being widely used with these populations (Mottron, 2004 meta-analysis);

being quick and easy to administer to typically and atypically developing individuals; and being available for use with a wide age range as used here.

Finally, the atypically developing participants in the current studies had mean chronological and mental ages beyond 8 years of age. In typical development 8-year-olds have adult-like patterns and rates of GA whereas younger children normally use less GA (Doherty-Sneddon et al. 2002). It may therefore be that younger children with an ASD or with WS may avert their gaze less than is evident here and extrapolation to younger children with an ASD or WS must therefore be made with caution. Indeed the WS group used in the current study had a large age range and future research may explore the developmental course of gaze aversion in this group using a larger sample size across a wide age range. In fact future research would benefit from a developmental trajectory approach to map the developmental course of the use of GA in these groups.

The current work shows that even in social encounters, and regardless of the familiarity of the interlocutor, GA is associated with thinking for typically developing as well as atypically developing groups. Social skills training must take this into account.

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Table 1 Participant demographic data for experiments 1 and 2 (standard deviation in parentheses).

	Experiment 1		***Experiment 2***	
	Autism	*Typical Matches*	*Williams Syndrome*	*Typical Matches*
Chronological age$^{\times}$ Mean: Range:	13:07 (1:04) 12:04-15:09	11:03 (2:04) 7:03-15:10	21:11 (9:02) 14:00-37:01	10:04(2:09) 7:04-15:10
BPVS raw scores ^ Mean: Range:	102 (20.48) 71-138	103 (18.41) 74-132	98 (16.52) 82-132	99 (16.17) 74-132
SCQ† Mean: Range:	25 (5.63) 17-37	n/a	n/a	n/a

× Expressed as years:months

^ BPVS II raw scores were used for matching

† Social Communication Questionnaire

Table 2: Percentage of gaze aversion across interaction phase and familiarity for participants with Autism and typically developing matches (standard deviation in parentheses). Comparison data from Doherty-Sneddon et al (2012) is given in the third row of data.

Interaction Type	**Listening** *Autism*	**Listening** *Typical Matches*	**Thinking** *Autism*	**Thinking** *Typical Matches*	**Speaking** *Autism*	**Speaking** *Typical Matches*
Familiar	27(22)	16 (17)	59(28)	52 (34)	46(28)	44(30)
Unfamiliar	20(27)	14(15)	55(29)	71(22)	50 (31)	51 (27)
Gaze Aversion during hard problem-solving	37(31)	22 (14)	82 (21)	92 (10)	37 (32)	29 (27)

* From Doherty-Sneddon et al. (2012)

Table 3: Percentage of gaze aversion across interaction phase and familiarity for participants with Williams syndrome and typically developing matches (standard deviation in parentheses)

Interaction Type	**Listening**		**Thinking**		**Speaking**	
	Williams syndrome	*Typical Matches*	*Williams syndrome*	*Typical Matches*	*Williams syndrome*	*Typical Matches*
Familiar	21 (24)	17 (16)	55 (32)	61 (26)	39 (25)	49 (29)
Unfamiliar	19 (18)	16 (14)	66 (23)	80 (18)	51 (26)	57 (26)
Gaze Aversion during hard problem-solving *	21(31)	26 (23)	88(12)	94(9)	23(20)	29(27)

* From Doherty-Sneddon et al. (2012)