Perception of Other People's Attention Direction in Typically Children and Children With Autism

An eye tracking study

Marita Andreassen

Master of Philosophy in Psychology

Cognitive Neuroscience

Department of Psychology

THE UNIVERSITY OF OSLO

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Abstract

An important social skill is to monitor other people's gaze to find out what catches their attention. Direct gaze alternated with raised eyebrows is an ostensive cue that make typically developing infants more interested in looking at the object attended to by another person. In the current study, we focused on the sensitivity to such cues in two groups of typically developing (TD) children (infants and preschoolers) as well as preschool children with an autism spectrum disorder (ASD). It is known that children with ASD fixate differently than TD children, and this fixation tend to be rendered in social settings. The aim was to study the early markers of ASD, the deviant sensitivity to follow the gaze of other people. With eye tracking, the effect of ostensive cues versus a neutral condition was investigated in a gaze following paradigm. We predicted that the children with ASD would find the social cues difficult to follow, and that this would be rendered in their fixation pattern. The findings in the current study indicate a different fixation pattern of which TD infants and ASD children attended less to the objects in the ostensive condition, than in the neutral condition. The opposite effect was found in the TD preschoolers. These findings contradict the findings of previous research, which suggested that infants depend on ostensive cues when following gaze of other people.

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Introduction

We live in a social world were we engage in conversations, meet each others gaze, receive a simple nod from the neighbor, and follow the direction of a finger pointing to something of interest. Responding to other people's gaze, facial gestures and pointing are core social behaviors. These social behaviors are established during the first year of life in typically developing children (Corkum & Moore, 1998). Individuals with autism spectrum disorder (ASD) are dysfunctional in these respects (Baron-Cohen, 1995; Dawson et al., 2004; Leekam & Ramsden, 2006). The aim of this current study is to focus on how social cognitive skills become evident in such atypical development, and to further study one of the possibly earliest markers for ASD, the deviant sensitivity to follow the direction of another person's gaze. These issues will be discussed with respect to the ability to understand other people's actions and intentions. First, the developmental course of gaze performance in relation to social cognition will be reviewed. Second, the consequences of social cognitive impairments, as they become evident in autistic individuals, will be reviewed. Finally, the outcome of the present study will be discussed.

Gaze and Social Cognition

Social cognition refers to the processing of information that makes us able to understand other humans. It entails the understanding of other people's actions, motives and the goals associated with them (von Hofsten, Uhlig, Adell, & Kochukhova, 2009). The gestures of human faces reveal information about emotions and intentions in others (Falck-Ytter & von Hofsten, 2011). We determine others age, sex, ethnicity, emotional state and identity by looking at their faces (Allison, Puce, & McCarthy, 2000). In everyday situations, we receive social information from facial gestures, gaze direction, and pointing that help us evaluate the attention and emotions of others (Corkum & Moore, 1998; D'Entremont, Hains, & Muir, 1997; von Hofsten, Dahlström, & Fredriksson, 2005).

Looking is one of the first behaviors to develop in the infant, and through experience, we learn to process the information conveyed through the gaze of others. Eye contact is a good cue when initiating or re-establishing a communicative link between two people (Csibra, 2010). Humans are sensitive to gaze at an early age, and research findings suggest that infants are born with the ability to interpret information from human faces (Morton & Johnson, 1991). When looking at faces, a face-specific area in the brain is recruited (fusiform face area) (Grelotti, Gauthier, & Schultz, 2002). This structural information guides the infants' fixation, and could help explain why they have a preference for face-like patterns (Morton & Johnson, 1991). During the first two months of life the infants continue to fixate on face-like patterns, and learn about the visual characteristics of a face (Morton & Johnson, 1991). Newborns show the tendency to selectively direct gaze at certain objects, people or events (Gredebäck, Johnson, & von Hofsten, 2010), and they discriminate between direct and averted gaze (Farroni, Csibra, Simion, & Johnson, 2002). In the latter study, the newborns oriented significantly more to the face that was directed to them as opposed to the face that looked away, indicating that this communicative skill is anchored in phylogeny (Farroni, et al., 2002).

Another important social function is to monitor other people's gaze to find out what catches their attention. It facilitates communication between people (Corkum & Moore, 1998; D'Entremont, et al., 1997), and it can provide important information about the mental states of others (Nation & Penny, 2008). Together, gaze and pointing are communication skills that constitute joint visual attention behavior. Joint visual attention is defined as a three-way exchange between the self, another being and objects through pointing and/or showing gestures (Kasari, Sigman, Mundy, & Yirmiya, 1990). It includes sharing attention, following attention of another, and directing the attention of another being. It is when you can both specify and verify that yourself and another person are attending to the same object or event (Dawson, et al., 2004). Corkum and Moore (1998) describes joint attention as a way of developing knowledge about the world, and about other beings as 'experiencers' (Corkum & Moore, 1998). In this way, joint attention could be seen as an important step in development in order for the child to develop knowledge and understanding of our social world.

Gaze following is a well-studied phenomenon of infant behavior. Scaife and Bruner (1975) where among the first that could report that infants follow gaze. In their study, infants as young as 2 months old would turn their head to follow adults' gaze direction. Furthermore, the authors showed that the proportion of successful gaze following increased with age. The authors found that 30% of the 2- to 4-month-olds had successful turns, whereas 100% of the 11- to 14-month-olds had successful turns (Scaife & Bruner, 1975). Both 3-month-olds (D'Entremont, et al., 1997) and 6-month-olds (Butterworth & Jarrett, 1991) can locate the target of attention to the correct side of the room, but only when the target is within their field of view. 18-month-olds however, would pinpoint both the direction and positioning of the target when it was placed within their field of view, and they would furthermore search for the target if it was placed behind them (if their field of view was emptied of disturbing targets) (Butterworth & Jarrett, 1991). Older infants (12-month-olds) discriminate gaze directions to objects attended to by another. With a static video presentation, von Hofsten and colleagues (2005) tested infants' ability to discriminate the gaze direction of another person. With an eye-tracker, the authors recorded the infants' gaze during a video session. The infants were shown several images of a model that performed attention-directing actions by looking or pointing to objects in front of her. The infants would spend more time looking at objects attended to by the model, rather than the unattended ones. In addition, the infants were more likely to attend to the attended object if the model either gazed, or gazed and pointed together, rather than pointing only. The infants would furthermore fixate longer at the correct object on the correct side, rather than the opposite (von Hofsten, et al., 2005), indicating that 12-month-olds correctly discriminate the gaze direction of others.

Gaze following could depend of whom the child is interacting with. In a longitudinal study, young infants improved their gaze following from the age of 2 months to 8 months. In addition, the infants followed the gaze of a stranger more than the gaze of their mother (Gredebäck, Fikke, & Melinder, 2010). The authors argue that this tendency could be driven by social cognitive motives in their interaction with others. That is, that they might want to interact with the stranger and that they would be driven by the need to understand the motives and intentions of that stranger (Gredebäck, et al., 2010; Senju & Csibra, 2008).

Different suggestions regarding the age of onset for accurate gaze following have been reported. Previous studies have pointed out 10 to 12 months of age to be a crucial period when infants' reorient to the gaze of an adult, and attend to the direction the adult is looking (Scaife & Bruner, 1975). In an experimental study using both feedback and non-feedback when following gaze or not, Corkum and Moore (1998) found that joint attention is not naturally acquired until 10 months of age. In a gaze following experiment, the authors tested if infants were likely to follow the gaze and head turn of an adult. In one condition, the children would receive feedback when they followed gaze, and in a second condition they would not receive any feedback at all. In a second experiment, the infants would receive feedback if they followed the experimenter's gaze (natural group), or when they did not follow the gaze (unnatural group). The youngest infants were likely to follow gaze, but only a small proportion (5%) would follow the experimenters' gaze well enough, that is, the gaze following of the youngest infants was accompanied with more spontaneous gaze pattern than the older ones. Furthermore, the results implied that gaze following could be learned from 8 months of age, and that the cues provided by the experimenter were important. It could seem that the physical characteristic, that is, the movement direction to either the left or the right side, facilitated the infants gaze following (Corkum & Moore, 1998).

From 4 to 6 months, infants respond to emotional signals. In a longitudinal study, Melinder and colleagues (2010) studied the developmental changes of infants reaction to the Face-to-Face Still-Face paradigm (FFSF) presented by the mother or a stranger at 2, 4, 6, and 8 months of age. FFSF is where a person interacts with the infant normally, accompanied with play and talking (Face-to-Face), before the person freezes and becomes unresponsive to the child (Still-Face). In this second phase, the infants' response is measured. After the still-face situation, the person interacts with the infant again (reunion play episode). In this study, Melinder and colleagues found that infants' negative reaction was more frequent to mothers' still face, than to strangers' still face. These authors found that positive and neutral expressions of the child in the still-face situation seem to increase during early development, while the negative expressions to this situation seem to be stable. Their negative expressions in this situation, however, seem to depend on whom they are interacting with. It thus seems that the infants' expectations to mothers' engagement influence their negative reactions (Melinder, Forbes, Tronick, Fikke, & Gredebäck, 2010).

Infants' Sensitivity to Ostensive Cues

Development of gaze elicit to gaze following in early infancy. Gaze is one of many social cues known as ostensive cues. Ostensive cues are signals that indicate a person's intention to initiate communicative interaction with another (i.e. the observer) (Senju & Csibra, 2008). The communicator (i.e. the one that wants to communicate) is also dependent that the observer understand and recognize the intention behind the communicative act (Csibra, 2010). The communicator can furthermore produce certain cues that generate the communicative intention he wants to address. The cue is ostensive because it captures one's attention. In order to develop the sensitivity towards ostensive cues, the cue must specify that the infant is the observer of the communicative act; it must be easy to discriminate by the infant; and it must induce orientation towards the source of the cue. There are at least three cues infants are especially sensitive to: direct gaze that establish eye contact by, for instance raising the eye brows, infant-directed speech, and contingent reactivity (the natural turn taking in a conversation) (Csibra, 2010).

Children's attention to objects that are attended to by others seem to depend on the initiation of a communicative act (Senju & Csibra, 2008). In two experiments, 6-month-olds watched a video presentation representing an actor that would either look directly at the observer before turning her gaze to an object nearby (ostensive cue), or not make eye contact with the observer (non-ostensive cue). In this second condition, a colorful moving image was projected on to the model's head. When the model gazed at the observer, she would slightly raise her eyebrows before turning to one of the objects. The results from this study indicated that 6-month-olds were more likely to follow others' gaze direction when a communicative act was present (i.e. the actor engaging in eye contact with the observer) (Senju & Csibra, 2008). Support for this is found in a longitudinal study (Melinder, et al., 2010) where the authors argue that infants develop a certain sensitivity to context between 4 and 6 months of age, and that this sensitivity becomes evident in the act of gaze following.

The Mirror Neuron System

The neural underpinnings of social cognition is suggested to be the mirror neuron system (MNS) (Gallese, Keysers, & Rizzolatti, 2004). This is thought to mediate action understanding by projecting observed actions onto ones own motoric representation of the observed action. Using single-cell recordings (di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996) researchers have found that an area in the rostral part of inferior area 6, area F5, in rhesus macaque monkey's premotor cortex discharge both when the monkey is performing an action, as well as when the monkey is observing another monkey, or an experimenter performing the similar action. Interestingly, hand movements without objects (e.g. food), grasping food using a tool (Gallese, et al., 1996), or a hand miming an action (Umiltà et al., 2001) do not discharge these neurons. It seems that these mirror neurons only discharge when there is a specific observed action. The mirror neurons also show a strict congruence between observed and executed action in terms of goal (e.g., grasping an object) or in terms of the achievement of the goal (e.g., the precision of the grip) (Rizzolatti & Arbib, 1998). Mirror neurons do not only discharge when the monkey sees an action, but also when the monkey knows the outcome of an action without seeing the final part of that action (Umiltà, et al., 2001).

There is an increase in findings pointing towards the existence of a mirror neuron system also in humans (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). Rizzolatti and Arbib describe mirror neurons as neurons that 'represent' the motoric properties of actions. The authors argue that this representation can be used in order to understand or predict actions of others. By generating a motoric representation of the observed event, the observer acquires knowledge of the event as if it was being performed by him/herself, including the intention and goal of the action (Rizzolatti & Arbib, 1998*)*. Fadiga and colleagues (1995) were the first ones to do demonstrate a human MNS (Fadiga, et al., 1995). With transcranial magnetic stimulation (TMS) of the human motor cortex, Fadiga and colleagues (1995) showed that when observing an action, an increase of motor evoked potentials (MEPs) occurred in the muscles the participants would have used in order to perform the same action. Similarly, using an electrophysiological approach, Cochin and colleagues (1999) observed that observation and execution of movement share the same network. The authors reported that compared to rest, Mu activity was blocked when observing an action as well as when executing the same action (Cochin, Barthelemy, Roux, & Martineau, 1999). The abovementioned results demonstrate that observation and execution of a movement is related to the posterior frontal cortex and the motor cortex (Cochin, et al., 1999; Fadiga, et al., 1995).

Action observation seems to recruit the same neural structures that would normally be recruited when performing the observed action. This tendency is also reflected in gaze performance, where individuals predictively shift gaze to the goal of the action, as they would have done if they were performing the same action themselves (Falck-Ytter, Gredebäck, & von Hofsten, 2006; Flanagan & Johansson, 2003). From 12 months on, infants show the tendency to predict future events. In an eye-tracking study, children and adults would watch a movie consisting of a model that would move objects to a goal (e.g. a bucket). The 12-month-olds, as well as the adults' gaze would arrive at the goal before the arrival of the hand (Falck-Ytter, et al., 2006), indicating that the participant's knew the outcome and intention of that specific action. Toward the end of the first year of life infants predict other people's actions, which is highly linked to the MNS (Falck-Ytter, et al., 2006). The ability to understand others actions and intentions are shaped by our own action development. That is, the child needs a system to project these actions onto (von Hofsten, et al., 2009).

Development of Social Cognition in Autism Spectrum Disorder

Autism Spectrum Disorders (ASD) describes several conditions classified as Pervasive Developmental Disorder (PDD). PDD include autism, Asperger syndrome and pervasive developmental disorder - not otherwise specified (PDD-NOS), childhood disintegrative disorder, and Rett's syndrome. However, only the first three conditions are usually considered as part of the ASD diagnosis (American Psychiatric Association, 1994).

ASD is considered to be one of the most severe childhood psychiatric disorders, affecting about 1 in 150 children (Fombonne, 2009). The ratio between males and females for ASD is considered to be between 3:1 and 4:1 (male: female) (Carr, 2006). Key symptoms in ASD are threefold and include significant impairments in social and communicative development, of which social reciprocity and social cognition is considered to be most challenging, repetitive and deviant behavior (American Psychiatric Association, 1994). These abnormalities entails impairments in the lack of eye contact, social awareness or appropriate behavior, one-sidedness in interaction, the inability to join in a social group, and the child's lack of imagination, flexibility and pretense when playing (American Psychiatric Association, 1994; Baron-Cohen, 1995). The diagnosis, however, is usually not given until the age of two at the earliest, and the diagnosis is made on the basis of behavioral symptoms (Coben & Myers, 2008; Nation & Penny, 2008).

During the first few years of life, children normally generate an understanding that there is an intention behind actions made by other people (Falck-Ytter, et al., 2006). Individuals with autism spectrum disorder (ASD) show impairments in several social cognitive skills (Baron-Cohen, 1995; Dawson, et al., 2004; Leekam & Ramsden, 2006). This could help explain why individuals with ASD seem to lack interest in others. Social impairments in ASD have an early onset, and are persistent over age (Sullivan et al., 2007). Deficits in joint visual attention, and more specifically deficits in gaze monitoring, are suggested to be one of the most robust indicators and early signs of ASD (Chawarska, Klin, & Volkmar, 2003). With a visual attention cueing paradigm, Chawarska and colleagues (2003) found that toddlers with ASD do not follow the gaze of others (Chawarska, et al., 2003). Baron-Cohen (1995) argues that a lack of a 'shared attention mechanism' could help explain the impairments of joint visual attention in individuals with ASD. Dawson and colleagues (2004) suggests that a general social orienting impairment in ASD is due to the children's failure to orient to social stimuli. In their study, 83% of the individuals with ASD could be recognized due to poor joint attention ability (Dawson, et al., 2004). A home videotape study of 1-year-olds later diagnosed with ASD demonstrated that young infants attended less to people, and showed impairments in joint attention behavior (pointing behavior and engaging others by showing objects), and furthermore failed to orient in the right direction when their names were being called (Osterling & Dawson, 1994). In a prospective study, Sullivan and colleagues (2007) examined response to joint attention, and found the children with ASD to show a deficiency in response to this behavior from the age of 14 months on. The study was performed on children with a high risk for ASD (Sullivan, et al., 2007). In another study, the children with ASD would show difficulty in social orienting to both gaze following, and to initiate acts of joint behavior (Leekam & Ramsden, 2006). Also, acts of joint attention are rarely accompanied by positive affect towards others (Kasari, et al., 1990), therefore leading to a hypothesis that deficits in joint attention are accompanied by disturbances in affective sharing. These studies add to the findings that suggest that response to joint attention, together with initiation of joint attention, are important intervention targets when identifying the possible causes of ASD.

So far, a vast amount of research on children with ASD reveals deficits of social abilities that in time affect their interactions with other beings. Children with ASD show less interest in faces than typically developing children. That is, they attend less to the face in a social context (von Hofsten, et al., 2009), engage in less mutual gaze (Volkmar & Mayes, 1990). Interestingly, researchers have found that individuals with ASD do not suffer from a general attention deficit. These individuals can determine where a person is looking (Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997), and they track an object smoothly (von Hofsten, et al., 2009). Individuals with ASD may fail to develop face specialization, and some of the information they fail to process is the gaze of others (Schultz et al., 2000), facial expressions (Celani, Battacchi, & Arcidiacono, 1999), socio-emotional reciprocity, and the ability to regulate social interaction (Critchley et al., 2000). Pierce and colleagues (2001) suggested that the autistic brain is unable to receive environmental stimulation in an optimal way, hence, developing abnormalities (Pierce, Müller, Ambrose, Courchesne, & Courchesne, 2001). Neuroimaging studies show atypical patterns of brain activation (a deactivation of the fusiform face area (FFA) in the fusiform gyrus (FG)) when individuals with ASD process faces (Schultz, et al., 2000). On the other hand, the authors found an increase in activity in the inferior temporal gyri (ITG), an area that is often involved in object-specific perceptual discrimination (Schultz, et al., 2000). Individuals with ASD thus seem to process faces in a different manner than what is seen in typically developing individuals. Instead of focusing on the face, they rely on individualistic features; like a hat for instance (Pierce, et al., 2001). Other findings indicate that they rely on lower face- and mouth regions instead of the overall face (Schultz, et al., 2000). In a conversation-study, the shadow cast by one of the models was very attractive to the children with ASD, and they attended less to the conversation between two people than typically developing (von Hofsten, et al., 2009).

One hypothesis is that when seeing faces (eyes especially), an increase of negative emotional response occur in individuals with ASD (Dalton et al., 2005). Others render the possibility that children with ASD look less at people and faces in general (Falck-Ytter & von

Hofsten, 2011; von Hofsten, et al., 2009). However, other researchers demonstrate activity in the FG when processing faces, suggesting that abnormalities could be found in other nodes of the face-processing system (Dapretto et al., 2006; Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). A possible solution for why the expected activations were not found when individuals with ASD process faces could be their inattentiveness towards the eye region. By cueing the participants to attend to the eye region, Hadjikhani and colleagues (2007) found activation of the FFA in high-functioning adults with ASD.

Mirror Neuron Disturbances in Individuals with ASD

A large debate revolves around the hypothesis that the disruptions seen in ASD stem from a dysfunctional mirror neuron system (MNS) (Dapretto, et al., 2006; Martineau, Cochin, Magne, & Barthelemy, 2008; von Hofsten, et al., 2009; Williams, Whiten, Suddendorf, & Perrett, 2001). Williams and colleagues (2001) were the first to propose a relationship between the MNS and ASD. The authors suggested that the deficits in language, 'theory of mind' skills including joint attention behavior and imitation could be due to a dysfunctional MNS. The authors argue that joint attention could be seen as a way of 'mirroring' each other, where one person's attentional focus mirror the other (Williams, et al., 2001). Further, it is hypothesized that a dysfunction of the MNS makes it difficult to project other people's actions onto one's own action system. This makes it hard to predict other's upcoming actions and events, which in time makes it difficult to function in a social context (von Hofsten, et al., 2009). It seems that expressions in the MNS do not get established in children with ASD as in typically developing children. This could thus explain the failure to develop social abilities such as joint attention (Critchley, et al., 2000; Williams, et al., 2001).

Cognitive neuroscientific studies of ASD have revealed patterns of dysfunctional brain networks in individuals with ASD (Courchesne, Redcay, Morgan, & Kennedy, 2005). When processing faces, an abnormal activation is seen in the amygdala, the IFC, and the STS (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2007; Pelphrey, Morris, & McCarthy, 2005). The latter study argues that gaze processing deficits in ASD is not due to problems in general gaze discrimination, but rather a deficiency in using the information conveyed in gaze direction (Pelphrey, et al., 2005), which in turn makes it hard to understand the intentions of another person. Areas along the STS respond to movements in faces and gaze, and are important in face processing (Schultz, et al., 2000), and thus seem to have an important role in social cognition and social attention. In addition, STS seem to have a more specific involvement in social information provided by direction of gaze, body movement and other biological motion (Allison, et al., 2000). These findings suggest that areas belonging to the MNS are causing the disturbances seen in individuals with ASD as these are involved in face processing. This indicates that the face-processing areas (e.g. FFA in the FG) are not involved in the impairments associated with ASD *per se*, as was originally thought (Hadjikhani et al., 2006).

The Current Study

The aim of the current study is to investigate how attention is directed in children with ASD and typically developing children. Perception of attention direction and initiation of attention to that location in space are important intervention targets when classifying the cause of ASD. Several cognitive neuroscientific measurements have been used in order to study the deficits seen in ASD, where functional magnetic resonance imaging is the most frequently measurement (Coben & Myers, 2008). The participants, however, are often high-functioning adults or adolescents with autism or Asperger syndrome (Hadjikhani, et al., 2007), and it has been more difficult to get appropriate measure for younger children with ASD. Because of the importance of ostensive cues in the controlling of other people's attention (e.g. eye contact and raised eyebrows) (Senju & Csibra, 2008), we focused this study on the sensitivity to such cues in TD children and children with ASD. It is known that children with ASD have a different fixation pattern than typically developing children (Volkmar & Mayes, 1990; von Hofsten, et al., 2009), and deficits in social attention can thus be reflected in gaze behavior. Through experimental techniques, we are able to measure what individuals prefer to look at, and what they actually attend to.

In the current study, eye tracking was studied in a group of children with ASD, as well as in two groups of TD children (10- to 12-month-olds and 3- to 4-year-olds). Typically developing preschool children are close in age with the ASD children. Because children with ASD show a deficit in social development, a younger group of children, that is, infants would be considered as a good comparison. The effect of ostensive cues on attention direction was investigated in a gaze following paradigm. The fixation patterns of these children were recorded.

The study by von Hofsten and colleagues (2005), aimed to test how young infants perceive attention direction, and to provide an evaluation of whether young children follow the direction of gaze. The infants were presented with a model that would either gaze, gaze and point, or just point at one out of four objects. By using a model in static video images, they could analyze the proportion of looking time, together with the number of gaze shifts from the face and hand AOIs (areas of interest) to the attended and unattended objects. In the current study, the findings by von Hofsten and colleagues were further investigated. These authors found the infants to overall attend more to the models' face, and to discriminate ostensive cues provided by eye and head direction. We want to see how children with an autism spectrum disorder perceive ostensive cues in terms of gaze following.

Instead of using static video images, we presented the children with dynamic video presentations where a female model attended to different toys with either a neutral face (non-ostensive condition), or by initiating direct eye contact with the observer by raising her eyebrows before looking at the target of interest. Just directing gaze directly at the targets alternated with looking directly at the participants and then raising the eyebrows before looking at the target, is ostensive and makes typically developing children become more interested in looking at the attended object (Senju & Csibra, 2008). Children with ASD may not be equally sensitive to this cue.

Hypothesis and Predictions

Children with ASD track moving objects in a similar way as typically developing children (von Hofsten, et al., 2009), and can detect gaze direction (Leekam, et al., 1997). Therefore, the problem is not a general attention deficit *per se*, but could be related to the social context in social situations. By adding a social context, we hypothesize that the children with ASD will show inferior performance in this situation, hence, finding the social information difficult to read. The eye tracking technique allows for an analysis of the scanning patterns of children. It further provides a good indication of how children perceive social information, and if they understand the intentions behind other's actions (i.e. gaze direction). Infants seem to monitor gaze direction well from 12 months of age (von Hofsten, et al., 2005). We therefore expect the infants and the preschoolers to follow the gaze of the model, and that gaze following would be more frequent in the ostensive condition (Senju & Csibra, 2008). However, we expect that the children with ASD would miss the information in the ostensive cue by not attending to the model's face as much as the TD children. As a function of a different fixation pattern, we expect that the children with ASD will attend more to the unattended objects than the attended ones.

Methods

Participants

Participants included seven preschool children with an autism spectrum disorder (ASD). Two of the participants were excluded due to poor eye calibration, leaving five participants (5 boys; mean age = 5.6 years, SD = 1.4, range = 3.5-7.3 years). The children with ASD were all recruited through Glenne Autism Regional Center in Horten, Norway (www.glennesenter.no). The children's diagnosis is based on clinical information in accordance with the criteria's set by the ICD-10 (International Classification of Diseases, Tenth Revision). The diagnosis is based on the results of an evaluation at Glenne, where a multidisciplinary team performed the examination. In addition, exclusion criteria were the child's primary language exposure other than Norwegian, and an intelligence quotient (IQ) score below 55.

A sample of twenty-three typically developing (TD) children was divided into two age groups: Twelve TD infants (3 boys, 9 girls) between 10 and 12 months old (mean age = 11.6 months, SD = 0.68, range = 10.5–11.6 months), and eleven TD preschoolers (5 boys, 6 girls) between 3 and 4 years old (mean age = 3.7 years, SD = 0.5, range = 3.1–4.7 years). In addition, six infants and one preschooler took part in the study, but were excluded in the analysis due to poor eye calibration. The younger infants were recruited by writing to the addresses provided by the Norwegian national register (Folkeregisteret/Skatteetaten). This recruitment procedure is commonly used by the Cognitive Developmental Research Unit (EKUP) at the University of Oslo. The TD preschoolers were recruited through day-care as well as through social networking. All participants, except of one child with ASD, had normal or corrected-to-normal visual acuity. The study was approved by the Regional Ethical Committee and was in accordance with the ethical standards specified in the 1964 Declaration of Helsinki.

Apparatus

The children's eye movements were measured with a cornea reflection technique (Tobii 1750 Eye-Tracker, Tobii Technology, www.tobii.com). Data and measurements were collected with ClearView analysis software (ClearView 2.7.1). The gaze of both eyes is measured with infrared light that is directed at the eye. The reflections of reference light on the cornea were measured relative to the center of the pupil. The method measures the gaze from each eye separately and makes an evaluation of where the individual is looking at the screen (von Hofsten, et al., 2005). The stimuli were presented on a 17" TFT display, with a resolution of 1280x1024 pixels. The eye-tracking procedure includes a camera mounted below a computer display that is hardly noticeable. Nothing is applied to the child. The eye-tracking system recorded gaze data at 50 Hz; accuracy is 0.5° of visual angle. A high resolution and a large field of view (20x15x20 cm) were used to capture images of the eyes, and thus provide effective tolerance to head-motion (30x15x20 cm). The light conditions were kept low in order to minimize visual distraction. The children were placed on a chair approximately 60 cm in front of the screen of the Tobii eye tracker, and the measurements could begin after a short calibration of 10 to 20 seconds.

Stimuli

Two sets of videos were presented to the child. In this paper, we will only present data from one of the experiments. Other stimuli that were shown to the participants, that will not be included here, were videos of two people or animated toy-trucks engaged in a conversation (see Bakker, Kochukhova, & von Hofsten, 2011). The experiment for this current study consisted of twenty stimuli, alternated with twenty attention-catching movies in between each stimulus. Stimuli were shown in a randomized order. The children were presented with twenty short movies with a duration of 5000-6000 ms, respectively. Altogether, the twenty movies lasted in 2:56 minutes. The movies consisted of a female adult sitting behind a desk with four distinct objects in front of her (see Figure 1). Each trial started with the female model looking down before attending to one of the four objects. The objects were a toy-rhino, a toy-frog, a pink egg with white dots, and a soap bubble container. The objects were chosen due to their colorfulness. The positions of the objects was randomized, switching the position of the two objects on the right side, and the two objects on the left side, respectively. The background was neutral, and the woman was wearing a black sweater, and had pulled her hair away from her face. Each trial consisted of either one of two phases that separated the experimental conditions. In one condition (ostensive condition), the model looked straight at the camera, raising her eyebrows slightly together with a smile (Figure 1A) before attending to one of the objects (Figure 1B). In a second condition (neutral condition), the model attended to one of four objects using gaze and head direction but without any ostensive cues (Figure 1C). The model's face remained neutral, avoiding any contact with the observer. In a third and fourth control condition, the model would either look into the camera with a neutral face, or with her eyebrows raised while not attending to any objects. Between each trial, the children's attention was drawn to the center of the screen with an animated attention-getting image accompanied with sound. Sound was only present for the attention catching movies, and presented with two speakers, one on each side of the screen.

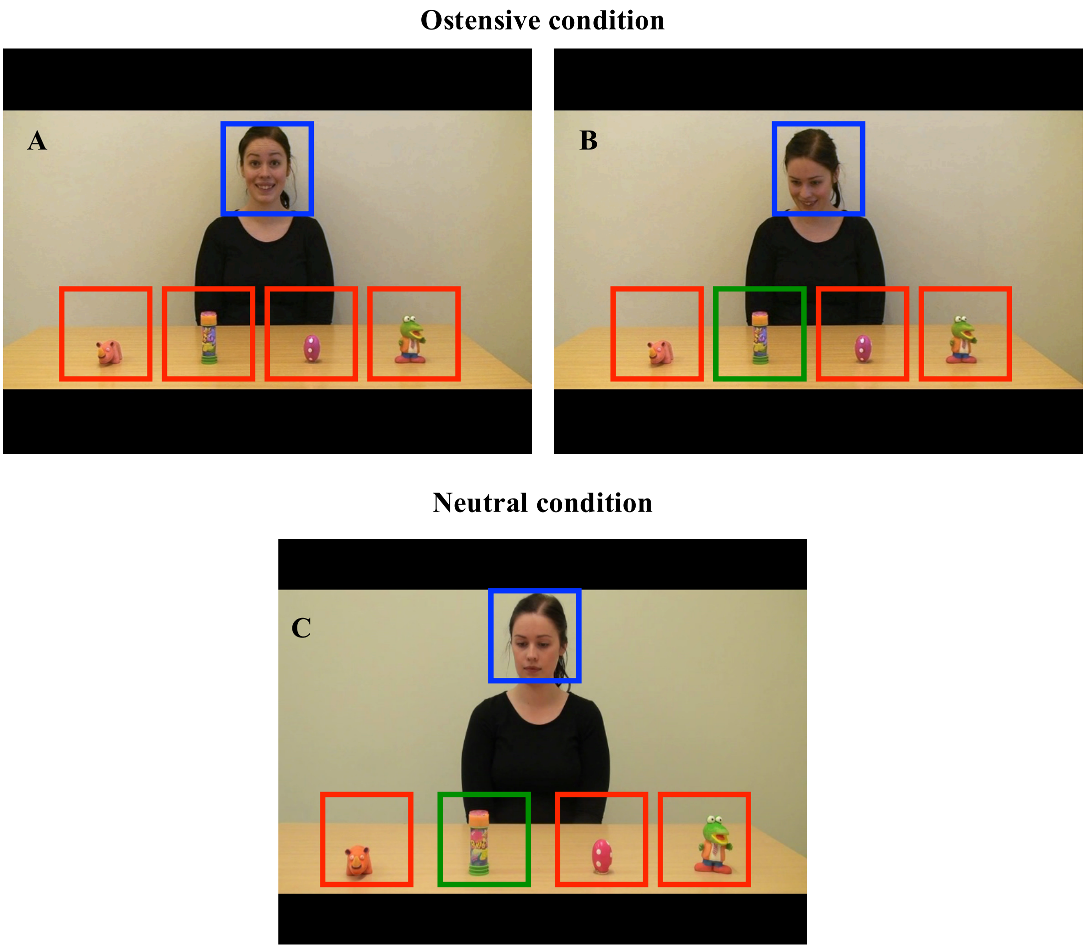

Figure 1. A set of selected frames from the two different conditions. The attention-getting phase (A) included direct eye contact combined with raising of the eyebrows before attending to one of the objects (B). The neutral condition (C) consisted of the model attending to one of the objects with a neutral face. The colored frames depict the areas of interest (AOI), whereas the blue frame depicts the face AOI, while the green depict the attended object, and the red depicts the unattended objects.

Procedure

All children with their families were contacted through letters. The letters are formulated according to the norm set by the Regional Ethics Committee, which hold a description of the study and an invitation to participate. Interested families were asked to answer the query through either e-mail, telephone or through a letter of reply. An appointment was made if the families decided to participate. Once in the lab, each family was provided with a verbal description of the study, its purpose, and the methods involved. The parents signed a consent form before the experiment began.

The children diagnosed with ASD were tested in a quiet and neutral room at Glenne Regional Autism Center. The typically developing children were invited to a testing room at EKUP, University of Oslo. The two testing rooms were made as similar as possible, including white walls and similar equipment. The following procedure was the same for all groups. The participants were seated in front of the monitor, and positions were adjusted in order to gain satisfactory gaze recordings. The older children usually sat on their own chair, while the infants were seated in their parents lap during the experiment. A partition consisting of a wall separated the experimenter and the participant in order to prevent the child from directing his/hers attention to the experimenter.

Before the experimental session, a short individual calibration of few seconds was performed. The parents with children sitting on their lap was asked to look away during the calibration procedure in order to prevent the eye-tracker from registering their eyes. We used a procedure including five calibration points. To attract the child's attention, a blue-and-white circular target was used, which expanded and contracted together with an attention-getting sound. Beforehand, the child was told to watch two short movies on a screen. Breaks between the two movies were given if needed. The infants were allowed to bring pacifiers. The children received a toy as appreciation for participating in the study. The parents were allowed to ask questions before and during the recordings. After the study, the parents were briefed about the hypothesis of the study, and all questions were answered.

Data Analysis

The gaze recordings from the eye-tracking camera were available as gaze plots and text files. Datafiles were analyzed in Timestudio (Timestudio 2012©, Uppsala University, www.babylab.se) using MATLAB (MathWorks Inc., Natick, MA). Statistical tests were calculated using SPSS (SPSS Inc., Chicago, IL). In Timestudio, areas of interest (AOIs) were defined in order to determine time of the gaze fixations. Five AOIs were defined in the video file in order to make sure that each area was within a certain set of pixels, and that that these covered the areas of interest. These AOIs included the head of the model, and each of the four objects, respectively (Figure 1). The AOIs was of the same size for all five areas, and was settled in all trials (150x150 pixels). The five AOIs were coded in different ways during the movie. The face AOI was coded to include all fixations during the entire recording. The AOI of the four specific objects, however, was coded to include all fixations by the time the model fixated the attending object, and in a period of three seconds. Time stamps for each movie were determined by frame-to-frame inspection in ClearView. By the time the model fixated an object, the four object AOIs was activated in a period of three seconds. After three seconds, the object AOIs was deactivated. Figure 1 shows the five different AOIs. The blue rectangle (head AOI) included all fixations. The green rectangle (the attending object) was coded as a 'Hit', while the additional three rectangles (the unattended objects) were coded as a 'Miss'. In the analysis, the total fixation time for the unattended objects (coded as 'miss') was divided by three. This was done because there were three different objects that could be coded as a 'miss', and only one object that could be coded as a 'hit'. Furthermore, a difference score (DS) was calculated as the proportion of looking time within the attended object minus the proportion time spent on the unattended objects (hit-miss). Results revealing gaze fixations for each AOI was available as text-files, which made it possible to import the data into SPSS for further analysis.

Four kinds of analysis were performed. First, we were interested in the average looking time (the total looking time within the AOIs; Figure 1). Second, we were interested in the proportion looking time spent on the objects (DS) and the unattended objects. Do they follow gaze to the attended toy (see von Hofsten et al., 2005), and is this different in a neutral versus ostensive condition (Senju & Csibra, 2008). And lastly, we examined if the children attend more the models face in the ostensive condition than to the model in the neutral condition. The control condition was only included in the total looking time analysis. Repeated measure general analyses of variance (ANOVAs) and Tukey post hoc comparisons were used to analyze the effect of condition (ostensive and neutral), and group effect for each of the three gaze measures (DS, miss and face fixation). The study thus represented a 3 (groups; ASD versus TD infants versus TD preschoolers) x 2 (conditions; ostensive versus neutral) mixed factorial design with the last factor as a within group factor. An alpha level of .05 was set for all statistical analyses.

Results

Outliers were defined as 3 SD away from the mean. One extreme outlier was present (one in the ASD group) and thus excluded from the analysis. The other four participants were reasonably similar and were used to present the ASD group. The analysis is therefore based on 4 children with ASD, 12 TD infants, and 11 TD preschoolers.

Looking Time Analysis

The three groups had a different fixation pattern. On average, children with ASD fixated less within the five AOIs (the total looking time). In addition, the children with ASD fixated less to the face of the model, and to the unattended objects than both TD infants and the preschoolers in the ostensive condition. In the neutral condition, the ASD children fixated less according to all the measurements. The TD infants, however, showed less average DS than the TD preschoolers and ASD children in the ostensive condition (see Table 1). Table 1 illustrates the mean looking times (s) for each of the three gaze measures for both conditions, and the mean total looking time within the five AOIs for the three groups.

Table 1
Mean looking time in seconds for each condition.

	ASD children	TD infants	TD preschoolers
Ostensive condition			
Face	.628	1.024	1.629
DS	.035	.022	.178
Misses	.008	.023	.030
Total looking time	.819	1.780	3.422
Neutral condition			
Face	.392	.740	1.287
DS	.048	.091	.160
Misses	.006	.029	.034
Total looking time	1.208	2.233	3.571

A repeated measures analysis of variance (ANOVA) was conducted to compare the total amount of looking time as the dependent variable, both conditions (ostensive and neutral) as within-subject factor, and group (ASD, TD controls) as between-subject factor. The results revealed no significant effect of condition, $F(1,24) = 1.918$, $p = .179$, $\eta^2 = .074$, group $F(2,24) = 2.870$, $p = .076$, $\eta^2 = .193$, or of the interaction condition*group, $F(2,24) = .230$ $p = .796$, $\eta^2 = .019$. Differences of gaze fixations within the five AOIs (total looking time) are depicted in Figure 2 (ostensive condition) and Figure 3 (neutral condition).

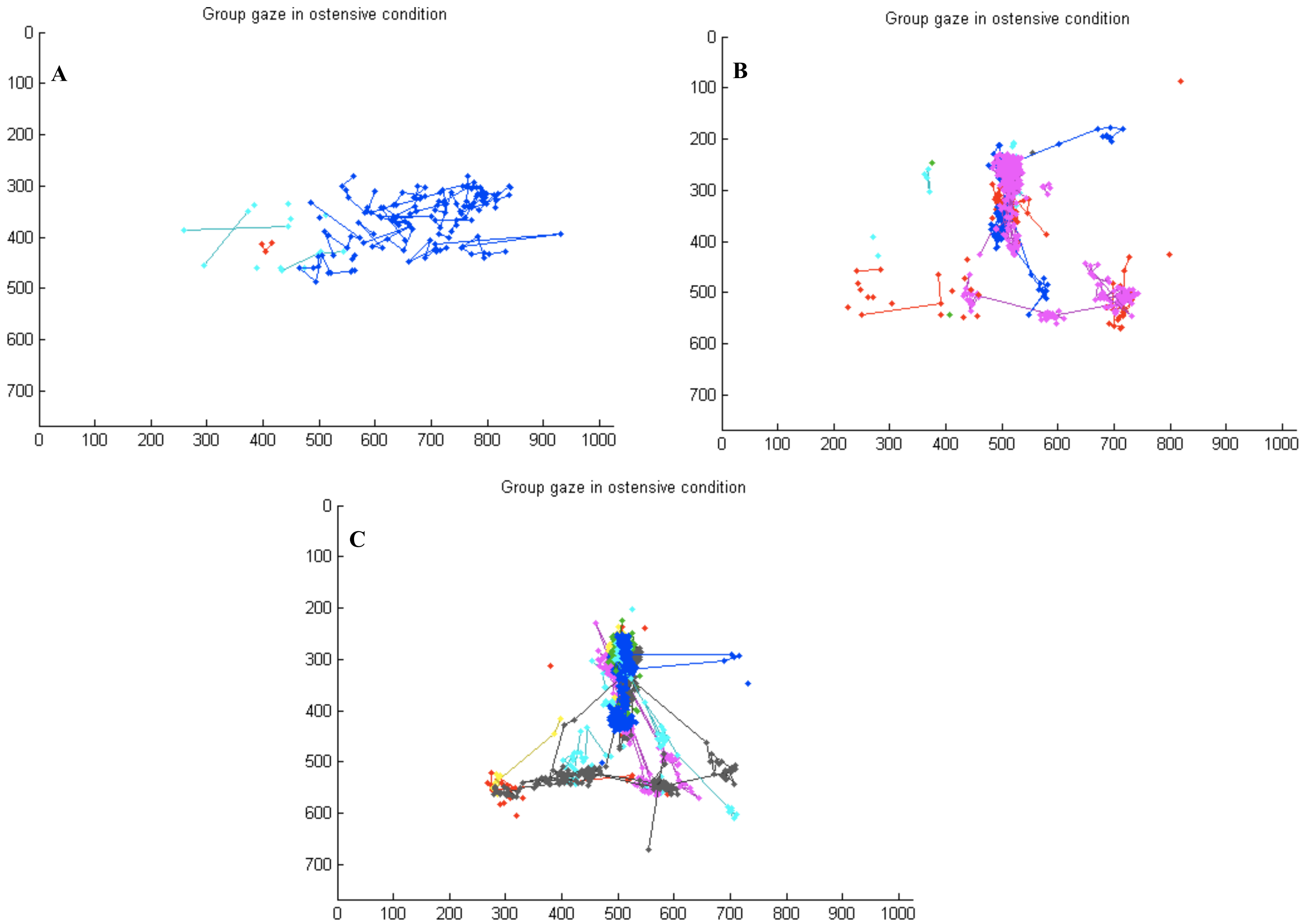

Figure 2. Group plot of gaze fixation within the AOIs in the ostensive condition. The colors represent each participant of the children diagnosed with ASD (A), the TD infants (B), and the TD preschoolers (C). In figure C) one can clearly see the head AOI and the four objects, respectively. This is less noticeable in figure B) and C). The looking patterns of the children diagnosed with ASD seem to be more scattered than the TD groups.

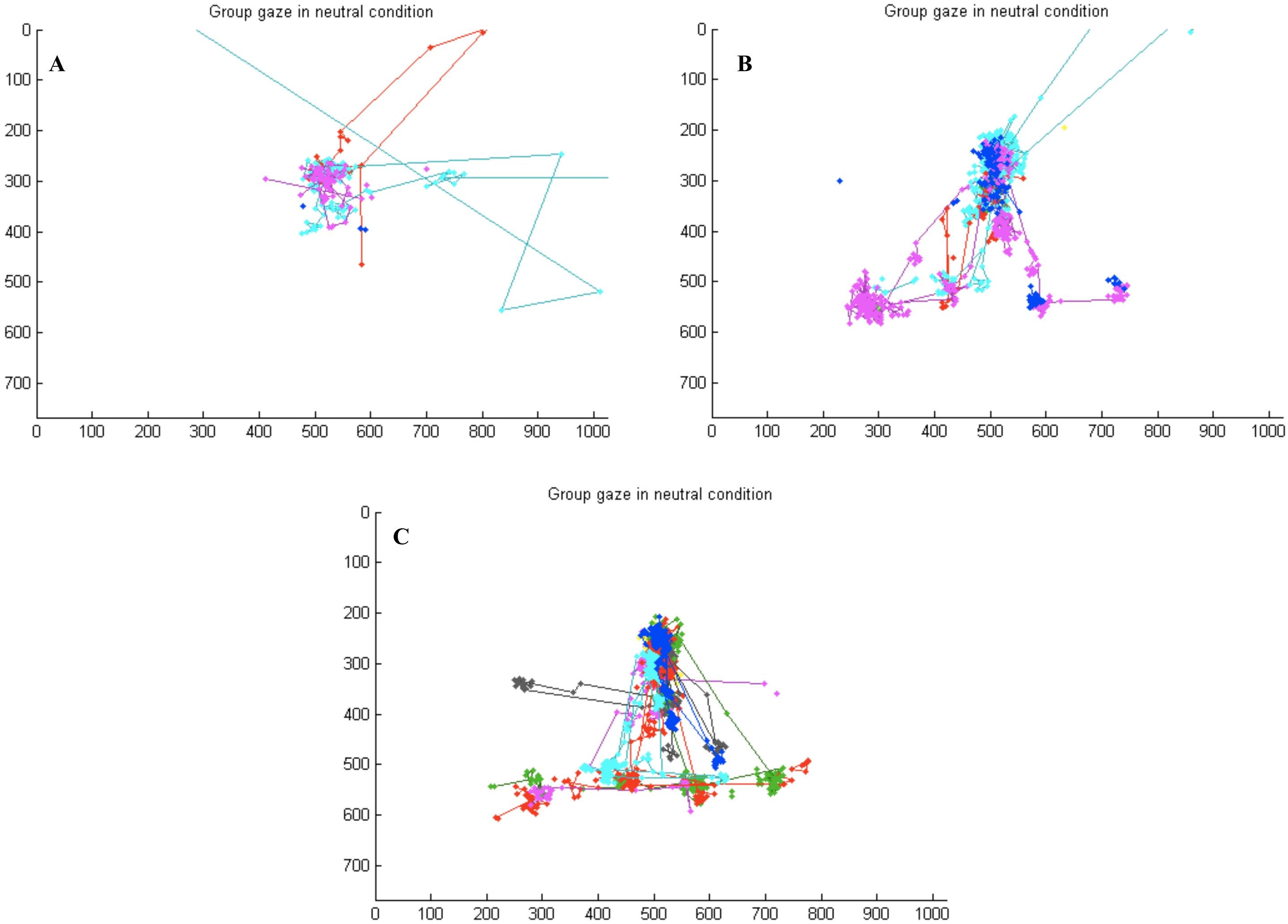

Figure 3. Group plot of gaze fixation within the AOIs in the neutral condition. The colors represent each participant diagnosed with ASD (A), the TD infants (B), and the TD preschoolers (C). In figure C) one can clearly see the head AOI and the four objects, respectively. This is less noticeable in figure B) and C).

Difference Score

A repeated measures ANOVA was conducted with the difference score (DS) as the dependent variable with condition as within-subject factor, and group as between-subject factor. The within subjects test revealed no main effect of condition, $F(1,24) = .958$, $p = .338$, $\eta^2 = .038$. Tests of between-subjects effects revealed a significant main effect of group,

$F(2,24) = 4.604$, $p = .020$, $\eta^2 = .277$. Post hoc comparisons with Tukey HSD test showed that TD infant's differed significantly with shorter looking times than the TD preschoolers (*M* = -.12, *SD* = .04, p = .030). There were no significant differences between ASD children and TD infants (*M* = -.01, *SD* = .06, *p* = .983) or TD preschoolers (*M* = -.13, *SD* = .06, *p* = .148*)*. There were no significant interaction of condition * group, $F(2,25) = 2.50$, $p = .102$, $\eta^2 = .167$. A separate one-way ANOVA analysis was conducted to test whether the amount of looking differed between the groups in the two conditions. The results revealed significant differences between the groups in the ostensive condition, $F(2,24) = 8.415$, $p = .002$, $\eta^2 = .414$, which was indicative of a large effect size. Post Hoc comparisons with Tukey HSD test showed that the mean score for the children with ASD (*M* = 1.09, *SD* = 1.32) were significantly smaller than the TD preschoolers (*M* = 1.63, *SD* = .77, *p* = .042). The TD infants (*M* = 1.02, *SD* = 1.07) were significantly different from the preschool children (*p* = .002), but not significantly different from the children with ASD (*p* = .970). There were no significant differences between the groups in the neutral condition: $F(2,24) = 1.526$, $p = .238$, $\eta^2 = .114$. These results are illustrated in Figure 4, showing that both the ASD group and the TD infants revealed less average DS than the TD preschoolers, and less DS in the ostensive condition.

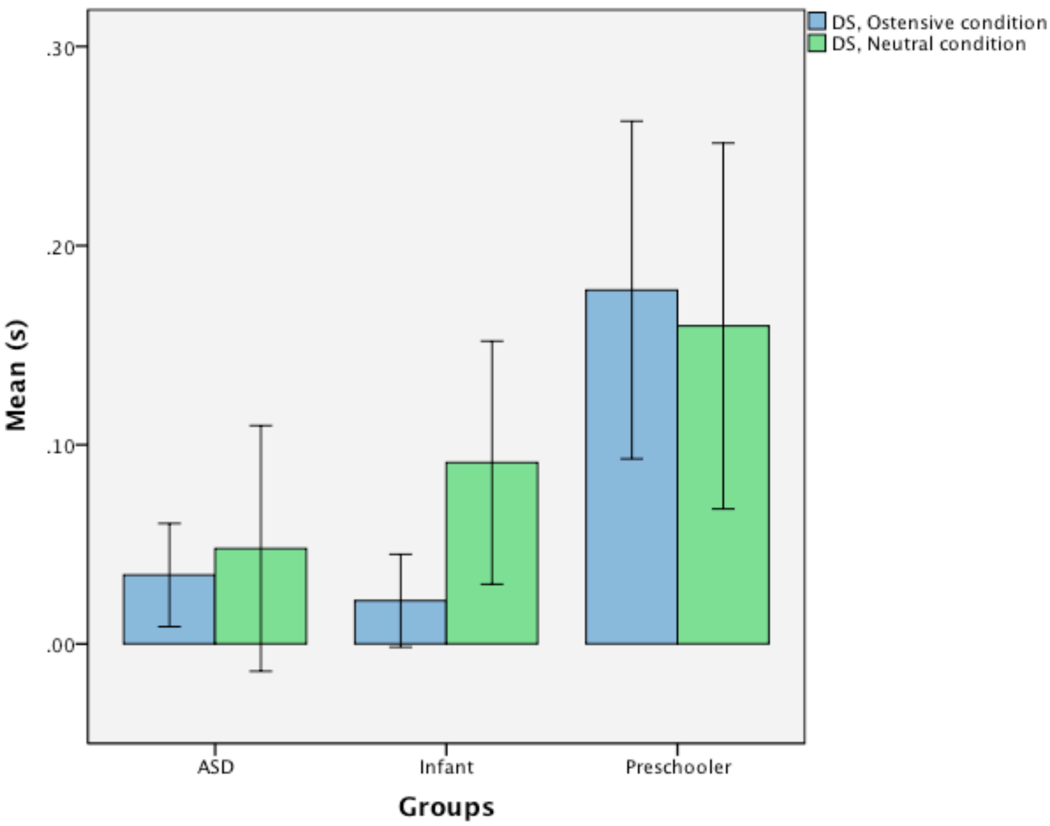

Figure 4. Average looking time (s) of difference score (DS). Bars indicate standard errors of

the mean.

Looking Time to the Unattended Objects

Difference scores (DS) are not especially informative regarding differences between the groups and the proportion of looking time to the attended (correct) and unattended (incorrect) objects. We calculated the proportion looking time to the unattended objects for both conditions, and entered this as our dependent measure into a repeated measures ANOVA. The results revealed no main effect of condition, $F(1,24) = .165$, $p = .688$, $\eta^2 = .007$, or group $F(2,24) = 1.391$, $p = .268$, $\eta^2 = .104$. The interaction was further not significant, $F(2,24) = .082$, $p = .921$, $\eta^2 = .007$. These results are illustrated in Figure 5.

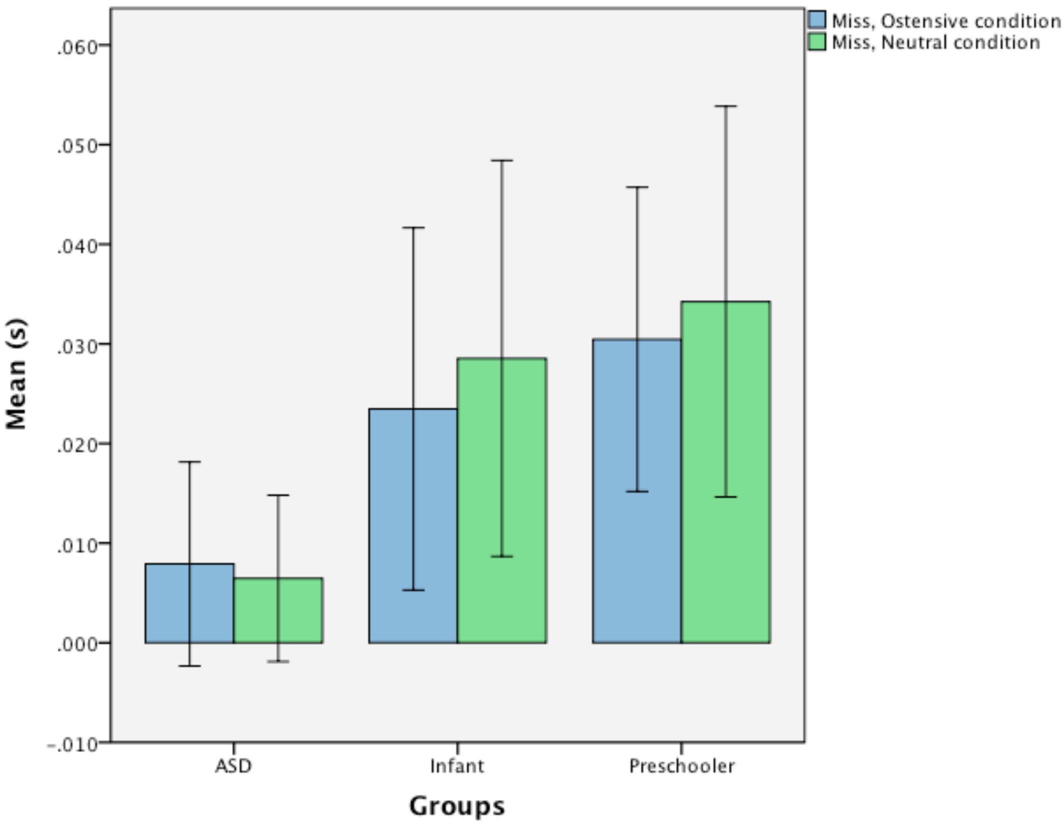

Figure 5. Average looking time (s) for each condition to the unattended objects ('miss'). Bars indicate standard errors of the mean.

Face Fixation

The children with ASD attended less to the face in both conditions than the TD children (see Figure 6). A repeated measures ANOVA was conducted to compare the proportion of fixation on the models face in both conditions, with groups as a between-subjects factor. The results showed a significant main effect of condition, $F(1,24) = 8.782$, $p = .007$, $\eta^2 = .268$, which was indicative of a large effect size. This effect is illustrated in Figure 6, where the groups attended more to the face region in the ostensive condition than in the neutral condition. The results revealed no significant interaction of group, $F(2,24) = 2.297$, $p = .122$, $\eta^2 = .161$, or of the interaction condition * group, $F(2,24) = .098$, $p = .907$, $\eta^2 = .008$. Compared to the ostensive condition, all three groups attended less to the face in the neutral condition (see Figure 6).

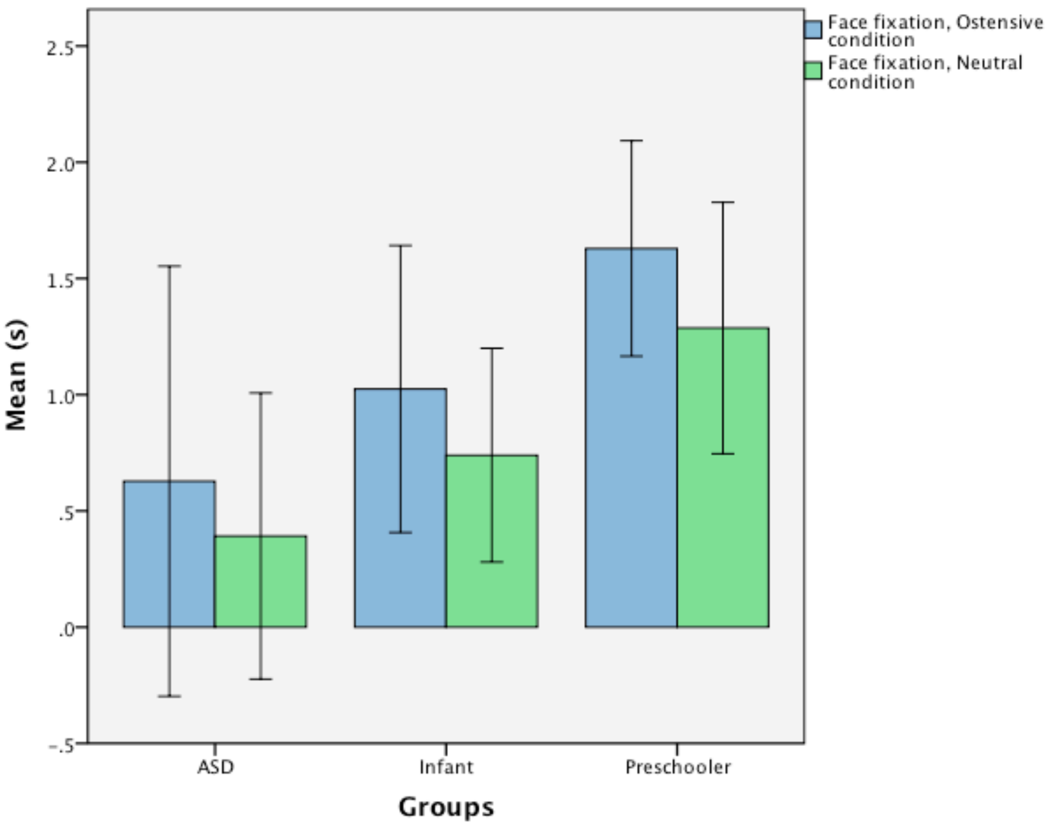

Figure 6. Average looking time (s) to the model's face. Bars indicate standard errors of the mean.

Discussion

In the current study, we wanted to further enhance our understanding of gaze following in typically developing (TD) children and children with an autism spectrum disorder (ASD). With an eye-tracking device, we aimed to test how children with ASD, compared to two groups of TD children follow the gaze direction of another person in an ostensive and a neutral condition.

With respect to the difference score, our results revealed a significant effect of group, with a large effect size. This effect was reflected in significant differences between the TD preschoolers and the TD infants. A one-way ANOVA revealed significant differences between the groups in the ostensive condition. These differences were evident between the TD infants and the TD preschoolers, and between the ASD children and the TD preschoolers. The children with ASD and the TD infants revealed less average DS in the ostensive condition (Figure 4), than the TD preschoolers. The findings indicating that the children with ASD revealed less average DS in the ostensive condition is in line with our predictions, indicating that the children could have struggled with the social information in this setting, and hence found the information conveyed in the ostensive cue difficult to follow. Pelphrey and colleagues (2005) argue that the dysfunctional gaze monitoring in children with ASD may not be a general gaze discrimination, but rather a deficiency in using the information conveyed in gaze direction (Pelphrey, et al., 2005). This is also supported in previous findings, where the children engage in less mutual gaze (Volkmar & Mayes, 1990), and that gaze monitoring is a robust and early sign of ASD (Chawarska, et al., 2003).

However, previous studies have found that immediately after birth, human infants are sensitive to eye contact (Farroni, et al., 2002), and that infants orient to signals from the eyes (D'Entremont, et al., 1997). At 6 months of age, infants seem to depend on strong ostensive cues when following gaze (Senju & Csibra, 2008) and from 12 months of age, they discriminate gaze direction to one out of four objects that are being attended to by another person (von Hofsten, et al., 2005). In the current study, both infants and the children with ASD attended less to the attended objects in the ostensive condition than the TD preschool children. Our data indicate that the TD infants did not perform as well as previous studies report (Senju & Csibra, 2008; von Hofsten, et al., 2005). The infants spent more looking time in the neutral condition, than in the ostensive one (see Figure 4). This performance does not necessarily mean that they have a general inability to understand the social information and the direction of gaze, but could be explained by the amount of looking time to the model's face (see Table 1). In the ostensive condition, the infants spent more time looking at the model's face than at the other objects, which is also illustrated in Figure 2. The child's interest in faces is in line with previous research where the infants attended more to the face than all of the objects together (von Hofsten, et al., 2005). Still, this tendency was different in the neutral condition as the infants attended less to the face, and made more average DS, and had longer looking time at the unattended objects (Table 1). This is not in line with the findings of Senju and Csibras' study, where the infants required strong ostensive cues (in terms of gaze alternated with raising eyebrows) for gaze following (Senju & Csibra, 2008). One interpretation is that they found the face more attractive in the ostensive condition. In this condition, the model would interact with the child and smile. An alternative explanation could be that the child looked more to the face because they wanted to engage with her. In the neutral condition, the model would not attend to the child, and hence, the child was not expecting an initiation of social interaction and therefore the gaze direction could be easier to follow. However, according to Gredebäck and colleagues (2010), infants are more likely to follow the gaze of a stranger rather than their mother (Gredebäck et al., 2010). Nonetheless, it is still unclear why the young infants would pay less attention to the direction of gaze in the ostensive condition. It is possible that within the limited time available, the greater attention devoted to the face of the model prevented the children to look long enough to the attended objects. Another measure that will be tried in the future is to analyze where the first look is directed after the fixation of the face.

When measuring fixation to face, there was a significant main effect of condition, in that all of the groups would attend more time to the face in the ostensive condition. The children with ASD and the TD infants spent almost equal amount of time looking at the faces in both conditions (see Table 1). TD preschoolers were especially interested in the model's face, and we could clearly see that this interest was stronger when the model directed her attention to the observer before looking at an object of interest, which was evident in more looking time to the face in the ostensive condition (see Figure 6). However, looking time to the face did not reveal any significant group differences. Thus, an important thing to notice is that the model's head was the only thing that moved in the videos.

The children with ASD and the TD infants paid almost the same relative amount of average DS, but with a different trend (see Figure 4). The ASD children looked relatively longer at the attended object than the other objects compared to the TD infants in the ostensive condition, which could be explained by the fact that they looked less at the face over all (Figure 6). The TD preschoolers, however, showed longer fixation time to the face, hence attending more to the attended toy, and less to the unattended ones in the ostensive condition. Notably, looking time to the unattended objects did not reveal any group differences. Still, Figure 5 illustrates that the ASD group spent less time looking at the unattended objects, which was not what we expected. One explanation could be that the looking pattern of the ASD children was overall less, and hence attended less to the objects.

This is illustrated in Figure 2 and 3. The ASD children were on average older than the TD preschoolers. Still, they attended less to the social situation than the TD preschoolers. These results are also in line with the aforementioned study (von Hofsten, et al., 2009) where the children with ASD would show problems with the social information in a conversation, but still track a moving object without any problems. This could in turn indicate problems understanding the social information, rather than a general attention deficit *per se.*

Notably, the children with ASD and the TD infants did not differ significantly from each other on either total looking time, average DS, fixation on the unattended objects, or fixation to the model's face. The TD infants were included in this study because the age group would be a good comparison to the ASD group due to the deficit in social development in children with ASD. Although recent findings indicate that ostensive cues guide infants to detect gaze direction (Senju & Csibra, 2008), the current study do not find the TD infants to perform better than the children with ASD in the ostensive condition. This is more evident in the gaze following of the TD preschoolers that attend more to the human face, and more to the attended objects in both conditions in this study.

Limitations and Future Directions

Despite of our findings of a different fixation pattern between the groups, there are some limitations that need to be considered. One limitation in this current study is the sample size of the children with ASD. After excluding three participants, we were left with four participants in this group. Four children with ASD make it difficult to generalize across all individuals with an autism spectrum disorder. The heterogeneity of the participants in clinical groups is a problem that is often encountered because they may deviate from typical children for different reasons. In this study, four of the five children with ASD from whom measurements could be obtained had reasonably similar results. They were used to represent the ASD. The fifth child had a very different attention pattern that deserves to be studied in more detail.

One could only speculate on why so few participants with ASD could be recruited for this study. The recruitment area expanded over a large county (Vestfold in Norway), and it could have been difficult for many to travel to Glenne in a limited period of time. We therefore see the importance that further work extends to a larger group. In addition, it would have been of great value to compare our findings with the ASD children's adaptive communication skill, language development and IQ. The only information we hold is that the children had received a diagnosis at Glenne Autism Center, and that they had an IQ score above 55. It would have been interesting to compare the children's gaze following with other sociocommunicative impairments. In addition, as aforementioned, an analysis of where the first look is directed after the fixation of the face would have provided more information on the children's fixation patterns.

Another limitation to the design is that the experimenter interacting with the children was the same as the one they saw in the movie. This might have affected the children's interest in the movies, but would not have affected the results in a systematic way.

Conclusions

Our study indicated significant differences between the typically developing infants and the preschoolers, and between the ASD children and the preschoolers when attending to the objects in the ostensive condition. Our findings illustrated a lower mean difference between the attended objects relative to the unattended ones than typically preschoolers. The findings support our predictions that the children with ASD could find the information conveyed by the ostensive cue difficult to follow which could be related to the social context rather than a general attention deficit. However, these findings contradict the findings of Senju & Csibra (2008), which indicated that typically developing infants from 6 months of age depends on ostensive cues when following gaze to a target of interest. Due to these findings, we conclude that further research is needed on this area in order to get a better understanding of the sensitivity to gaze following in both children with ASD and typically developing infants.

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