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The eye-gaze direction of an observed person can bias perception, memory and attention in adolescents with and without Autism Spectrum Disorders

Abstract

The reported experiments aimed to investigate whether a person and their gaze direction presented in the context of a naturalistic scene cause perception, memory and attention to be biased in typically developing adolescents and high-functioning adolescents with ASD. A novel computerized image manipulation program presented a series of photographic scenes, each containing a person. The program enabled participants to laterally maneuver the scenes behind a static window, the borders of which partially occluded the scenes. The gaze direction of the person in the scenes spontaneously cued attention of both groups in the direction of gaze, affecting judgments of preference (Experiment 1a) and causing memory biases (Experiment 1b). Experiment 2 showed that the gaze direction of a person cues visual search accurately to the exact location of gaze in both groups. These findings suggest that biases in preference, memory and attention are caused by another person's gaze direction when viewed in a complex scene in adolescents with and without ASD.

Key words

Autism spectrum disorder; gaze direction; scene preference; memory bias; attention; change blindness

Living in a social world, it is important to make use of the social cues people generate in order to understand their thoughts, beliefs and intentions. Doing so enables us to be highly proficient at interacting with others and to thrive in society. We find people inherently interesting and given the choice, we tend to look at people, especially faces, much more frequently than at other stimuli (Slater & Butterworth, 1997; Goren, Sarty & Wu, 1975; Johnson, Dziurawiec, Ellis & Morton, 1991). Eye-gaze direction is an important social cue. It may reflect a person's desires and intentions or correspond to an important social event in the environment (Ristic, Mottron, Iarocci, Burack & Kingstone, 2005). Research has shown that perception of people's direction of gaze can strongly influence one's own focus of attention and preferences (see Frischen, Bayliss & Tipper, 2007 for a review). For instance, we are highly perceptive of people's direction of gaze and we generally attend to where others are looking (Watt, 1992; Langton & Bruce, 1999; Freeth, Chapman, Ropar & Mitchell, in press), even if it is not predictive of anything (Driver et al. 1999; Bayliss & Tipper, 2005; Friesen & Kingstone, 1998). Processing eye gaze direction can even cause an individual to prefer a particular object which has been looked at over one that has not (Bayliss, Paul, Cannon & Tipper, 2006).

The propensity to be interested in the information conveyed by people's eyes is an important social mechanism that develops early in life; two to five-day-old newborns are able to discriminate between direct and averted gaze, showing a preference for looking at direct gaze (Farroni et al. 2002). Hood, Willen and Driver (1998) have reported some joint attention behavior in children as young as 3 months of age. By 9-10 months infants follow head-turns and gaze shifts spontaneously. They are able to search for objects on the basis of head cues alone, even if the object is not in their immediate visual field (Butterworth & Jarrett, 1991; Corkum & Moore, 1998; Scaife & Bruner, 1975). By 10–12 months typically developing children are able to follow gaze direction alone. By 14-18 months of age, normal human infants all exhibit joint attention (reception and production) and gaze following (Bruner, 1983). However, although perceptual contingencies appear to be appreciated early in infancy, Moore and Povinelli (2007) argue that infants do not gain the conceptual understanding that an adult's gaze direction may indicate that the adult is looking at something until approximately 24 months of age.

For people with a diagnosis on the autism spectrum, the process leading up to the development of joint attention skills appears to be disrupted. Face processing difficulties are widely reported (e.g., Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001; Chawarska & Shic, in press; Joseph and Tanaka, 2003; but see Back, Ropar & Mitchell, 2007) and a marked impairment in eye contact in infancy, childhood and adulthood is a diagnostic feature of the disorder (DSM-IV; APA, 1994; Lord et al. 2000). Leekam, Lopez and Moore (2000) found specific deficits in both dyadic (child-adult) and triadic (child-adult-object) joint attention in autistic children of approximately 4 years of age. Their results suggest that children with autism rely on the presence of objects in their visual field to guide attention rather than social cues coming from an adult and that 3 to 4 year olds with autism resemble typically developing 8 to 12 month olds in terms of their joint attention abilities. Charman et al. (2000) have argued that a deficit in joint attention could hamper the development of theory of mind abilities in autism. As noted by Corkum and Moore (1998), if knowledge of social meaning is absent then opportunities to learn about words, faces and objects are lost. Abnormalities in early joint attention behavior may cause individuals with ASD to start off on a different developmental trajectory compared to their typically developing peers. This may cause enduring social difficulties into adulthood.

Although research exploring eye gaze following in young children with autism has found deficits, many studies which have tested older children, adolescents and adults with autism have not found impairments. Specifically, studies using Posner-type attention cueing paradigms (Posner, 1980) have shown that individuals with ASD are able to use eye-gaze direction as a cue when the visual array is relatively uncomplicated (Ristic et al., 2005; Kyllianen & Hietanen, 2004; Swettenham, Condie, Campbell, Milne & Coleman, 2003). One possible explanation for the successful gaze following on these attention cueing paradigms could be that they develop atypical, rule-based strategies over time and therefore appear to perform normally on such tasks. However, individuals with autism still fail to use appropriate eye contact and gaze following in everyday life. Perhaps older individuals with autism are able to succeed on attention cueing tasks as they are relatively simple and do not require one to actively select what to attend to. It could be that the main problem for individuals with autism is selecting relevant social information from a visually complex array.

At present, although we have considerable knowledge regarding processing of eye-gaze directional information in older individuals with ASD using relatively simple stimuli, we do not know whether these individuals follow gaze direction when presented with more complex stimuli. Are gaze-direction cues attended to and used spontaneously by individuals with ASD when rich arrays of competing visual stimuli are present? By devising tasks which present complex scenes containing people looking in various directions, we can observe if there are any differences between individuals with and without ASD in terms of how the scenes are processed (see also Freeth et al., in press).

Experiments 1a and 1b investigated how complex naturalistic scenes containing people are globally processed by typically developing individuals and those with ASD. The aims were to discover whether a person and their gaze direction are attended to, deemed important, and are captivating enough to cause perception and memory to be biased when presented within a complex scene. Experiment 1a and 1b were closely related tasks that investigated preference (Experiment 1a) and memory (Experiment 1b). The two experiments were completed by the same group of participants one week apart. The order in which the experiments were administered was counterbalanced.

EXPERIMENT 1a

Experiment 1a presented a series of different complex photographic scenes to participants, each of which contained one person either looking straight out of the photo or looking towards an object. Participants were required to adjust the position of the photos behind a window, the borders of which occluded 1/3 of each photo overall. Participants moved the photos to the position which made each “look best”. The start position of the person in each of the photos varied throughout the task. The final positions chosen were compared to the start positions in order to investigate whether there was an overall tendency to centralize or marginalize the person in each photo. Analyses also investigated whether variations in the person's gaze direction impacted on participant preferences.

People are highly salient to typically developing individuals so we expected the person in the photo to be the main focus of attention and consequently placed significantly closer to the centre than would be expected by chance. We anticipated that the gaze direction of the person would cue participants’ attention towards the object looked at, perhaps causing participants to view the person and the object as a perceptual unit – forging a relationship that would not be present if the person looked straight out of the photo. We anticipated that this may cause the viewer’s focus of attention to shift in the direction of gaze and cause the centre point of attention to be somewhere between the person and the object they looked at, leading the chosen centre point of the scene to be selected at this point.

For individuals with ASD, in naturalistic settings people appear to be less salient (Dawson, Meltzoff, Osterling, Rinaldi & Brown, 1998; Klin, Jones, Schultz & Volkmar, 2003; Swettenham et al. 1998). It is therefore likely that a person in a scene and their direction of gaze would have less impact on scene perception for individuals with ASD. Alternatively, it is possible that individuals with autism do attend to people and are influenced by their gaze direction but it is other aspects of real-life situations that are responsible for differences in individuals with ASD. Experiment 1a is able to discriminate between these two possibilities as people are presented in a complex naturalistic scene but the stress of a social encounter is eliminated.

If the person and their direction of gaze are spontaneously attended to and deemed important to individuals with ASD, then we would expect preference to be affected by these factors – as we predicted for the typically developing individuals. However, if these aspects of the scene are deemed to be largely irrelevant by individuals with ASD when making judgments of preference then the person and their gaze direction will not affect their decisions. This paradigm gives an estimate of the importance of a person and their gaze direction in the context of a naturalistic scene. Are these factors prioritized by individuals with ASD when there are many salient items competing for the viewer's attention?

Method

Participants

Sixteen 13- to 16-year-old high-functioning (Full-Scale IQ >70) boys with an autism spectrum disorder (ASD) - autism or Asperger syndrome - and 16 age, gender and

Full-Scale IQ matched typically developing adolescents participated in the study. IQ was measured using the Weschler Abbreviated Scale of Intelligence (WASI).

All of the participants with ASD had received an official diagnosis from a clinical psychologist based on DSM-IV criteria (American Psychiatric Association, 1994). All of the ASD participants attended specialist schools specifically equipped for individuals with ASD. An Autism Spectrum Screening Questionnaire (Ehlers, Gillberg and Wing, 1999) was completed by a teacher or parent of 15 of the 16 participants in each group giving an indication of current level of autistic features. The ASSQ served to identify between group differences on current levels of autistic features. As all participants in the ASD group had an official diagnosis from a clinician, participants were not included or excluded from the ASD sample on the basis of ASSQ scores. All participants had normal or corrected-to-normal visual acuity. See Table 1 for further details of participant information.

(Insert Table 1 about here)

Stimuli and Apparatus

Photographic scenes were constructed using a digital camera and Adobe Photoshop 7.0. Each photo had an initial resolution of 1920 x 1440 pixels. Each photo contained one person with a neutral expression (half were male; half were female) sitting towards the left of the image or towards the right of the image - the two versions were mirror reverses of each other. The person was either looking straight out of the photo or looking at an object on the opposite side of the photo. In each photo, the bridge of the nose of the person in the photo was 120 pixels to the left or right of centre (12.5%) and at a height of 96-120 pixels (20-25%) above the centre.

The middle of the object looked at was approximately 120 pixels to the left or right of centre (12.5%). The photos were then vertically cropped and compressed to a final stimulus size of 960 x 480 pixels. Two example stimuli are shown in Figure 1.

(Insert Figure 1 about here)

Eight sets of target photos were created. Each participant was presented with one photo from each set. Each set of photos contained four versions of the same scene. The four versions enabled counterbalancing of person location (left vs. right - mirror image of left version) and gaze direction (straight vs. towards object in location 1). This meant that the content of specific photos could not impact on the experimental factors of interest. Three filler photos were also constructed, each was of an everyday scene containing one person that was positioned in the centre of the photo either looking straight ahead, left or right. These photos were included to distract the participant from the set-up of the target photos.

A custom written JAVA program was used to present the photographic scenes on a laptop PC with a 15-inch color LCD monitor. The 960 x 480 pixel photographic scenes were presented behind a 640 x 480 pixel window centered on the computer screen this meant that 1/3 of the scene was occluded from view at all times by the borders of the window (Figure 2). A blank background surrounded the window. Key press adjustments in increments of 16 pixels could be made to change the position of the photo behind the window by pressing the left and right arrow keys. The final position of the photo was recorded.

(Insert Figure 2 about here)

Procedure

Warm-up task. Participants were shown a picture of shapes on the laptop monitor. They were told that they could move the image behind the window, to the left and to the right to reveal and hide different parts of the picture using keys labeled with an arrow indicating the direction of movement. After a demonstration they were asked to move the picture on the laptop monitor to two different positions to match pictures held by the experimenter. The aim of the warm-up task was to ensure that participants were able to move the picture on the laptop monitor to the position they desired.

Experimental task. Participants were informed that they would be presented with a series of 11 photos which they could move around in the same way as they had done with the picture in the warm-up task. Participants were told to move the photos behind the window to the position that they thought made the photo look best. Participants were allowed to freely explore the photo using the arrow keys for as long as they chose. Pressing the ENTER key accepted the position of the image, recorded the data and moved on to the next image until all images had been adjusted.

Results and Discussion

All participants were able to satisfactorily complete the warm-up task, twice matching the position of the picture on the laptop screen to the picture held by the experimenter and so participated in the main experiment. Using a linear transformation, the raw scores of the final lateral position of the photographic scenes were converted from pixels to a measure of person centering, expressed as a percentage. If the person was positioned exactly in the centre, a score of 100% was obtained. If the chosen position resulted in the person in the photo being moved through this centre point, the person centering score decreased linearly with each move. If participants chose to move the person further away from the centre than the position they had initially been in, a negative person centering score was obtained. If participants accepted original position of the image on each trial, an overall score of 0% was obtained.

Two one-sample *t*-tests tested whether scores were significantly greater than 0, the mean score expected by chance. Both groups displayed highly significant positive person centering overall, see Figure 3 - typically developing group, $t(15)=4.55$, $p<.001$, $d=1.13$ (mean = 36pixels; SD = 31); ASD group, $t(15)=4.76$, $p<.001$, $d=1.19$ (mean = 36pixels; SD = 28). These results show that participants thought that overall photos looked better when the person was closer to the centre – indicating the salience and importance of the person. There was no significant difference between groups on this measure, [$t(30)=0.64$, $p=0.95$, $d=0.2$], indicating that the person in the photo was similarly salient to each group.

A mixed measures ANOVA (group x gaze direction) showed a significant main effect of gaze direction on person centering scores. Person centering scores were significantly higher when the direction of gaze was straight out of the photo than when it was directed towards an object, $F(1,30)=11.2$, $p=.002$, $\eta_p^2=0.27$. There was no main effect of diagnosis, [$F(1,30)=0.004$, $p=.95$, $\eta_p^2<0.001$], or interaction between group and gaze direction, [$F(1,30)=0.75$, $p=.39$, $\eta_p^2=0.02$], see Figure 3. The effect of gaze direction on the positioning of the photo was large for the typically developing group, $d=0.8$ and medium for the ASD group, $d=0.4$. The magnitude of the effect of gaze direction was not significantly correlated with ASSQ score, [$r(13)=0.11$, $p=.69$] indicating that having a diagnosis of ASD and current level of autistic features was unrelated to the strength of the preference bias caused by gaze direction.

(Insert Figure 3 about here)

Inspection of the raw data indicated that the average final position of the person in the "gaze towards an object" photos consistently showed more of the scene in the direction of the person's gaze than could be seen in the "straight gaze" photos. When the person was looking towards the right hand side, the person in the photo was positioned an average of 35 pixels further left by participants in the ASD group and 121 pixels further left by typically developing participants. When the person was looking towards the left hand side, the person in the photo was positioned an average of 100 pixels further right by participants in the ASD group and 98 pixels further right for typically developing participants.

This experiment demonstrated that typically developing individuals and individuals with ASD do selectively attend to people and their gaze direction when viewed in the context of visually complex photographic scenes. The importance of these features was demonstrated by the final position of the person in the photos being more central after participant manipulation and the final position of the photos being systematically biased towards the direction in which the person in the scene was looking by participants in both groups.

EXPERIMENT 1b

Scene memory can be systematically biased in both typically developing individuals (e.g., Intraub & Richardson, 1989) and in individuals with ASD (Chapman, Ropar, Mitchell & Akroyd, 2005). Asking participants to re-create a scene from memory can reveal cognitive biases which can be informative about the aspects of a scene that the individual found salient and also about how information was encoded and retrieved (Intraub & Richardson, 1989; Gottesman & Intraub, 1999; 2003). As yet it is not known whether the presence of a person in a scene, or their eye-gaze direction, can bias memory of that scene overall.

Experiment 1b required participants to view a series of photos for five seconds each and in a later surprise recall phase, to match the position of each photo to the exact position they had previously seen it in. Participants were required to do this from memory. Experiment 1a demonstrated a strong perceptual scene bias caused by the person in the photo and their gaze direction. From those results it is unclear whether people and their gaze directions merely affect preference or whether the effect also produces more robust cognitive biases. Experiment 1b aims to discover whether participants are hampered by a systematic bias in their attempts to arrive at the correct answer - whether memory for how a scene previously looked is in part a fabrication influenced by social aspects of the stimulus.

It has previously been shown that there is a tendency to mis-remember items as being closer to the central focus of attention than they actually were at the time of encoding (Recker, Plumert, Hund & Reimer, 2007). We anticipated that the memories of typically developing individuals would be biased by the location of a person in a scene as the person would be a central focus of attention, resulting in the person being placed significantly closer to the centre than was the case at the time of encoding. We also predicted that the direction of the person's gaze would shift the centre of the remembered scene in the direction of gaze as we anticipated that viewing a person looking at an object would result in the person and the object being viewed as an important perceptual unit causing the centre of attention to shift towards the object.

Individuals with ASD are widely reported to focus on small details in their visual array (see Happé and Frith, 2006 for a review) and have enhanced perceptual processing – an atypical processing style which is biased towards local details and enables enhanced perception of static stimuli (Mottron, Dawson, Soulierès, Hubert & Burack, 2006). When coupled with evidence for a general reduced focus on information from the eyes (e.g., Dawson et al. 1998; 2004; Klin, Jones, Schultz, Volkmar & Cohen, 2002; Baron-Cohen, Campbell, Karmiloff-Smith, Grant & Walker, 1995) it seems wise to anticipate that a general cognitive bias caused by social aspects of scenes that affects scene memory would not be observed in individuals with ASD. We therefore predicted that these individuals would be less prone to systematic biases caused by the social aspects of the scenes, consequentially producing more accurate memory traces.

Method

Participants

The same participants that completed Experiment 1a took part in Experiment 1b (see Table 1 for participant details).

Stimuli and Apparatus

The same apparatus was used as in Experiment 1a. In the encoding phase photos were presented sequentially in a custom written JAVA program, displaying the central 640 x 480 pixels of each of the photos. The recall phase presented photos using the same program as in Experiment 1a which allowed participants to make adjustments to the photos before accepting the final position of the photo.

Procedure

Phase 1. Eleven photos were sequentially presented for five seconds each (8 target photos; 3 filer photos). Participants were told that all they needed to do in this phase was to look at the photos. The lateral position of each of the experimental photos within the window had a centre point of 0 pixels.

Phase 2. This took part immediately upon completion of phase 1. The same warm-up task as in Experiment 1a was administered. A surprise scene recognition task followed. The same photos that had been presented in phase 1 were re-presented but the start position of the photo behind the window was shifted 112 pixels to the left or 112 pixels to the right (see Figure 2) – resulting in the person being located either more or less centrally than in phase 1 – the direction of shift was counterbalanced between participants. Participants were required to move the photo behind the window to the position in which they remembered it being in phase 1. Key press adjustments in increments of 16 pixels could be made to change the position of the photo behind the window by pressing the left and right arrow keys. Participants had to choose which of the 20 possible positions was correct. When participants were happy that the image in the window "matched their memory of how the photo had looked before", they pressed the ENTER key to accept their choice. This procedure was repeated for all images viewed in phase 1.

Results and Discussion

As for Experiment 1a, all participants were able to satisfactorily complete the warm-up task. An accuracy score was calculated for each participant by determining the mean number of pixels that each participant deviated from an overall accurate reproduction of the position of the photos. An independent samples *t*-test did not detect any significant difference in the accuracy of performance between the two groups [$t(30)=0.65$, $p=.54$, $d=0.22$].

The raw final lateral positioning data were then transformed into person centering scores in the same way as for Experiment 1a. In this task a positive person centering score indicated that the position of the photo had been mis-remembered and the person placed closer to the centre in the scene recognition phase than had been the case at the time of encoding. A negative person centering score indicated that the person had been placed further from the centre than had been the case at the time of encoding. Photos that were positioned accurately obtained a person centering score of 0%. A one sample *t*-test tested whether scores were significantly greater than 0, the mean score expected by chance. Participants in the typically developing group displayed a highly significant person centering bias, $t(15)=7.53$, $p<.001$, $d=1.9$ (mean = 27pixels; SD = 14) . This result was in line with prediction. Unexpectedly, participants in the ASD group also displayed a highly significant person centering bias, $t(15)=7.42$, $p<.001$, $d=1.9$ (mean = 38pixels; SD = 21), indicating that a robust cognitive bias was being caused by the person in the scene. There was a trend for the person centering bias to be stronger in the ASD group, that approached significance, $t(30)=1.89$, $p=.069$, $d=0.7$. This was surprising as we had anticipated that the individuals with ASD would show less cognitive bias in relation to the person.

A mixed measures ANOVA (group x gaze direction) showed a significant main effect of gaze direction on person centering bias. Person centering scores were significantly higher when the direction of gaze of the person in the photo was straight out of the photo than when it was towards an object, $F(1,30)=4.72$, $p=.038$, $\eta_p^2=0.14$. As mentioned in the previous analysis, there was a trend for the ASD participants to centre the person in the photo more than the typically developing participants, which approached significance, $F(1,30)=3.57$, $p=.069$, $\eta_p^2=0.11$. There was no interaction between group and gaze direction, [$F(1,30)=0.74$, $p=.40$ $\eta_p^2=0.02$], see Figure 4. The effect of gaze direction on the positioning of the photo was small in the typically developing group, $d=0.3$ and medium in the ASD group, $d=0.6$. This indicates that participants tended to mis-remember the position of the person in the photo and place the person closer to the centre when the direction of gaze was straight. Eye-gaze direction had an effect on how the photo was remembered; the bias was to include more of the scene in the direction of gaze than when the person looked straight out of the photo. Overall these results suggest that the preference biases related to the social aspects of the scenes observed in Experiment 1a were robust enough to also cause memory biases. The magnitude of the effect of gaze direction was not significantly correlated with ASSQ score, [$r(13)=0.23$, $p=.40$] indicating that having a diagnosis of ASD and current level of autistic features is unrelated to the strength of the memory bias caused by gaze direction.

(Insert Figure 4 about here)

A Pearson's correlation was conducted on the overall person centering scores for the preference task (Experiment 1a) and the overall person centering scores for the memory task (Experiment 1b) as we wanted to know whether, in the absence of a strong memory of the scene, participants were just positioning the photo according to their preference. There was no significant correlation between the overall person centering scores on the two tasks, [$r(30)=0.25$, $p=.17$], which lead us to conclude that performance on the two tasks was largely independent.

The performance of the participants that completed the preference task before the memory task was compared to the performance of participants that completed the memory task first. Multivariate ANOVAs were conducted on the accuracy and person centering scores. There was no effect of task completion order on either accuracy [$F(1,28)=2.72$, $p=.11$, $\eta_p^2=0.09$] or person centering [$F(1,28)=0.36$, $p=.55$, $\eta_p^2=0.01$], indicating that overall there were no order of task completion effects. There was also no group x order interaction on either the accuracy scores [$F(1,28)=0.62$, $p=.44$, $\eta_p^2=0.02$] or the person centering scores [$F(1,28)=1.37$, $p=.25$, $\eta_p^2=0.05$] providing no indication that the groups were affected by task completion order.

In summary, the results of Experiment 1b suggest that the effects observed in Experiment 1a form part of a wider, robust cognitive bias which hampers objective performance due to the heightened importance of people and their gaze direction in relation to other aspects of scenes. The effects were observed both in typically developing individuals and in individuals with ASD and appeared to be unrelated to current level of autistic features.

EXPERIMENT 2

From Experiments 1a and 1b, is it apparent that both typically developing individuals and individuals with ASD spontaneously attend to people when presented with a complex visual scene and gain information from their eye-gaze direction. However, from these experiments it is not clear how specifically or accurately gaze direction information is being processed. That is, are individuals attending to the general direction of gaze or are they attending to the object being looked at? This is addressed in Experiment 2.

When rapidly searching scenes for objects, many researchers have argued that we can be strongly influenced by the visual attributes of a scene, resulting in search being driven by bottom-up features such as color, orientation and intensity (e.g., Itti and Koch, 2001). There is also evidence to suggest that top-down influences play an important role in visual search (e.g., Henderson & Hollingworth, 1999; Land & Hayhoe, 2001; Foulsham & Underwood, 2007). A study by Langton, O’Donnell, Riby & Ballantyne (2006) on typically developing individuals showed that when participants were presented with a scene containing a person whose body, head and eyes were oriented in a particular direction, participants were faster to notice changes to objects that were in the direction of gaze than when gaze cues were not present or when gaze was directed towards a non-changing object. Also, participants' ability to detect a change deteriorated linearly as the changing object was located progressively further from the line of regard of the gazer. At present it is not known whether eye-gaze direction alone can influence the allocation of attention within scenes in typically developing individuals or in individuals with ASD.

When viewing a scene for the first time, if the specific object that the person in the scene is looking at is cued by eye-gaze direction, then participants should be faster to notice details of that object. If general areas are also being cued by eye-gaze direction then participants should be faster to notice details of all objects in the general direction of gaze and slower to notice changes to objects located opposite to the direction of gaze. If objects are not being cued at all by eye-gaze direction, participants should be equally fast to notice changes when eye-gaze directional cues are present and when absent.

In order to decide between these three possibilities of specific, general or no object cueing by eye-gaze direction in both typically developing individuals and those with ASD, we presented participants with a Flicker paradigm task (Rensink, O'Regan & Clark, 1997). This paradigm has been shown to be appropriate for use with high-functioning individuals with ASD (Fletcher-Watson, Leekam, Turner & Moxon, 2006). Objects in various locations within a scene appeared and disappeared whilst gaze direction of the person in the photo was systematically manipulated between trials. Participants were required to identify which object was appearing and disappearing in each trial. Gaze direction was only a predictive cue for the disappearing object on 1/6 of trials so consistently looking to the eyes of the person before searching the rest of the scene would not be a particularly logical or efficient strategy. The scenes used were very similar to the stimuli used in Experiment 1a and 1b. The objects that disappeared were either in: the exact location of gaze (location 1); a location on the same side of the photo as the direction of gaze (location 2); a location on the opposite side of the photo to the direction of gaze (location 3).

We predicted that although the gaze cue used in this experiment was purely the direction of eye-gaze, rather than head and body orientation, the results would be similar in nature to those observed by Langton et al. (2006) as previous research using simplistic stimuli has shown eye-gaze to cause reflexive shifts in visual attention (Friesen & Kingstone, 1998; Driver et al. 1999) in typically developing individuals. Therefore we predicted that typically developing individuals would be cued by gaze direction with the result that spotting objects disappearing in the exact location of gaze would be strongly facilitated (time taken to spot changes to objects in Location 1 in the Gaze Object condition would be much shorter than in the Straight Gaze condition); objects disappearing in the general direction of gaze would be weakly facilitated (time taken to spot changes to objects in Location 2 in the Gaze Object condition would be slightly shorter than in the Straight Gaze condition) and spotting objects disappearing in a location opposite to the direction of gaze would be delayed (time taken to spot changes to objects in Location 3 in the Gaze Object condition would be longer than in the Straight Gaze condition).

Little research has previously been carried out on how specifically eye-gaze direction cues attention in individuals with ASD. In terms of eye-gaze direction discrimination, Leekam, Baron-Cohen, Perrett, Milders and Brown (1997) suggested that individuals with ASD are able to determine the direction of gaze relatively accurately; conversely Ashwin, Wicker and Baron-Cohen (2006) suggested that gaze direction perception is abnormal in individuals with ASD. As individuals with ASD often do not attend to the global content of stimuli unless prompted (e.g., Happé & Frith, 2006) and gaze cues have been shown to be voluntary rather than reflexive in individuals with ASD (Ristic et al., 2005) we predicted that eye-gaze direction would not cue individuals with ASD at all when searching for an object that is appearing/disappearing as it was not directly relevant to the task, hence no differences between the Straight Gaze conditions and the Gaze Object conditions were predicted for spotting the disappearing objects in any of the three locations.

Method

Participants

Twenty-four 11- to 16-year-old high-functioning (Full-Scale IQ >70) adolescents (21 males, 3 females) with an autism spectrum disorder (ASD) - autism or Asperger syndrome - and 24 age, gender and Full-Scale IQ matched typically developing adolescents participated in the study. IQ was measured using the Weschler Abbreviated Scale of Intelligence (WASI).

All of the participants with ASD had received an official diagnosis from a clinical psychologist based on DSM-IV criteria (American Psychiatric Association, 1994). Ten of the ASD participants attended specialist schools specifically equipped for individuals with ASD. The remaining 14 ASD participants attended mainstream school, had a statement of special educational needs and received additional classroom and pastoral support. An Autism Spectrum Screening Questionnaire (Ehlers, Gillberg & Wing, 1999) was completed by a teacher or parent of each participant giving an indication of current level of autistic features. All participants had normal or corrected-to-normal visual acuity. See Table 2 for further details of participant information.

(Insert Table 2 about here)

Apparatus and Stimuli

The task was presented on a laptop PC connected to a 17-inch color LCD monitor. Responses were made using an electronic keypad. The screen resolution was set to 1024 x 768 pixels. Participants sat approximately 60cm from the monitor. Eight sets of photos of different scenes containing one person were constructed. Some of the scenes were the ones used in Experiment 1a and 1b, some were newly constructed. Each photo had a resolution of 960 x 480 pixels and was presented on a blank background. Each photo contained one person; the bridge of the nose of the person was 120 pixels to the left or right of centre (12.5%) and at a height of 96-120 pixels (20-25%). Each photo set depicted a different person.

(Insert Figure 5 about here)

Three different distinctive objects were placed in three locations in each photo: Location 1 – the exact location of gaze; Location 2 – on the same side of the photo as the location of gaze but not in the direction of gaze; Location 3 – on the opposite side of the photo to the direction of gaze. Each set contained versions of the room scene with no object missing, the object from location 1 missing, the object from location 2 missing or the object from location 3 missing; see Figure 5 as an example. We constructed two different versions of each photo, each version containing a different set of objects in the three locations. We did this to increase the variety of objects searched for and to reduce the potential impact of particularly salient or non-salient objects.

We verified that in each scene the object in location 1 was in the exact location of gaze by conducting a pilot study on 20 undergraduate and postgraduate students at the

University of Nottingham. At least 17 of the 20 pilot participants were able to correctly identify the object being gazed at in each photo. Two one-way ANOVAs were run on the distances of the objects from the person in the photo's eyes and also on the size of the objects. There were no significant differences between the objects in the different location categories.

The experiment contained three types of trial (object missing from location 1; object missing from location 2; object missing from location 3), for this design 32 versions of 8 target photo scenes containing missing objects were required (256 different photos in total). The 32 versions enabled counterbalancing of the following factors for each target scene: person location x 2 (left/right); gaze direction x 2 (straight/towards object in location 1); object set x 2 (object set 1/object set 2); objects present x 4 (object missing from location 1; object missing from location 2; object missing from location 3; no missing object – for the alternate cycle).

Procedure

Participants were presented with a modified version of Rensink's Flicker paradigm (see Rensink, O'Regan & Clark, 1997) which repeatedly, sequentially presented participants with two versions of the same scene for 300ms separated by a blank screen for 100ms, up to a maximum of 40 changes. The first version of the photo presented contained all three objects of interest; in the second version, only two objects of interest were present. Participants were asked to press the spacebar as soon as they spotted which object was disappearing and re-appearing. Trial reaction time was recorded. After pressing the spacebar, participants were asked to indicate which object they thought had been disappearing either by naming or pointing to the object. N.B. One object always disappeared on each trial – there were not any "no change" trials.

Each participant was presented with 24 “spot the difference” trials. The trials were presented in a random order. Person location (left vs. right), gaze direction (straight vs. towards location 1) and object set (1 vs. 2) for each scene were counterbalanced between participants independently of photo content.

Results and Discussion

All participants appeared to find this Flicker-paradigm task very engaging and enjoyed the game-like nature of trying to “spot the difference” as quickly as they could so we were confident that both groups were motivated to respond as quickly as possible. Data from trials in which the disappearing object had not been correctly identified were removed. Data from trials that had timed-out due to an inability to spot the change were recorded as missing. These corresponded to 5% of the total responses in the ASD data and 1% of the total responses in the typically developing participants’ data. Mean reaction time raw data can be viewed in Tables 3 and 4. Because the reaction time data was positively skewed, two natural log transformations were applied to ensure that the data was normally distributed and therefore suitable for parametric analysis.

An independent samples *t*-test showed that overall speed of response did not differ between groups [$t(46)=1.54$, $p=.13$, $d=0.4$]. In order to discover whether direction of eye-gaze facilitated or inhibited the speed with which participants noticed changes to objects in the three locations in the scenes, three mixed measures ANOVAs (group x gaze direction) were conducted on the time taken to notice the object disappearance – a separate ANOVA was conducted on data from each of the three locations. Reaction time data to spot disappearing objects in each of the three locations were treated separately as object salience and salience of object position in the scenes was not strictly controlled for across locations.

A mixed measures ANOVA (group x gaze direction) on the transformed reaction time scores for objects in location 1 showed a significant main effect of gaze, $F(1,46)=11.47$, $p=.001$, $\eta_p^2=0.20$, as participants tended to notice the disappearance of objects in location 1 faster when they were being looked at than when the person in the photo had straight gaze. The ASD group were slower to spot the changes overall, $F(1,46)=4.41$, $p=.041$, $\eta_p^2=.09$ but there was no gaze x group interaction [$F(1,46)=1.64$, $p=.207$, $\eta_p^2=0.03$]. Analysis of the effect size in each group revealed that the eye-gaze cue had a medium effect on the typically developing group, $d=0.6$ and a small effect on the ASD group, $d=0.3$ (Figure 6). ASSQ scores did not correlate with the magnitude of the reaction time advantage caused by the person's gaze being directed at the disappearing object, [$r(22)=-0.07$, $p=.76$] indicating that the strength of the gaze cueing effect was not related to current level of autistic features.

(Insert Figure 6 about here)

A second mixed measures ANOVA (group x gaze direction) on the transformed reaction time scores for objects in location 2 (the same side as the direction of gaze but not in the exact location of gaze) showed that participants did not benefit from gaze being directed towards the same side of the photo as the changing object [$F(1,46)<0.001$, $p=.98$, $\eta_p^2<0.001$]. There was no main effect of diagnosis, [$F(1,46)=0.004$, $p=.33$, $\eta_p^2=0.02$]. There was no gaze x group interaction [$F(1,46)=0.08$, $p=.78$, $\eta_p^2=0.002$]. ASSQ scores did not correlate with the magnitude of the reaction time advantage caused by the person's gaze being towards the general direction of the disappearing object, [$r(22)=-0.13$, $p=.55$].

A third mixed measures ANOVA (group x gaze direction) on the transformed reaction time scores for objects in location 3 (the opposite side to the direction of gaze) showed that gaze cues did not affect the time taken to spot the disappearance of the objects [$F(1,46)=0.06$, $p=.81$, $\eta_p^2=0.002$]. There was no main effect of diagnosis, [$F(1,46)=0.83$, $p=.37$, $\eta_p^2=0.02$] There was no group x gaze interaction [$F(1,46)=0.06$, $p=.81$, $\eta_p^2=0.001$]. ASSQ scores did not correlate with the reaction time difference between the straight gaze and the gaze towards an object conditions, [$r(22)=0.17$, $p=.44$].

The results from the three ANOVAs considered together indicate that the benefit of the eye-gaze cue for both groups is specific to the object in the exact location of gaze and that attention to general regions is not strongly affected by direction of gaze. The pattern of results was very similar for both groups and gaze cueing was not related to current level of autistic features. This pattern of results is slightly different than the results obtained by Langton et al. (2006) who found that general areas of scenes were also cued by gaze direction rather than just the specific location looked at. However, inspection of the means (Table 4) for the typically developing group does demonstrate trends in the data for eye-gaze direction cueing attention towards and away from general areas but these effects are clearly small and not systematically reliable. Perhaps eye-gaze direction alone is a qualitatively different type of cue than eye, head and body orientation and is more indicative of attention to an exact location rather than a general direction.

The finding that gaze direction of the person in the photo influenced visual search for disappearing objects in this task demonstrates the captivating nature of another person's eyes as all participants knew their task was to search for the object that was disappearing and re-appearing and the difference between the "straight gaze" and "gaze towards an object" scenes was only pupil location. Remarkably both groups rapidly attended to the person in the photo and were influenced by their eye-gaze direction when searching for a disappearing object, even though the eye-gaze cue was only predictive of the location of the disappearing object in 4 of the 24 trials. The strength of the gaze cueing effect was not related to current level of autistic features. This result illustrates the engaging nature of social aspects of scenes and the strength and specificity of eye-gaze as a cue for attention in both typically developing individuals and those with ASD.

General discussion

The objective of the series of experiments reported in this paper was to investigate whether a person and their gaze direction are attended to, deemed important, and captivating enough to cause memory and attention to be biased when presented in the context of a naturalistic scene. These issues were investigated in typically developing adolescents and high-functioning adolescents with ASD. Examples of visual scenes containing social information that could be viewed in everyday life were presented but the stress of a social encounter was eliminated. Experiments 1a and 1b showed that a person in a scene is typically centralized by preference and remembered as taking a more central position in a scene than was the case on initial viewing of the scene. The person's direction of gaze also influenced participants' preference and caused further systematic memory biases; this was true for both the typically developing group of participants and for participants with ASD. These effects represent robust, enduring cognitive biases caused by the heightened importance of the person in the scenes and their eye-gaze direction relative to other aspects of the scenes. Experiment 2 demonstrated that an observed person's gaze direction cued participants to the exact location of gaze in both typically developing individuals and those with ASD. The gaze cueing effect was not related to current level of autistic features.

A diagnostic feature of ASD is having problems with social interaction and many studies have demonstrated the nature of these problems in real-life situations (e.g., Dawson et al. 1998; Leekam et al. 2000; Swettenham et al. 1998). It has been suggested that these problems may be linked to differences in social attention between individuals with ASD and typically developing individuals (e.g., Klin et al. 2002). Experiment 1a demonstrated that individuals with ASD do attend to and process some social information when presented in the context of complex stimuli and this is an area of spared ability. Experiment 1b demonstrated that problems with social interaction also cannot be attributed to information about people and their gaze direction failing to be encoded in memory in individuals with ASD. Systematic memory biases were observed in relation to the person in the scene and their eye-gaze direction. Experiment 1b demonstrated that these biases were at least as strong in individuals with ASD as in typically developing individuals. The results of the current study support the findings of Recker et al. (2007) in demonstrating that important items can be mis-remembered as being closer to the central focus of attention than they actually were at the time of encoding and extends this finding to social information. It is possible that the trend for stronger memory biases caused by the person and their gaze direction observed in the ASD group may demonstrate that scene information was not being encoded effectively on initial viewing but further work would be required to explore this possibility.

In accordance with previous work, Experiment 2 in particular demonstrates the captivating nature and strength of gaze direction as an attentional cue (e.g., Langton & Bruce, 1999; Driver et al., 1999; Friesen & Kingstone, 1998). Gaze strongly cued participants' attention to the exact location of gaze even though attending to the eyes should have been entirely peripheral to the task; participants knew they were required to search the scene for a disappearing object, and gaze direction actually served as a misleading or useless cue on five out of every six trials. The gaze cueing effect was not related to current level of autistic features. These effects have not previously been shown in response to complex, naturalistic stimuli in individuals with ASD and are important in demonstrating a feature of social processing that is intact in high functioning adolescents with ASD.

As well as answering the key questions set out in the experimental rationale, the data collected also produced an unexpected trend in Experiment 1a. A distinct laterality bias was noted in the ASD data. On closer inspection it appears that although overall performance between the typically developing group and the ASD group was not different on these tasks and both groups displayed the person centering bias and gaze direction bias described earlier, the ASD group performed differently to the typically developing group when viewing scenes in which the person was located on the left hand side. The effect of gaze direction on preference was much weaker than in the typically developing group. When viewing a scene containing a person located on the left, presumably this information is being processed by the right hemisphere. The suggestion of abnormal face processing in the right hemisphere in individuals with ASD is not a new one (Dawson, Webb & McPartland, 2005) and abnormal cortical specialization has previously been suggested (Webb, Dawson, Bernier & Panagiotides, 2006) but the laterality bias observed in this study highlights the need for further investigation into asymmetries of specialization for gaze information processing. It is also important that researchers take laterality biases into account when designing future studies.

It is clear that in everyday life all individuals with ASD suffer social impairments. However, the experiments reported in this paper demonstrate that problems with social interaction and differences reported in social attention in high-functioning individuals with ASD cannot be attributed to these individuals displaying a general lack of interest in people or a lack of desire or ability to extract gaze direction information from complex stimuli - the reason for the social problems must lie in other areas. Incrementally adding levels of complexity to stimuli such as movement, sound, social complexity, situational complexity and task demands will enable identification of specific areas of difficulty. These are all factors that were not present in the stimuli used in these experiments but that are present in real life. Also, analyzing how these factors interact may facilitate the discovery of the roots of social problems experienced by individuals with ASD. Clearly, from these experiments it is not possible to tell whether the scenes are being processed in a qualitatively similar way by participants in each group but they do suggest that the spontaneous tendency to use and follow eye-gaze direction accurately is an area of spared ability in high-functioning adolescents with ASD. These findings may provide an important starting point for future work on identification of deficits and also for work on intervention programs.

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Figure Captions

Figure 1. Example stimuli

Figure 2. Representation of novel computerized image manipulation program. Red box outlines the borders of the window, the interior of which could be seen by participants. Pressing arrow keys adjusted the position of the photo behind the window. Black vertical lines indicate amount of adjustment made by 1 key press.

Figure 3. Mean person centering scores with standard error bars for performance on the preference task.

Figure 4. Mean person centering scores with standard error bars for performance on the memory task.

Figure 5. Person right, gaze towards object. Objects in locations 1, 2 and 3 are indicated. These items disappeared from the scene in different trials.

Figure 6. The effect of gaze direction on the time taken to notice the disappearance of an object in location 1 (the exact location of gaze).

Table 1

Participant characteristics – Experiment 1a & 1b

	ASD participants	Typically developing participants
N	16	16
Age (years; months)		
Mean	14;8	14;8
SD	1.01	0.68
Range	13;5 – 16;4	13;6-15;6
Verbal IQ		
Mean	105.1	99.9
SD	19.6	12.5
Range	64-139	78-133
Performance IQ		
Mean	104.1	104.6
SD	12.8	10.3
Range	84-123	84-118
Full-scale IQ		
Mean	105.6	102.5
SD	16.8	10.0
Range	73-133	87-128
ASSQ		
Mean	25.6**	1.8**
SD	9.8	2.5
Range	8-43	0-7

** $p<0.001$: Participants with ASD scored significantly higher on the ASSQ than typically developing participants.

Table 2

Participant characteristics – Experiment 2

	ASD participants	Typically developing participants
N	24	24
Age (years; months)		
Mean	13;10	14;0
SD	1.37	1.37
Range	11;6 – 16;8	11;2-16;4
Verbal IQ		
Mean	90.18	94.0
SD	17.00	11.02
Range	63-135	72-109
Performance IQ		
Mean	105.3	98.0
SD	14.09	11.02
Range	73-126	77-125
Full-scale IQ		
Mean	97.0	95.5
SD	13.6	9.53
Range	74-129	79-112
ASSQ		
Mean	**18.4	**3.13
SD	12.8	4.04
Range	0-42	0-14

** p<0.001: Participants with ASD scored significantly higher on the ASSQ than typically developing participants.

Table 3

Time taken to correctly identify disappearing objects in Experiment 2 (seconds)

ASD participants

	Location 1 Mean (SD)	Location 2 Mean (SD)	Location 3 Mean (SD)
Gaze Towards Object	1.69 (0.5)	2.58 (1.2)	3.07 (1.1)
Straight Gaze	1.91 (0.8)	2.48 (1.1)	2.96 (0.8)

Table 4

Time taken to correctly identify disappearing objects in Experiment 2 (seconds)

Typically developing participants

	Location 1 Mean (SD)	Location 2 Mean (SD)	Location 3 Mean (SD)
Gaze Towards Object	1.37 (0.4)	2.33 (1.3)	3.01 (1.5)
Straight Gaze	1.68 (0.6)	2.44 (1.6)	2.86 (1.4)

Figure 1. Example stimuli

a) Person left straight gaze

b) Person left, gaze towards object

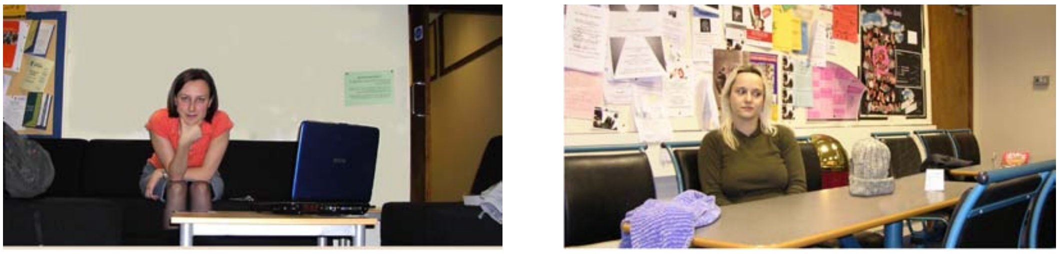

Figure 2.

Representation of novel computerized image manipulation program. Red box outlines the borders of the window, the interior of which could be seen by participants. Pressing arrow keys adjusted the position of the photo behind the window. Black vertical lines indicate amount of adjustment made by 1 key press.

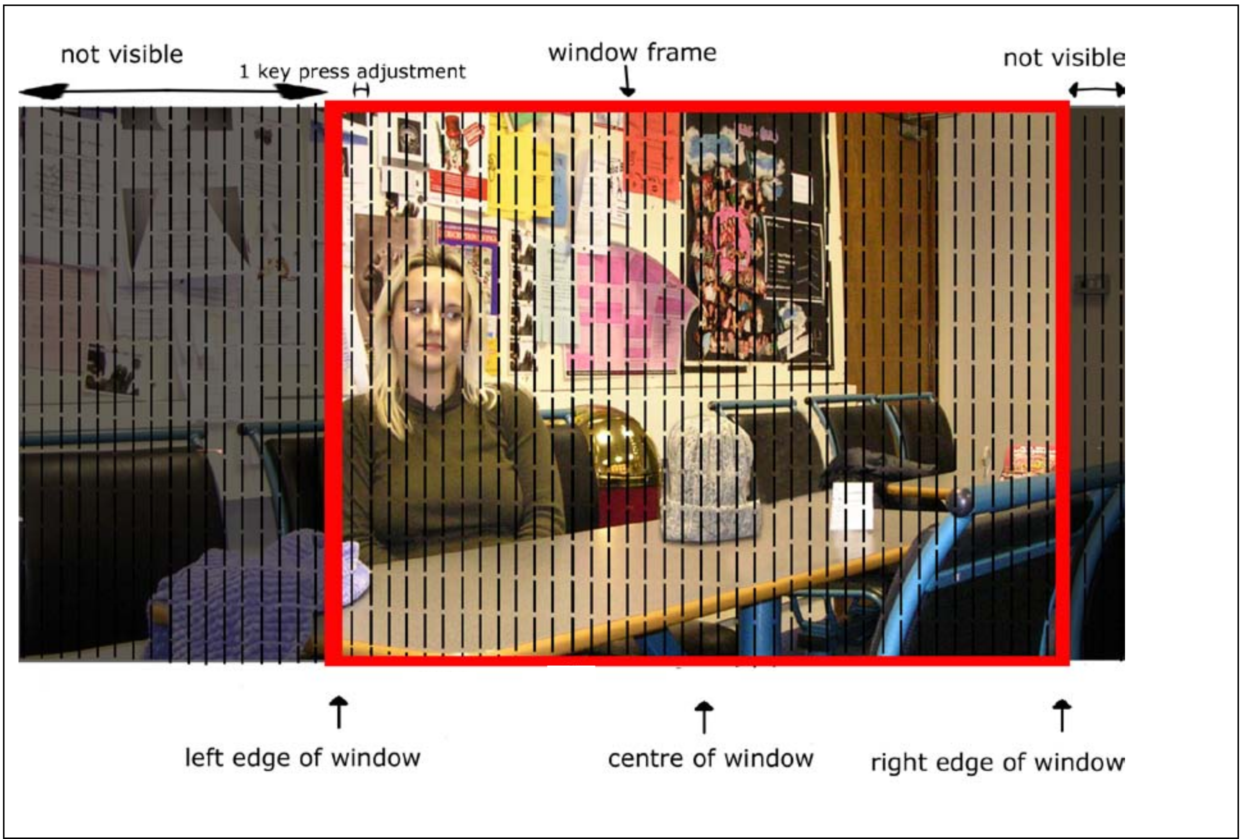

Figure 3.

Mean person centering scores with standard error bars for performance on the preference task.

Figure 4.

Mean person centering scores with standard error bars for performance on the memory task.

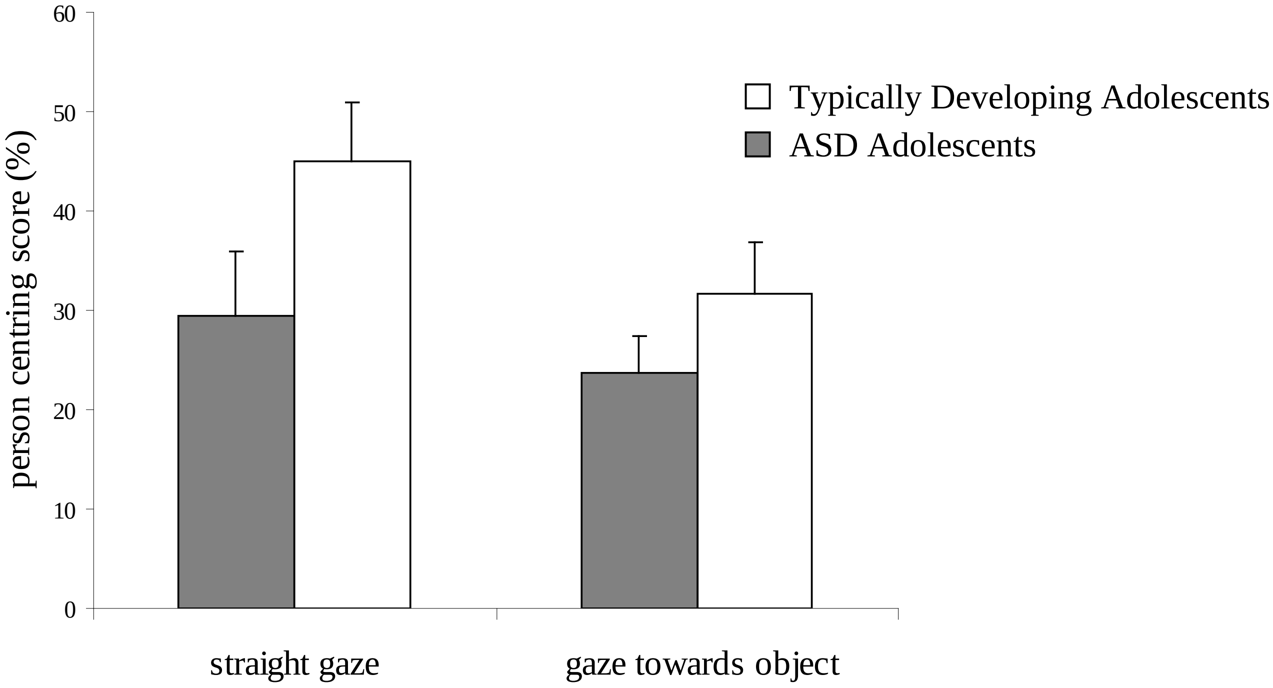

Figure 5.

Person right, gaze towards object. Objects in locations 1, 2 and 3 are indicated. These items disappeared from the scene in different trials.

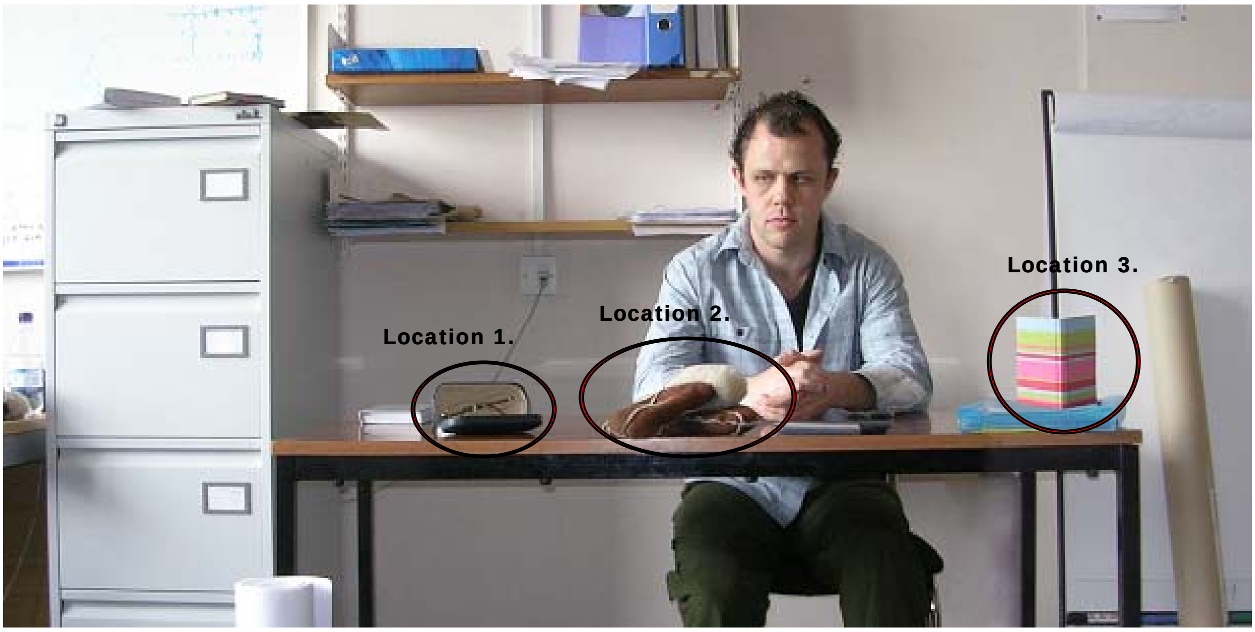

Figure 6.

The effect of gaze direction on the time taken to notice the disappearance of an object in location 1 (the exact location of gaze).