Impaired use of gaze in children with autism

Diagnostic features or individual differences?

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II

Abstract

Recent research in the use of eye-gaze and joint attention behaviour shows inconsistent evidence of social orientation impairments in children with ASD. These inconsistencies have been linked to both differences in levels of functioning between children with autism and limitations in design as well as to methodological factors. This study explored individual differences in use of eye-gaze among 3-4 years olds with high and low functioning autism spectrum disorders (HF- and LF-ASD). The design of this study enabled comparison with children with mental retardation without autism (MR) and typical development (TD). **Methods:** Frequency, duration and targets of gaze were coded based on video recordings of two ADOS-G activities. The results of these measures were compared to parental and clinical reports of eye-gaze and joint attention behaviour in the two autism diagnostic instruments, ADI-R and ADOS-G. **Results:** Mean use of eye-gaze was lower in the ASD groups compared to control groups. No difference in within-group variance was found between children with ASD and TD. Levels of functioning were not associated with the amount of eye-gaze initiated by children with ASD. However, higher levels of both cognitive and social functioning were related to better responsive joint attention (RJA), while only social functioning was related to initiating joint attention abilities (IJA). **Conclusion:** Children with ASD are as heterogeneous as children with typical development in use of eye-gaze, and this diversity across groups might be related to differences in levels of functioning on more advanced joint attention behaviour. The findings are discussed in relation to methodological factors, causal theories and the importance of early identification and intervention.

IV

Acknowledgements

VI

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Table of contents

X

1   Introduction

Research on autism spectrum disorders (ASD) has escalated the last few decades and current knowledge on the heterogeneity of symptom manifestations and the optimizing effects of early intervention has replaced previous beliefs that all children with autism are unreachable, highly deviant and indifferent to other people. Still, most of the research previously conducted has focused how individuals with ASD deviate from children with other developmental disorders and/or children with typical development. The importance of these studies should not be underestimated because they increase our knowledge on the early manifestations of ASD which also enables early identification and intervention. However, too much focus on between-group differences also creates the risk of preventing early identification and diagnosing due to fear of labelling relatively well-functioning children as deviant and strange. A stronger focus on the heterogeneity in ASD symptoms and capabilities in high-functioning children with ASD could hopefully help to broaden our understanding of the autism spectrum disorders and decrease possible stereotypical conceptions associated with this diagnoses. A first step to achieve this goal could be to describe the variety in functioning on behaviour commonly associated with ASD, such as the use of eye-contact and joint attention behaviour.

1.1 From autism to ASD

Autism in its most severe form was first described by Leo Kanner in1943. His patients displayed social isolation, insistence on sameness, and motor stereotypes (Kanner, 1943, ref. in Caronna, Milunsky & Tager- Flusberg, 2008). Individuals with "childhood psychoses", as was the term he then used, seemed rare. With Kanners introduction of the initial criteria for diagnosing "childhood autism" in the1970 and -80's the first estimates of prevalence were about 5/10,000 cases (Newschaffer et al., 2007).

Autism is a neurodevelopmental disorder, defined by the presence of 1) deficits in social interactions, 2) deficits in communication and 3) restricted, repetitive and stereotyped patterns of behaviour, interest and activities (APA, 2000). Due to the observation that these features may vary in severity and time of onset the concept of autism was broaden to Autism Spectrum Disorders' (ASDs) (Stoltenberg, et al. 2010). The term ASD does not appear in

DSM- IV TR or ICD- 10, but is widely accepted in research, lay literature and clinical practise (Caronna et al., 2008). Symptoms of ASD rang from severe and unmistakable stereotypical behaviour together with absent language development in very low functioning children, to subtle signs of social- communicative dysfunction in high functioning individuals (Coronna et al., 2008). Usually ASD refers to the three DSM-IV diagnoses of Autistic disorder (299.00), Asperger's disorder (299.80), and Pervasive Developmental Disorder- Not Otherwise Specified (PDD-NOS) (299.80) (Coronna et al., 2008). Together with the two diagnoses (299.10) Childhood Disintegrative Disorder and (299.80) Rett's Syndrome, they are all considered subdiagnoses of the DSM-IV category Pervasive Development Disorders (PDD) (APA, 2000). In clinical practice however the labels autism, ASD and PDD are often used interchangeably (Coronna et al., 2008) and the same convention are applied in this thesis.

   Autistic disorder is the most severe form of the ASDs and is classified as "childhood autism" in ICD-10. Children with autistic disorder show marked impairment in reciprocal social interaction, non-verbal and verbal communication skills and stereotypical, repetitive behaviour with onset prior to three years of age on at least one of these areas. In addition, these children have delayed and/or deviant language development (APA, 2000). According to the DSM- IV there is an associated diagnosis of mental retardation, today mostly referred to as intellectual disability (M. Rutter, personal communication, July 21, 2010), in most individuals with autistic disorder which range from mild to profound (APA, 2000). However, there seems to be a discrepancy in the older and more recent research literature regarding prevalence of children with autistic disorder and intellectual disability. While previous studies, using more stringent diagnostic criteria, found most autistic children to have IQ's below 70, recent studies show a broader variation of IQ among children with autism. By introducing the broader concept "ASD", an increase in prevalence of children with milder symptoms of autism and less cognitive impairment has been identified. When research on children with Asperger's disorder and PDD-NOS are included, several studies show that fewer than half of the ASD- children have significant cognitive impairment (Van Naarden Braun, Schieve & Daniels et al. 2002; Newschaffer et al, 2007).

Asperger's disorder is often associated with higher functioning individuals and frequently referred to as "a mild form of autism". By definition, children with Asperger's disorder have

average or above average cognitive abilities, and typical language development. However, the interlocutor might experience a decreased level of reciprocity in social interaction, an important aspect in the development and maintenance of friendships (Wing, 2008).

For children diagnosed with *PDD- NOS* the criteria for pervasive developmental disorders are not met because of sub-threshold symptomatology (criteria for only one or two of the domains of impairment are met), atypical presentation, late age of onset (> 3 years) or all of these (APA, 2000). PDD-NOS include the ICD- 10 diagnoses "atypical autism" which often occurs in individuals with severe mental retardation or severe impressive language disorder (WHO, 1994).

1.1.1 High- and low functioning ASD

Variation in level of cognitive functioning and language skills are the main factors contributing to the diversity in individuals with ASD (Engeland & Buitelaar, 2008). ASD-individuals with IQ levels below and above 70 are often labelled low- functioning (LF) and high- functioning (HF) respectively. Higher functioning individuals can meet DSM criteria for autistic disorder without having significant cognitive impairment, and may function with minimal support and show giftedness in one or more areas. Low functioning individuals in contrast, more often show additional medical diagnoses such as syndromes and epilepsy that might also influence their cognitive and social functioning (APA, 2000). ASD is found to be four to five times more prevalent in males than in females (APA, 2000), but according to the DSM- IV, females with ASD are more likely to exhibit more severe intellectual disability.

By broadening the concept from autism to "ASD" there has been a gradual increase in prevalence rates towards the 1990's (1/1000) with an escalation of identified cases the previous decades (0.7 %, Lenoir et al., 2009). The possible reasons for the increase in identified cases are highly debated with factors pointing to both etiological and methodological explanations. Probably most important is the broadening of understanding of autism as a spectrum of disorders with diverse symptom manifestations and severity levels. Lenoir et al.'s (2009) recent meta-analysis concluded that an increase in "artificial" cases based on methodological arguments seems most reasonable. More accurate and reliable diagnostic instruments with less stringent criteria for diagnosing ASD are used today compared to the early instruments used to assess "childhood autism". It is very likely that

individuals who would previously have be diagnosed with mental retardation and/or specific learning disorders are now diagnosed with ASD.

Additionally, lack of multiple informants in previous prevalence studies might partly explain the highly variable and seemingly underestimated prevalence rates reported. In the Norwegian "Bergen Child Study" the total population of children aged 7- 9 years in Bergen (n= 9430) were screened for ASD- related features and with the results of prevalence rates as high as 2.7 % (Posserud, Lundervold & Gillberg, 2006). The study collected both teacher and parent forms of the Autism Spectrum Screening Questionnaire (ASSQ). More teacher completed forms were returned (97%) than parent completed forms (71%). Still, higher ASSQ- scores (indicating more ASD- symptoms) was found in the group of children with only teacher completed forms than children who had questionnaires completed by both parents and teacher. To sum up, identification and diagnosing of ASD- cases requires information collected from multiple sources.

Today, more children are also diagnosed at a younger age which might also play a role in the estimation of prevalence based on newer birth cohorts. The present study will use data collected in "The Autism Birth Cohort (ABC)" study (Stoltenberg, et al., 2010). The ABC-study carries the strengths of broad assessment of children screened for autism already by the age of 36 months. It involves both clinical observations of the child as well as information gathered from multiple informants such as caregivers, preschool teachers and other relevant health care practitioners. As such, this study employs early identification of ASD-cases with a wide variety of symptom manifestations and severity levels. The present study makes use of this extensive material to study differences in early manifestations of ASD in high- and low functioning children (HF- and LF-ASD).

The course of development in individuals with ASD is highly variable, depending on the child's language skills, the overall intellectual functioning and age of onset. The point in time being diagnosed and the quality and quantity of intervention received, play significant roles in a child's development (Makrygianni & Reed, 2010). Better knowledge in the variety of early manifestations within the ASD-group can possibly help to avoid that actual affected ASD- cases remain unidentified. Impaired social orientation is one of the core features of autism, manifested as reduced eye-contact, social smiles and joint attention skills. According to DSM- IV, abnormality in eye-to-eye gaze are one of the diagnostic criteria of ASDs (APA, 2000) and eye-contact and joint attention impairments are probably among the most

4

commonly known symptoms of ASD. However, these symptoms are also more subtle and difficult to define than symptoms seen after 2 years of age (APA, 2000). Thus, the significance of eye- contact and joint attention has been frequent targets of investigation in substantial amounts of research on both typical and atypical development (Itier & Batty, 2009).

1.2   Use of gaze in typical development

1.2.1 The function of eye-contact and joint attention

According to Amy Klin, the director of the Autism Research Department at the University of Yale, the eyes are the window to the soul because we are provided with information concerning the emotion and state of mind of others (Falck-Ytter, Gredebäck, & von Hofsten, 2006; Itier & Batty, 2009). But "the eyes are also a window into social development", Klin later adds (Gordon, 2008). More than any other facial feature; the eyes are central to all aspects of social communication such as emotions, direction of attention and identity (Itier & Batty, 2009). The eye region is used as a diagnostic feature to discriminate gender and identity, to process all facial expressions and to attract and direct attention (Schyns et al., 2007). Besides being essential for visual perception, gaze movement is a necessary tool used to inform others about our focus of attention. In the literature the different terms eye-contact, eye-gaze, eye-to eye gaze, mutual gaze and direct gaze are used interchangeably. By means of simplicity the term "eye-gaze" will mostly be used hereinafter to refer to "looks directed towards other people's eyes." This term is distinguished from the term "direct gaze" which is applied when contrasting the direction of eye-gaze such as in comparisons between direct and averted gaze.

Typical developing infants during the first 6 weeks of life exhibit a strong sensitivity to social stimuli. The sounds, movements and facial features of humans attract more attention than other stimuli (Maurer & Salapatek, 1976; Morton & Johnson, 1991). Already at 5 months infants have been shown to react to only small changes in gaze direction (deviations of about 5^0) during social interactions with an adult by smiling and attending less when the adult's eyes are averted compared to when they are directed towards the infant's eyes (Symons, Hains & Muir, 1998). It seems that in everyday life gaze direction, either direct or averted, functions as a powerful social orienting behaviour which can influence person

perception and recognition. Studies have shown that direct gaze signals approaching behaviour and a potential for social interaction (both positive and negative). Averted gaze, however, often signals avoidance behaviour and implies that the person is attending to something or someone else than the observer (Hietanen, Leppaänen, Nummenmaa & Astikainen, 2008a). According to Frischen, Bayliss and Tipper (2007) a review of the past and current research of gaze perception and behaviour suggested that gaze contact, defined as "engaging attention on the faze followed by pupil motion" is vital to give rise to the more complex behaviours involved in joint attention in infancy.

Joint attention refers to "the ability to coordinate attention between interactive social partners with respect to objects or events in order to share an awareness of the objects or events" (Mundy et al., 1986, p. 657, in Dawson et al., 2004). Joint attention skills include sharing attention through the use of gaze- switching, following others attention through gaze- or point following, and directing the attention of others using alternation of gaze, gestures and vocalizing. The first clear evidence of joint attention behaviours is seen in children as young as 6 months old, when they seem to be able to coordinate the direction of the caregivers head turn to a visible target by the use of gaze- following (Morales, Mundy & Rojas, 1998).

Moreover, joint attention is commonly dived in two classes; response to joint attention (RJA) and initiation of joint attention (IJA) (Mundy, Sullivan & Mastergeorge, 2009). RJA refers to infant's ability to follow the direction of gaze, head posture or gestures to other people and consequently share a common social point of visual reference. IJA refers to infant's ability to spontaneously create or indicate a shared point of reference by the use of gestures, or more frequently; alternating gaze between objects or events and other people. Both RJA and IJA function as social signals that designate interest in objects or events, but while RJA involves information processing of others signals, IJA is related to processes involving volitional generation of goal- related behaviour (Mundy et al., 2009). Distinguishing between these two types of joint attention is especially important in the study of autism as will be demonstrated in this study.

Eye-gaze and joint attention abilities are also considered prerequisites for the later emergence of social referencing, shared attention, theory of mind abilities, and language development (for a definition of these concepts the reader are referred to Itier & Batty, 2009).

Thus, direct gaze seems to be a prerequisite to social interactions, and both joint and shared attention play fundamental roles in social cognition. It is thereby likely to assume that individual differences in use of gaze and joint attention abilities play significant roles in level of social functioning in both clinical and non-clinical populations.

1.3 Use of gaze in children with ASD

1.3.1 Impairments in eye-gaze and joint attention abilities

Most studies investigating gaze in individuals with autism have shown deviant use of eye-contact in children with ASD compared to typically developed children. Retrospective studies analyzing videotapes from children with autism's first year of life found abnormal eye contact (Adrien et al., 1993) and less amount of time spent looking at people compared to typically developing children (Osterling and Dawson, 1994). Actually, Osterling and Dawson (1994) discovered that frequency and duration of looking at other persons were the two best predictors of later diagnosis of autism. In the early years much research in autism included comparison groups of children with developmental delays without autism. Similarly to the studies comparing only controls and children with ASD, these studies usually found lower levels of eye- contact in children with autism compared to the other groups (Baranek, 1999; Wimpory, Hobson, Williams & Nash, 2000; Osterling, Dawson & Munson, 2002; Clifford, Young & Williamson, 2007). For instance, Wimpory et al (2000) interviewed parents of children aged six to 24 months before their children were diagnosed with ASD. A very distinctive profile of diminished frequency and referential use of eye contact and other joint attention behaviours was found in children with autism compared to children with developmental delays. In summary, these findings indicated consistent impairment in use of gaze among children with ASD.

1.3.2 Variation in use of gaze

Much of the research on use of eye-gaze in individuals with ASD has been conducted with attention- cuing methods. These studies have primarily investigated response to joint attention (RJA) abilities by studying how typical and atypical children detect others direct gaze and follow gaze- shifts. Leekam, Baron-Cohen, Perret, Milders, & Brown (1997) first found that school-aged children with autism failed to spontaneously orient their attention to the target of

another person's gaze. However, in a later follow-up study (Leekam, Hunnisett & Moore, 1998) when different informants and methods were used, nuanced effects were discovered. Three methods were employed to study gaze orienting in individuals with autism; parental interviews, direct observations and experiments designed to teach children gaze-following skills. The results showed that although children with autism were generally impaired across methods compared to controls, a relatively large proportion of children with autism actually followed gaze spontaneously both in the direct observation and in the baseline phase of the experiment (Leekam et al. 1998). Interestingly, when told explicitly to pay attention to gaze, individuals with ASD can discriminate gaze direction and identify whether someone is looking at them or what others are looking at (Ristic Mottron, Friesen, Iarocci, Burack & Kingstone, 2005; Wallace, Coleman, Pascalis, Bailey, 2006). These findings contradict the previous assumptions about consistent impairments in ASD children compared to control's RJA abilities. Instead it might be suggested that many children with ASD are indeed capable of following gaze, but as a group they tend to spontaneously orient less to cues of eye-gaze than other children. Thus, perhaps the targets that attract the visual attention of children with ASD differ from the targets that attract other children's visual attention?

Different types of attention cues have been used to investigate gaze orienting in children with ASD which could help to explain the differences observed between diagnostic groups. Baranek (1999) compared the visual attention of children with ASD to children with developmental disability or mental retardation (including Down syndrome, Williams syndrome and nonspecific mental retardation). Gaze orienting was analyzed in ten minute home videos recorded when the children were between 9 and 12 months of age. Similar to other findings the researchers discovered that attention to non-social novel visual stimuli was among the most prominent factors distinguishing children with ASD from children with mental retardation. Senju, Yaguchi, Tojo and Hasegawa (2003) found that typically developed children locate targets cued bye eye gaze more quickly than children with ASD, but targets cued by arrows are detected as fast for ASDs as for typically children. Furthermore, no differences in detecting averted gaze were found for these two groups. Children with ASD seem to be cued by both social and non- social stimuli, but opposite to typically developed children they are faster and more often oriented by non-social stimuli than by social stimuli (Senju, Toyo, Dairoku & Hasegawa, 2004). In sum, it seems that children with ASD are capable of gaze orienting, but in contrast to the typically developed children whom usually orients toward social stimuli, children with ASD are usually attracted by physical, non-social

8

stimuli. The task stimuli used in attention-cuing studies could therefore play a role in the amount of eye-gaze and joint attention behaviour encouraged by children with and without ASD.

Lately, even more sophisticated measures of gaze have been employed to study use of gaze in both clinical and non-clinical populations. The use of eye-tracking technology enables very precise measures of visual attention and targets of gaze. Several eye- tracking studies show that children with autism tend to focus more on the mouth, the chin, the hair line or the ears than on the eyes (Dalton, et al, 2005; Klin, Jones, Schultz, Folkmar & Cohen, 2002; Pelphrey,

Sasson, Reznick, Paul, Goldman & Piven, 2002) and it seems that these children do not use the eyes as a social cue to orient their attention (Klin, 2008). Jones, Carr and Klin (2008) used eye tracking to compare the visual fixation patterns of two year old children with autism to typically developing children, as well as developmentally delayed, non-autistic children. Children with autism looked at the eyes about 30 % of the time compared to nearly 55 % of the time for both of the other groups. The children with autism spent almost 40 % of the time staring at the mouth area, compared to 24 % in the other groups. In another recent eye-tracking study (Klin, Lin, Gorrindo, Ramsay & Jones, 2009) preferential looking to biological and non-biological motion (point-light animations of children's games) were compared in 2-year old children with autism and typical development. Preferential attention to biological motion is a fundamental mechanism observed across species (Fox & McDaniel, 1982; Oram & Perrett, 1996). Thus, expectedly typically developed children showed significant preferential looking to the biological motions. Surprisingly, however, children with autism oriented more to the physical contingencies such as the audiovisual synchronies between point lights and sounds than biological motions. Cynthia Johnson, director of the autism centre at Children's Hospital of Pittsburgh argued that these findings confirmed "in a higher-tech way" the sense that children with autism do not make eye contact (Gordon, 2008). Yet, previous findings of spontaneous gaze-following in children with ASD indicates that they are capable of making eye-contact, but they don't socially orient to eye- gaze in the same degree as others. Rather than spending time looking towards others eyes they prefer to look at more physical, non social stimuli.

Although the internal validity of eye- tracking studies is high, one can question the ecological validity of these studies. The artificial contexts of eye-tracking and attention cuing

studies might limit the potential to generalize findings to daily social interactions with familiars and strangers. In real life our facials expressions are seldom neutral, nor does gaze following and social referencing occur in isolation. Usually these are parts of an interactive context where the child is not only a passive responder, but an active contributor. Possibly the different exposures to naturally occurring joint attention behaviour in everyday life and the simplistic displays of facial stimuli in laboratory research could elicit different amounts and use of eye-gaze in children with and without ASD. In fact, three to six year old children with ASD showed no social referencing deficits during interactions with their mothers in a study that combined observations of social referencing, spontaneous symbolic play, declarative joint attention and imitation of symbolic play (Warreyn, Royers & De Groote, 2005). In a longitudinal study of typical children, Striano and Bertin (2005) found that joint attention looks increased while interacting with strangers compared to when children interacted with their mothers. The latter observation indicates that interactional partners, context and activity may affect the amount of eye-gaze displayed by both children with and without ASD. In parental interviews conducted in Leekam and colleagues' (1998) study, only one of the parents in the autism group reported adequate response to head turn-cues compared to eight parents in the control group. Still, clinical observations registered spontaneous gaze orienting in a large proportion of the children with autism. Several factors could contribute to these findings. One possibility is that children with autism might have better abilities than what is observed by parents. Alternatively, primary caregivers might develop scaffolding strategies that facilitate use of eye-gaze in their children. Whatever reason, these findings points to the importance of studying children with ASD's use of eye-gaze in different contexts with different interactional partners. By the use of multiple sources of information one can more reliably investigate whether there are in fact consistent impairments in eye-contact and joint attention abilities across the autism spectrum. Yet another possibility is that the inconsistent observations reflect actual variation in gaze and joint attention abilities within the ASD-population. Perhaps there are relatively large individual differences in use of eye-gaze within the group of individuals with ASD. This could range from highly abnormal use of eye-contact, via potentially small deviations in amount of eye-gaze not easily detected, to normal use of gaze.

1.4 Use of gaze and levels of functioning

1.4.1 Eye-gaze and cognitive functioning

With the increase in prevalence of ASD cases without intellectual impairments most studies today focus on high functioning ASD individuals and find inconsistent results (Itier & Batty, 2009). In contrast, early research in eye-gaze and joint attention abilities probably studied more severely affected low- functioning individuals with the result of finding consistent impairments. Thus, few studies so far have compared use of gaze in individuals in both ends of the autism spectrum continuum. The need for comparisons of face and eye gaze perception in high- and low functioning ASDs is requested by Itier & Batty (2009) in their latest review of literature in this area.

In Leekam and colleagues' (1998) study the chronological age range of children was relatively large (1,1 – 12.6 years) which could imply that some of the children with autism who spontaneously followed gaze in the baseline and experimental part of the study might have developed such skills with age. When children were compared on mental age (verbal and non-verbal) it turned out that the ability to follow eye gaze and head turn was found almost exclusively in children with mental ages above 4 years. Furthermore, data obtained in the parent interviews indicated that children with autism began to follow head turn and gaze direction years later than typically developing children. Thus Leekam and colleagues argued in favour of a significant delay in development of gaze orienting more than impairments or absences of such abilities in children with ASD.

If a mental age of four years was sufficient to explain impairments in gaze- orienting in children with ASD one should expect to find consistent difficulties in all children with mental ages below 4 years of age. Yet this was not evident in the studies comparing three year old ASD-children to children with mental retardation without autism (Baranek, 1999) or in comparison of two- year olds children with ASD and typically developed children (Chawarska, Klin & Volkmar, 2003). In one visual attention cuing study children aged 8-11 years with high functioning ASD obtained normal scores on responsive joint attention (Swettenham, Condie, Campbell, Milne & Coleman, 2003). The chronological age of ASD-participants have been highly different in these studies, and it seems that mental age alone is not a significant predictor of gaze- following abilities. Thus perhaps different levels of IQ contribute to the differences in observed eye-gaze. If so, more use of eye-gaze could be

expected in children with high-functioning ASD compared to children with low-functioning ASD.

Interestingly, impaired IJA is considered to be a more reliable diagnostic tool to identify children with autism than RJA (Leekam et al., 1998; Mundy, Sigman & Kasari, 1994). Still, most studies have mainly investigated RJA in children with and without autism. In contrast to RJA, however, IJA usually persist into preschool and adolescent years. Some findings link IJA abilities to levels of IQ (Mundy et al., 2007, Ulvund & Smith, 1996). Ulvund and Smith found that frequency of engagement in joint attention behaviors was positively related to levels of IQ and language acquisition. Here as well, more consistent correlations were found between IJA and IQ compared to RJA and IQ associations. If levels of IQ are in fact related to possible within-group variability in use of gaze, perhaps IQ affect eye-gaze, RJA and IJA in different degrees. Comparisons of high and low functioning children with ASD on measures of eye- contact, RJA and IJA could help distinguish the possible influence of IQ on these abilities. Nevertheless, since better gaze orienting are found in MR-groups compared to ASD-groups mental age or cognitive functioning are unlikely to be the only factor distinguishing these children's eye-gaze and joint attention abilities.

1.4.2 Eye-gaze and social functioning

Reduced social orienting, mutuality in social interactions and interest in other people are the core diagnostic features distinguishing autism spectrum disorders from the DSM-IV diagnose mental retardation (APA, 2000). More high-functioning ASD children are diagnosed with Asperger's disorder and PDD-NOS which usually indicates better social skills and subthreshold ASD- symptomatology (Newschaffer et al., 2007). Since high-functioning children with autism have been found to show normal rates of joint attention behaviours (Chawarska et al., 2003; Leekam et al., 1998; Swettenham et al., 2003), it's likely that levels of social functioning could influence the amount of eye-gaze initiated by children with ASD. Jones and colleagues (2008) found a strong negative correlation between level of social disability in 2 year olds with autism and time spent fixating at the eyes, a result strengthening this assumption. However, no previous studies have directly compared ASD children with different levels of social functioning on frequency and duration of eye-gaze.

Again, contrary to RJA, IJA has consistently been associated with social and affective symptom presentation in autism (Charman, 2004; Dawson et al., 2004; Hobson & Hobsen,

12

2007; Lord et al., 2000; Mundy, Sigman, Ungerer & Sherman, 1986; Sigman & Ruskin, 1999). IJA includes pointing and showing, but the use of gaze alternations was found to be superior for initiating joint attention (Mundy, et al. 1986). Differences in IJA alternating gaze behaviour predicted both variance in total IJA-scores (Mundy et al., 2007), social cognition in 4 year old typically developed children (Charman et al., 2000), and symptom outcomes in 4 year old children with autism (Charman, 2004). Thus, besides being a very important marker for distinguishing between groups of children with ASD, mental retardation and typical development (Mundy et al., 1986), impaired initiation of gaze alternations could perhaps also be related to differences in ASD symptom intensity. Still, studies focusing primarily on initiation deficits are currently sparse in eye-gaze and joint attention research (Mundy, Sullivan & Mastergeorge, 2009).

In summary, it seems that joint attention impairments are neither absolute nor uniform in autism. This evidence contradicts findings presented in early research in this area. If current public knowledge is still in line with previous ideas, it might represent a challenge to early identification and diagnosing of ASD, especially for high functioning ASD children. Children with autism might show a variety of different levels of eye-contact and gaze following behaviour, but perhaps the non-social aspect of gaze in children with high-functioning autism might not be as easily detected as the almost entirely lack of eye contact shown in low-functioning ASD children. Research investigating individual differences in joint attention abilities and associations with both cognitive and social functioning could therefore be of significant value to explore in greater depth the variation in functioning within the autism spectrum. More importantly it can help nuance and broaden the assumptions of autism shared by parents, health personnel and others who might not be up to date on recent empirical evidence presented in this area.

1.4.3 Mechanisms behind variation in use of gaze

Presumingly, children with ASD are capable of spontaneous gaze orienting, but are faster and more often attracted by physical than social stimuli. Several theories tried to account for this seemingly lack of social orientation in children with autism. A presentation of all theories would extend this papers limit of scope. Thus, the following discussion is restricted to a short discussion of the most recent theories relevant to the purpose of the present study. For a

summary of the dominating cognitive theories of autism the reader are referred to Engeland and Buitelaar (2008).

Lately, researchers have argued in favour of adopting a developmental perspective if we are to understand the mechanisms behind abnormal use of eye-gaze in individuals with autism (Leekam et al., 1998; Nation & Penny, 2008, Jones & Klin, 2009; Itier & Batty, 2009). Rather than a long term absence or impairment of eye- gaze and joint attention abilities, it's suggested that children with autism are delayed in development of this behaviour due to reduced social learning experiences. The possible underlying mechanisms are debated. Some hypothesize that autism primarily is an affective disorder where the neural systems involved in children's sensitivity to the reward value of social stimuli are disrupted (Mundy & Sigman, 2006). An alternative hypothesis is that the magnocellular system which typically serves to orient babies to faces is disrupted in individuals with autism (Vuilleumier, Armony, Driver & Dolan, 2003). Other speculate whether the executive control mechanisms required to shift attention between dynamic and complex stimuli such as faces, voices and gestures might be impaired (Bryson, Landry & Wainwright, 1996).

If less spontaneous orientation to the eyes of others contribute to a lack of social learning experiences as these theories suggests, one might speculate whether children with different levels of cognitive functioning miss out on this learning experiences at different degrees. Perhaps children with higher cognitive abilities are better able to learn the rewarding value of eye-contact and joint attention behaviour than more disabled children. If so, the amount of eye-gaze displayed by children with ASD could also impact on outcome. More use of eye-contact could imply better information processing and shared attention abilities, which improves social functioning. This hypothesis could have promising implications for interventions. On the other hand, early intervention research evaluating the long-term benefits of different types of treatment programs found that independent of type of treatment, interventions targeted at improving language made no differences to IQ (Rutter et al., 1977; Hemsley et al., 1978; Rutter, 1980; Howlin, 1981; Rutter 2001). However, although training doesn't necessarily increase levels of IQ, perhaps IQ have a moderating effect on the effect of training. Higher levels of IQ could increase the capacity to learn both communicative and social skills. Indeed, Rutter et al.'s study observed huge individual variation in outcome where the most intellectual disabled children made the least progress. Comparable investment of therapist time and energy in treatment was given despite differences in cognitive

functioning. If IQ influence on the capability to learn spontaneous gaze orienting, than more substantial training and perhaps other ways of intervening are needed for children with LF-ASD compared to children with HF-ASD.

An alternative hypothesis is that children with autism are no different from other children without autism in use of eye-gaze indicating that other factors than specific diagnostic traits and levels of functioning can explain the previously inconsistent findings. Abnormal and reduced explorations of the eye-region have been observed in other clinical populations, such as in some patients with amygdala lesions (Spezio, Huang, Castelli & Adolphs, 2007), in Schizophrenia (Hooker & Park, 2005) and Turner Syndrome (Elgar, Campbell & Skuse, 2002). These observations made Itier and Batty (2009) hypothesize that dysfunction in the same underlying mechanism (an eye-detector mechanism according to their theory) could result in problems with extracting the relevant information from the eye-region of the face. Interestingly, by the use of eye-tracking technology, Dadds, Masry, Wimalaweera and Guasella (2008) demonstrated that children with high psychopathic traits failed to spontaneously orient to the eye-region of others. Dadds and Rhodes (2008) hypothesized that this impaired gaze-orienting were related to their difficulties of processing fear. Since both psychopathy and ASD is associated with Amygdala dysfunction (Itier & Batty, 2009), perhaps a similar underlying mechanism causes decreased eye-gaze orientation in children with and without autism. If so, Klin (2008, 2009) speculates whether this mechanism affects children's development at different times leading to different disruptive effects with varied outcomes. Thus, recent advantages in research methods and new theories in the area of eye-gaze and autism indicate a need for further knowledge in the heterogeneity of autism spectrum disorders.

1.5 The present study

To understand the reasons behind deviant use of gaze in individuals with ASD and the possible differences in outcome, one needs to establish if deviant use of eye-gaze is in fact universal traits specific to individuals within the autism spectrum. If so, lack of eye-gaze is an appropriate diagnostic marker for early identification and intervention. Alternatively, limits and differences in the methods used to study gaze-orienting and joint attention abilities could have created an overestimated impression of qualitative between-group differences in eye-gaze. Several approaches have been made to advance the precision of gaze tracking

15

technology as well as to limit the potential influence of artificial contexts. Different experiment- and control groups are included, and various instruments, informants, designs and task stimuli are employed. This study explores the possible influence of these factors by assessing the variety in use of gaze across diagnostic groups in social interaction with familiar and unfamiliar persons and contexts.

Frequency, duration and targets of gaze were coded in DVD-recordings of two ADOS-G activities where children and experienced clinicians are engaged in symbolic play. Presumably, play situations are familiar to all children and can hopefully optimize the opportunity for children to display their natural use of eye gaze in social interactions. To avoid examining gaze uniquely elicited in parent- child interactions, coding are based on observations of children's initiation of gaze in interaction with an unfamiliar experimenter. Still, whether eye-contact is encouraged and initiated in play could probably be influenced by how much effort is used to interact with the child. When effort is made to take part in the child's initiated play, one could expect eye-gaze to be more frequently elicited and longer sustained compared to when the child is encourage to play alone. According to my knowledge, no studies so far have directly compared children's use of eye-gaze in situations with different degrees of social interaction. Moreover, due to current limited knowledge on ASD-children's initiating behaviour (Mundy et al. 2009), this study focused on gaze-behaviour initiated by the child more than on responses to initiatives made by the experimenter.

The quantitative measures of eye- gaze were compared to independent qualitative ratings of eye-contact based on parental and clinical evaluations recorded in the two autism diagnostic instruments; ADI-R and ADOS-G. Additionally, by comparing diagnostic group's mean scores on independent evaluations of gaze and joint attention behaviours this study could explore possible differences in initiations of eye-gaze alone, compared to use of more advanced joint attention behaviour.

The main aim of this study is to investigate the variability in use of gaze among children with ASD. By comparing high and low functioning children with ASD to cognitively high and low- functioning controls (children with MR and TD) one can explore both between- and within-group differences in use of gaze and joint attention abilities. The second aim is to investigate if variation in initiation of eye- gaze is influenced by the degree of reciprocal interaction in play.

16

The research questions guiding the present study are:

1. Is the variation in use of eye- gaze among preschool aged children with autism spectrum disorders (ASD) as large as the variation in use of gaze among children with mental retardation (MR) and typical development (TD)?

2. Is use of eye-gaze and joint attention behaviours in preschool aged children with ASD related to their level of social and cognitive functioning?

3. Does degree of reciprocal interaction in play influence the amount of eye-gaze initiated by children with ASD, MR and TD?

4. Are children with ASD visually attracted by other targets of gaze than children with MR and TD?

2 Methods

2.1 Participants

All participants have been selected based on participation in the ongoing Norwegian Autism Birth Cohort Study (ABC). ABC is a project-collaboration between the Norwegian Institute of Public Health, The Mailman School of Public Health at Columbia University and the National Institute of Neurological Disorders and Stroke. The ABC- study is a sub-study of the population based Norwegian Mother and Child Study (MoBa; Magnus et al., 2006). Families invited to participate in ABC are screened for ASD-traits through their response given in a MoBa- questionnaire when the child is 36 months. Children are screened positive if they meet one or more of the following five screening criteria: 1) low score on the Social Communication Scale (SCQ-33 score >= 12); 2) full score, i.e. 9 out of 9 points in the repetitive behaviour sub-domain of SCQ; 3) Parent report of language delay AND the child has been referred to a specialist for it; 4) Parents report autism/autistic traits OR the child has been referred to a specialist for it; 5) Parent reports that the child shows very little interest in playing with other children. A final screening criteria was added in February 2007 to increase the specificity for ASD and reduce the number of false positives invited to participate; 6) Parent reports that others (family, day-care staff, well-baby nurse) have expressed worry for the child's development. In summary children are now screen positive if they meet criterion 4 (autism/autistic traits) or they meet one or more of criteria 1/2/3/5 AND meet criterion 6.A randomly selected control group from the MoBa- cohort is also invited to take part in the clinical assessments which lasts about 1- 1.5 day and takes place in Oslo. The diagnostic evaluation is based on clinical assessments, medical examination, and interviews performed by experienced clinical psychologists and psychiatrists, research assistants and medical doctors. The ABC study's main focus is to identify ASD- cases, but other developmental disorders are diagnosed as well. By December 31st 2009, 628 children had participated in the ABC- study, 78 (12,4 %) of them diagnosed with ASD.

18

Exclusion criteria for selection to the present study included the presence of a neurological disorder of known etiology (for the ASD group only) and significant sensory and motor impairment and/or neurological disease. Due to presence of comorbid psychiatric disorders, missing and/or bad DVD- recording of the relevant ADOS- sequences, 30 children with ASD were excluded from the present study. A total of 48 children (35 males, 13 females) were finally selected. Within a 3 month range, all groups were matched on chronological age ranging from 37 – 54 months (M = 42.8, SD = 4.1). These children were allocated into 3 groups based on the clinical conclusion in ABC;

       1) Children with autism spectrum disorders (ASD) (n = 24)

              1a) High- functioning children with autism (n = 12; 9 males, 3 females)

              1b) Low- functioning children with autism (n = 12; 9 males, 3 females)

       2) Children with mental retardation (MR), (n = 12; 11 males, 1 female)

       3) Children with typical development (TD), (n = 12; 6 males, 6 females)

The ASD- group was further divided in two groups according to the children's obtained IQ- estimate on the Standford- Binet Intelligence Scale 5 (Johnson, Howie, Owen, Baldwin & Luttman, 1993) during clinical assessment in the ABC- study. Children obtaining IQ- scores within normal range (IQ > 70) were defined as High- Functioning children with ASD (HF- ASD) whereas children with IQ- levels below 70 where defined as Low- Functioning children with ASD (LF). The TD group included children without any diagnose or clinical significant problem identified.

Table 1 (p. 20) presents the means, standard deviations and range of the children's age and IQ- scores. IQ- scores was missing for two children in the LF- ASD group. No statistical age difference was revealed. Because the ASD groups (LF- and HF- ASD) were matched on mental age (IQ- levels below or above 70) with the two control groups (MR and TD), the LF- ASD and MR groups had significantly lower levels of IQ than the groups of children with HF- ASD and TD: $F (3, 42) = 91.7$, p= .000. According to Cohen's (1988) classification of effect sizes, the calculated eta square of .87 is considered a large effect. There were no

significant differences in mean level of IQ between the MR- and LF- group, or between the TD- and HF- ASD group.

Table 1: Children's age in months and estimate of IQ

	HF- ASD (N=12)			LF- ASD (N=12)			MR (N=12)			TD (N=12)		
	M	(SD)	Range	M	*(SD)*	Range	M	*(SD)*	Range	M	*(SD)*	Range
Age	42.7	(5.4)	37-54	42.6	*(3.0)*	38-47	41.9	*(3.3)*	37-47	44.1	*(4.3)*	38-51
IQ	97	(12.5)	76-118	53	*(5.4)*	49-64	58	*(7.2)*	49-70	102	*(9.0)*	88-115

There are potential limitations with using The Stanford Binet Intelligence Scale as a basis for estimating IQ. The test is not standardized for Norwegian usage. Instead of measuring full scale IQ, four selected subscales assess cognitive functioning in the ASD- study; Nonverbal Fluid Reasoning, Nonverbal Knowledge, Verbal Knowledge, and Working Memory. Thus, the accuracy of the IQ- estimate might be hampered, but since it applies to all subjects, the scores were considered appropriate indications of IQ.

2.2 Procedure

As part of the protocol in ABC, all children were assessed for ASD with the Autism Diagnostic Observation Schedule- Generic (ADOS-G; Lord, Rutter, DiLavore, & Risi, 2002). The ADOS-G is an assessment tool that clinicians and researchers currently use to diagnose ASD. Experienced clinicians assessed the child's abilities and behaviours in communication, social interaction, play and imaginative use of objects. The presence of atypical, repetitive and/or restrictive behaviours observed during administration of the ADOS-G is also documented. The total duration of one ADOS administration is 30 minutes.

The current version of ADOS-G includes four modules adapted to different age and developmental levels, ranging from "Module 1" appropriate for nonverbal children to "Module 4" appropriate for adults. Because expressive language level is considered the strongest predictor of an individual's ASD profile (Kobayashi, Murata, & Yoshinaga, 1992;

Venter, Lord & Schopler, 1992), module selection is based on the individual's level of expressive language rather than chronological or mental age (Lord et al., 2002).

The children selected for the present study was administrated either module 1 or 2 depending on the clinicians evaluation of the child's expressive language level during the first ten minutes of administration. Module 1 was used in cases where the child's expressive language level was less than 3 years (using only single or two-word phrases), while module 2 was administered to children who spoke in short phrases, with an expressive language level between three and four years of age. Module 1 includes ten activities which focus on a child's abilities in functional and symbolic play, joint attention, and anticipations of routines. Module 2 consist of a greater number of items (= 14) more appropriate for verbal preschool aged children. It includes several of the activities from module 1 with more advanced toys, in addition to items assessing the child's conversational, imitative and storytelling skills. All children with high- functioning autism spectrum disorders (HF-ASD) and typical development (TD) was administered module 2 of the ADOS-G. Eleven children with low-functioning ASD (LF-ASD) were administered module 1, while only one child was assessed with module 2. Among the children with mental retardation (MR) eight children was administered module 1, and four children were assessed with module 2.

Each child was individually tested while seated at a table opposite to the experimenter. The child's parent(s) was seated behind the child. All assessments were videotaped with two small and neutral cameras in the two corners of the room furthest away from the child.

2.2.1 Measures of, frequency, duration and targets of gaze

For the present study, four minutes of the video recorded ADOS- G was coded for each child by two independent raters who were blind to what groups the children belong to. The coded segment was two minutes from the "pretend-play" part and two minutes from the "interactive-play" part (when module 2 was administered) separated by when the clinician asked to join the child in play. This segment was chosen because it gives the children opportunities to take initiative and to respond to an adult's attempts to engage them. It also provides an opportunity to investigate whether the difference in level of interactivity between child and experimenter influence on the frequency or duration of gaze initiated by the child.

The interactive play part is not included in module 1 because higher levels of expressive language are needed for the child to be able to meet the specific goal of this subtest. The goal is for the child (not the examiner) to develop the interaction and to provide novel initiatives that goes beyond a direct response to the examiner's overtures. For children assessed with module 1 of the ADOS- G the segment called "Birthday party" was used as a replacement for the interactive play part. In this segment the examiner asses the child's functional and symbolic play skills during a typical "birthday party" scenario. It provides an opportunity for the examiner to observe how the child interacts with a baby doll, whether or not the child spontaneously contributes actions to the party, or imitates behaviours modelled by the examiner. For this particular scenario, the coded segment was two minutes beginning immediately after the clinician says "It is the dolls birthday, today!" This segment was chosen based on the assumption that compared to an open free play situation, a well known script based situation might provide a better opportunity for children with less developed language and/or play skills to engage in interactive play. However, comparisons of frequency and duration of gaze between free play and interactive play might be limited by differences in level of structure and instructions given in the "interactive play"- compared to the "birthday party" segment.

The recorded ADOS segments were coded by means of the "The Observer XT 9.0" (Noldus LPJJ, 1991) to allow exact coding of frequency and duration of each gaze. This is a software system for coding and analyzing frequencies and durations of observed events. The use of this video tape analyses system enables coding behaviour at different VCR playback speeds, while maintaining a proper time reference. It thereby enables an exact coding (in hundredths of seconds) of the start and end of each occurrence of gaze behaviour. However, in contrast to eye-tracking technology, it is impossible to rate eye- contact with exact precision based on DVD- recordings of ADOS test situations. Thus, a coarse measure of eye-gaze was adopted where looks towards the experimenters face (instead of eyes) were coded. All recordings which wasn't properly zoomed in on the child and the experimenter and thus made it difficult to determine the child's targets of gaze were excluded. Whenever the child's front side came out of focus, resulting in an inability to view the child's eyes, the particular sequence was subtracted until the child's faze was again in focus. The equivalent amount of time was then added and eye- gaze was coded after the initial 4 minutes was recorded. Every gaze was coded in the sequence they appeared on separately coded timelines. Since less eye-gaze in the ASD group compared to the other diagnostic groups was probable, and the present

22

study wants to investigate which aspect of gaze that differs between ASD- and other groups of children, it was useful to have a coding for where they look. For descriptions of the different codes used to categorize gaze, see table 2 (p. 24). Gaze shifts were defined as change in gaze direction shown by movement of the child's eyelids. The beginning of a look is marked by the first picture frame after an exchange of glances, and the end of the gaze is marked by the last frame before the next shift in gaze. The duration of a gaze is calculated by the time in seconds between two shifts of gaze.

2.2.2 Inter- rater reliability

Twenty percent of the sample (n = 9) was randomly selected and coded by another independent rater to check inter-rater reliability. Interclass correlation coefficients (ICC) were calculated for each specific target of gaze. All calculations of agreement except one (frequency of "Uncertain look"= .59) was high, ranging from .85- 1.0. The specific ICC coefficients for frequency (f) and duration (d) of different targets of gaze were as follows: looks towards the experimenters faze ("eye-gaze") (f: .99, d: .1.0), - the experimenters body (f: .90, d: .89), -parents (f: .88, d: .89) – the child's own actions (f: .97, d: .93), - the experimenters actions (f: 98, d; .98), - joint actions (f: .94, d: .96), - other objects (f: .91, d: .96), -the open environment (f: .94, d: .85) and uncertain looks (f.: .59, d:, .99).

Table 2: *Codes and descriptions of gaze*

Codes	Descriptions
1) look towards the experimenters face (also referred to as "eye-gaze")	The child looks toward the experimenters face. The code is interrupted by the first look outside of the perimeter of the experimenter's face.
2) look towards the experimenters body	The child's gaze is directed towards the experimenter's body. Looks towards the experimenter's hand(s) is excluded from this category as they are defined by code 4 "look towards the experimenter's action".
3) look towards the child's own action	The child's gaze follows its own actions or is directed towards objects manipulated by the child.
4) look towards the experimenter's action	The child's gaze is directed towards the experimenter's hands or objects manipulated by the experimenter.
5) look towards joint actions	Both the child's and experimenter's hands are so close together that it can't be revealed if the child looks at its own or the experimenter's actions. The child shows no change in eye movements, but looks straight at their hands or objects they handle simultaneously.
6) look toward(s) parent (s)	The child's gaze is directed towards the parent's face, body or actions.
7) Look towards other objects	The child looks at objects placed on the table which is not manipulated by either child or experimenter.
8) Look towards the open environment	The child looks towards furniture, walls, the door, the window, the roof etc. "Blank looks" is coded here.
9) Uncertain look	Looks without identifiable target

2.3 Independent variables

The quantitative ratings or gaze were compared to independent variables of eye-gaze, joint attention, cognitive functioning (IQ) and social functioning (symptom intensity). Summary descriptions of the independent variables are presented in table 3 (p. 28). The following paragraphs describe the instruments used to measure these variables in further detail.

2.3.1 Parental reports of direct gaze: ADI-R

Scores obtained in the ADI-R (Couteur, Lord & Rutter, 2003) item 50: "Direct gaze" were collected for all subjects within the ASD and MR- groups. Previously, the ADI-R was not part of the assessment protocol for controls participating in the ABC-study. Accordingly, mothers of only two children with TD included in the present study were administered the ADI-R interview and these data were excluded from analyses. Mothers (or very infrequently if the mother was absent, other close caregivers) of children participating in the ABC- study are interviewed by experienced research assistants. The specific item tapping children's use of direct gaze assesses the child's ability to use direct gaze to communicate, and response to others attempts to catch their eyes. The scores vary between 0 and 3 were lower scores indicate better use of direct gaze. A score of 0 is obtained if the child uses normal, reciprocal direct gaze to communicate across a range of situations and people. The score 1 is applied if the child uses direct gaze briefly and inconsistently in social interactions, while score 2 indicates that children uses gaze only occasionally and/or it's uncertain whether the gaze is actually direct. If the child's gaze is unusual or oddly used a score of 3 is coded.

2.3.2 Clinical reports of unusual use of gaze: ADOS-G

Item B1 in ADOS-G module one and two; "Unusual Eye Contact" is coded based on the clinician's evaluation of children's eye-contact during the whole ADOS-G assessment. Clear, flexible, socially modulated, and appropriate gaze that is used for a variety of purposes is distinguished from gaze that is limited in flexibility, appropriateness, or context. If children are shy and gaze changes markedly and consistently during assessment coding are based on impressions from the latter part more than the former part of assessment. Codes vary from 0- 2. To obtain a score of O appropriate gaze with subtle changes meshed with other communication is required. The child receives score 2 if he/she uses poorly modulated eye contact to initiate, terminate, or regulate social interaction.

2.3.3 Joint attention measures: ADOS-G

The obtained score (made by an independent clinician) on the ADOS-G items; "response to joint attention" (RJA) and "initiate joint attention" (IJA) was used as measures of the children's joint attention abilities. Scores range from 0 to 2 where higher scores indicate lower abilities.

Response to joint attention (RJA) refer to the child's responding to the examiner's use of gaze, pointing, or both in directing the child's attention to a distal object (Lord et al., 1989). While the child played quietly, the experimenter placed him- or herself in front of the child and established eye- contact by first calling the child's name and next, if necessary, providing a physical prompt. When eye- contact was made the experimenter said "Look, [child's name]" and looked toward a toy (a cuddle bunny) that had been placed in front and about 65° to one side of the child. If the child did not respond to the experimenters gaze shift prompt the probe was repeated by the phrase "look at that" appended to the verbal prompt. If the child failed to respond to this bid, the experimenter repeated the prompt and pointed to the toy. A score of 0 indicates a successful response to the examiners gaze shift, while a score of 1 was given when the child required a point to attend to the toy. If the child didn't respond to any of the joint attention probes or the experimenter was unable to capture the child's attention even after five attempts the score 2 was applied.

The child's ability to initiate joint attention (IJA) refers to his or her attempts to direct an adult's attention to objects that neither the child nor the adult was touching solely for the purpose of sharing attention rather than for requesting the objects (Lord et al., 1989). The score on this item was based on the examiner's judgment of the child's attempts at protodeclarative attention bids (i.e., the use of gestural bids to share an object rather than to request an object, Whalen & Schreibman, 2003) throughout the course of the entire ADOS-G observation. To obtain a score of 0 the child had to successfully direct an adult's attention to a distal object by gazing at it, establishing eye contact, and redirect gaze to the object. Using a point or vocalization was acceptable, but not necessary or sufficient to obtain a zero-score. A score of 1 was obtained if the child on at least one occasion partially referenced a distal object either by looking at the object or adult together with a point or vocalization without redirection. Thus, the child receives a score of 1 when he/she failed to integrate gaze switching with pointing or vocalizing. If the child didn't initiate a bid for joint attention to reference a distal object throughout the ADOS- G assessment he/she got the score of 2.

2.3.4 Measures of ASD- symptom intensity: ADOS- G

 To investigate whether levels of ASD- symptom intensity was related to frequency or duration of gaze, the total score on ADOS-G was used as a measure of symptom intensity. Each item on the ADOS-G is scored on a three-point scale, independent of module administered. A score of zero indicates no evidence of abnormal behaviours related to autism, a score of two indicates presence of abnormal behaviours, and a score of three indicates the presence of severe abnormalities. A subset of these item- scores are then summed for two domain scores and one combined score. These domains are the "Communication" domain, The "Social interaction" domain and the summed score on these two domains combined. The three sum scores ads up to a total score. The total score can then be compared to a cut-off score (> 12 for autistic disorder, > 8 for Autism spectrum), to check whether the child's score on ADOS is consistent with a diagnosis of autistic disorder or ASD (PDD- NOS, Asperger syndrome). Children who score below these cut-offs are interpreted as presenting behaviours not consistent with a diagnosis of autistic disorder or ASD.

Table 3: Short descriptions of independent variables

Independent variables	
10) Cognitive functioning (IQ)	Clinical estimates of IQ based on subscale performances on the Stanford Binet Intelligence Scale 5; Non-verbal fluid reasoning, non-verbal and verbal knowledge and working memory.
11) Social functioning (Symptom intensity)	Total score on ADOS-G. The sum of scores obtained in the communication and social interaction part of the Autism Diagnostic Observation Schedule-Generic (ADOS-G) algorithm.
12) Parental report of eye-gaze	Score on item 50: "Direct gaze" in the Autism Diagnostic Interview- Revised (ADI-R).
13) Clinical report of eye-gaze	Score on item B1: "Unusual Eye Contact" in the ADOS-G.
14) RJA	Score on ADOS-G item B11 in module one or item B7 in module two: "Response to Joint Attention"
15) IJA	Score on item B10 in module one or item B6 in module two: "Spontaneous Initiation of Joint Attention"

2.4 Analysis

All analyses were conducted in SPSS version 14.0 and 16.0. To compare means and variance between groups, independent samples t-test and one-way between-groups analyses of variance (one-way between-groups ANOVA) was conducted. Pearson Product-Moment Correlations were used to explore associations between levels of IQ, symptom intensity and measures of gaze. Mixed between- within subject analysis of variance (mixed between-within ANOVA) were used to explore the possible impact of interaction in play on eye- gaze behaviour

between diagnostic groups. Missing cases were excluded pair-wise. An alpha level of .05 was used for all statistical tests.

Because of violation of assumptions of normality on all variables, preliminary analysis was conducted with parametric and non- parametric tests. The non- parametric tests used to compare means between groups was Kruskal Wallis tests and Mann- Whitney U test. To explore correlations, Spearman's Rank Order Correlation was used. Only small non-significant differences were found between the results of parametric and non- parametric tests (the correlation coefficients analysing symptom intensity and use of eye-gaze were .01-.03 higher in analyses conducted with Spearman's r compared to Pearson's product moment correlations). Although the distribution of eye-gaze scores was skewed, the parametric tests were preferred due to the skews working in the same direction in the groups to be compared. With small sample sizes the superior robustness of the parametric approaches compared to non-parametric analyses would increase the probability of finding significant effects if such were present (M. Rutter, personal communication, May 13, 2010). Thus, only the results of the parametric tests are presented.

3 Results

3.1 Variation in use of eye-gaze within and between diagnostic groups

1. Is the variation in use of eye- gaze among preschool aged children with autism spectrum disorders (ASD) as large as the variation in use of eye-gaze among children with mental retardation (MR) and typical development (TD)?

3.1.1 Within-group differences in use of eye-gaze

The main aim with this study was to explore the within-group variation in use of gaze among children with a diagnosis of ASD to investigate whether children with ASD are as heterogeneous as typically developed children and children with mental retardations. Two different approaches were taken to compare the diagnostic group's variance of frequency and duration of looks towards the experimenters face.

First, each individual score was subtracted from the group average, all negative scores were transformed into positive, and one-way between-groups analyses of variance were conducted. Figure 1 a and b display box plot distributions of frequency and duration of eye-gaze, while Table 4 (p. 32) provides mean within-groups variance scores for frequency and duration of eye-gaze in four diagnostic groups. No statistically significant differences were found between the within-group variance in either frequency of eye- gaze: $F_{(3, 44)} = .67$, $p = .57$ or duration of eye- gaze: $F_{(3, 44)} = 1.7$, $p = .19$.

To confirm these results an additional way of analysing variance was conducted based on results of Levene's test for equality of variances. This analyses tests whether the variance of scores for two groups is the same, a finding which is true if the reported significance level is larger than .05. Pair-wise comparisons of mean frequency and duration of eye-gaze with all possible combinations of group were conducted using independent samples T- tests. Levene's test for equality of variances was found to be significant at $p < .05$ level for only two group-comparisons. For frequency of eye-gaze only, Levene's test was significant when comparing

the MR- group with both the HF- ASD- group (p = .03) and the LF- ASD group (p =.01). All remaining comparisons were non-significant, meaning that the within-group variances are assumed to be equal. Children with ASD vary as much as typical developed children, but the individual differences in use of gaze are even larger among children with mental retardation without autism.
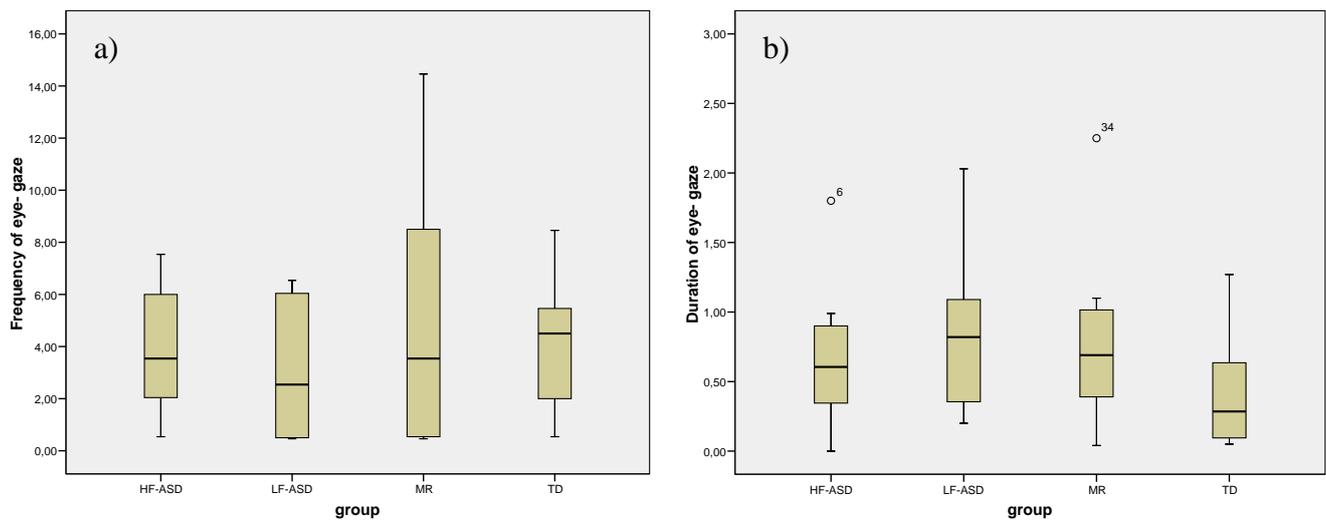
Fig. 1a and b: *Distribution of frequency (a) and duration (b) scores in four groups of children with high- (HF-ASD) and low functioning (LF-ASD) autism spectrum disorders, mental retardation (MR) and typical development (TD).*

Table 4

Mean (SD) within-groups variances in frequency and duration of looks towards the experimenters face in four diagnostic groups

Group		Frequency		Duration		Levene's test
	n	M	*SD*	M	*SD*	(p)
HF- ASD	12	3.94	*2.23*	.65	*.50*	HF (.03)
LF- ASD	12	3.19	*2.63*	.85	*.54*	LF (.01)
MR	12	4.92	*4.88*	.97	*.99*	
TD	12	5.33	*5.59*	.42	*.40*	

(with "⟨ MR" bracket spanning the HF (.03) / LF (.01) rows)

3.1.2 Between-group differences in use of eye-gaze

In accordance with most previous findings presented in the literature, on average more frequent and longer sustained eye-gaze was assumed to be initiated by control children (TD and MR) compared to looks initiated by children with ASD. Furthermore, if the former supposition was confirmed, differences within the ASD group were assumed as well, where more and longer looks were expected in the HF- ASD group compared to the LF-ASD group. One-way between groups ANOVA were conducted to explore the mean differences in a) frequency of looks and b) duration of looks toward the experimenters face between diagnostic groups.

a) There was a statistical significant difference at $p < .01$ level in frequency scores for the four groups: $F (3, 44) = 4.3$, $p = .01$.The effect size, calculated using eta squared, revealed a large effect of .23. Post-hoc comparisons using the Tukey HSD test revealed that the high-functioning ASD group (HF-ASD) (M = 4.92, SD = 3.80) and the low- functioning ASD group (LF-ASD) (M = 4.58, SD = 2.91) displayed significantly fewer looks than the control group (TD) (M = 10.92, SD = 7.05). The group of children with mental retardation (MR) (M = 9.76, SD = 6.70) did not differ significantly from any of the other three groups. Thus for frequency of eye-gaze the supposed differences between children with ASD and TD was confirmed, but the expected difference between ASD and MR did not reach significance and

was thereby disconfirmed. Furthermore, children with HF-ASD did not display more frequent eye-gaze than children with LF-ASD, disconfirming the previous assumptions.

b) The same type of analyses revealed significant differences in duration of looks toward the experimenters face at $p < .05$ level across diagnostic groups: $F(3, 44) = 3.0$, $p = .04$. For duration as well as for frequency scores, the effect size was large; .17. Mean duration score for the HF- ASD group ($M = 1.41$, $SD = .74$) was significantly lower than the mean duration score for the MR- group ($M = 2.44$, $SD = 1.25$). Contrary to assumed, no other group differed significantly in duration of eye-gaze although a close to significant difference ($p = .08$) was found between the LF- ASD ($M = 1.51$, $SD = .99$) group and the MR- group ($M = 2.44$, $SD = 1.25$).Thus, children with ASD tended to look as long as typically developed children towards the experimenter's face, but children with mental retardation looked the longest.

The lack of significant differences observed between children with mental retardation and ASD in frequency of gaze, as well as the similar duration of eye- gaze observed between typical developed children and ASD-children was unexpected, but could be explained by small samples and high standard deviations in all groups. To confirm the above results, analyses were conducted again with the two ASD groups (HF and LF) analyzed as one total ASD-group.

a) Significant differences were found in frequency of looks towards the experimenters face between the ASD- groups and both the MR and the TD groups: $F(2, 45) = 6.7$, $p = .00$. Once again the effect sizes was large; .23. Post- hoc tests showed that the mean frequency score in the ASD group ($M = 4.75$, $SD = 3.31$) was significantly lower than the mean score in both the MR ($M = 9.76$, $SD = 6.70$) and TD- group ($M = 10, 92$, $SD = 7.05$).

b) Children with ASD also displayed significantly shorter looks towards the experimenters face ($M = 1.46$, $SD = .86$) than children with MR ($M = 2.44$, $SD = 1.24$): $F(2, 45) = 4.6$, $p = .02$. No significant differences in duration of eye-gaze were found between the ASD- and control (TD) groups.

To compare the former and latter analyses, the difference in frequency of eye-gaze between the MR-group and the ASD- group reach significance when the two ASD-groups

was analysed as one. However, the difference in duration of gaze between typically developed children and ASD- children remained insignificant with the latter analyses.

3.2 Associations between levels of functioning and use of eye- gaze

2. Is use of eye-gaze in preschool aged children with ASD related to their levels of cognitive and social communicative functioning?

Table 5 (p. 35) presents descriptives of mean levels of IQ and symptom intensity in the different diagnostic groups with estimates given for analyses of the ASD as a whole group as well as for analyses conducted with the ASD- group divided in HF and LF-ASD groups. All analyses were conducted using one-way ANOVAs and Tukey post-hoc test to compare groups. Pearson's r correlation coefficients for associations between measures of eye-gaze and IQ and symptom intensity within the three diagnostic groups (ASD, MR and TD) are presented in table 7 (p. 39).

All three groups significantly differed in mean level of IQ: $F(2, 43) = 18.14$, $p = .00$.

Pearson's product- moment correlations showed no significant associations between frequency and duration of looks towards the experimenters face and level of IQ within any of the three groups.

Social and communicative functioning was measured as symptom intensity and operationally defined as total score on ADOS- G. As expected, with the high and low functioning ASD- groups analysed as one joint ASD- group, a statistically significant difference was found in symptom intensity across the three diagnostic groups: $F(2, 45) = 26.2$, $p = .00$. As evident in table 5, post-hoc tests revealed significant higher total score on the ADOS-G in the ASD- group compared to the MR- group and the TD- group. Comparing all four groups: $F(3,44) = 22.86$, $p = .00$, further revealed a significant difference in ADOS total score between the two ASD- groups, with the LF- ASD group obtaining a higher mean total score on the ADOS- G ($M = 14.75$, $SD = 6.27$) than the HF- ASD group ($M = 9.67$, $SD = 4.52$). The two control groups (MR and TD) did not significantly differ from each other in

symptom intensity. There were no significant association between frequency and duration of looks towards the experimenters face and symptom intensity (total score on ADOS) within groups. Thus, although the subgroups of ASD differed in levels of social functioning, this difference was not associated with the amount of eye-gaze displayed by these children.

Table 5

Between-group comparisons of differences in mean levels of IQ and symptom intensity with the ASD group both analysed as one total group and divided in two: HF and LF-ASD.

Diagnostic Group	IQ				Symptom intensity			
	n	M	SD	F	n	M	SD	F
ASD	22	77	24.5	18.14**	24	12.21	5.94	26.2**
MR	12	58	7.1		12	4.25	3.72	
TD	12	102	9.0		12	1.17	1.40	
HF-ASD	12	97	12.5	91,7**	12	9.67	4.52	22.86**
LF-ASD	12	53	5.4		12	14.75	6.27	

**. $p < .01$

3.3 Differences in joint attention behaviors between diagnostic groups

The quantitative eye- gaze measures conducted in the present study was complemented with parental and clinical qualitative ratings of eye-gaze and joint attention behaviours in the two diagnostic instruments ADI- R and ADOS-G. Table 6 (p. 36) presents mean scores and standard deviations on ADI and ADOS measures of gaze and joint attention behaviours in the four diagnostic groups.

Table 6:

Between-group comparisons of parental reports of direct gaze in ADI-R, and clinical observations of unusual use of gaze, response to joint attention (RJA) and initiating joint attention (IJA) in ADOS-G.

	Parental report of eye-gaze		Clinical reports of eye-gaze		RJA		IJA	
	M	SD	M	SD	M	SD	M	SD
HF-ASD	.58	.79	1.17	1.03	.17	.58	.50	.52
LF- ASD	1.0	.60	1.67	.78	1.08	.79	1.33	.89
MR	.25	.62	.25	.62	.25	.45	.33	.65
TD	-	-	.00	.00	.00	.00	.08	.29

Independent T- tests compared high and low- functioning ASD children on unusual use of gaze, response to joint attention (RJA) and initiating joint attention (IJA). No significant differences between groups in use of eye- gaze were found in either parental reports in ADI-R; t (22) = -1.45, p= .16 (two-tailed), or clinical observations in ADOS-G: t (22) = -1.34, p= .19 (two-tailed). However, clinical observations of joint attention abilities were significantly different between the two ASD-groups. LF- ASD children showed significantly higher scores than HF- children on both ADOS- measures of RJA: t (22) = -3.24, p= .00, and IJA: t (22) = -2.80, p = .01. The magnitude of the differences in the means calculated using eta squared was very large (.32 and .26 respectively).

Due to the interesting results differentiating HF and LF-ASDs joint attention abilities, one-way between groups ANOVA were conducted to compare the ASD-groups performance with the control groups' on the same measures.

Because parents of only two typically developed children were administered ADI-R, the TD- group was excluded from this particular analyses. Parental reports in ADI-R were significantly different between the MR and LF-ASD group, but not between the MR- and HF-ASD group. Parents of children with MR report relatively normal use of eye-gaze, while parents of children with LF- ASD report less use of eye-gaze: F (3, 34) = 3.06, p = .04. Effect size was large (eta squared = .21).

36

In clinical evaluations of eye-gaze based on observations during the total ADOS-G assessment, significant differences were found between groups: $F (3, 44) = 14.22$, $p = .00$, where both HF and LF-ASD groups obtained lower mean scores than the two control groups (MR and TD). Differences in diagnostic group explained almost 50 % of the variance in use of eye-gaze judged by clinicians (eta squared = .49). On measures of both response to joint attention (RJA): $F (3, 44)$, 9.62, $p= .00$, and initiating joint attention (IJA): $F (3, 44)$, 8.98, $p= .00$, low- functioning children with ASD, in contrast to HF-ASD children, obtained significantly lower scores than both control groups. Here, as well the calculated effect sizes were very large (.40 and .38, respectively).

In sum; the results show that children with ASD as a group showed significantly weaker joint attention abilities than children with MR and TD, but the high- functioning ASD children scored significantly better than low-functioning ASD children on measures of joint attention. In contrast no difference were found between low functioning and high functioning ASD children on parental or clinicians evaluation of their use of eye-gaze. Compared to controls (TD and MR), however, both ASD- groups displayed more unusual use of eye-gaze according to clinical observations, while only parents of children with LF- ASD reported less use of direct gaze compared to parents of children in the comparison groups (HF- ASD and MR).

These findings were complimented with Pearson-product moment correlations calculated within the total ASD- group to confirm the apparent associations between joint attention abilities and levels of functioning (IQ and ASD symptom intensity). All correlation coefficients are presented in table 7 (p. 39). Higher levels of IQ were significantly associated with both RJA and IJA, while higher symptom intensity was related to IJA only.

3.4 Associations between frequency and duration of eye-gaze, parental reports of gaze and clinical evaluations of joint attention behaviours

To investigate whether the quantitative measures of eye-gaze were consistent with parental and clinical reports of children's use of gaze, as well as clinical evaluations of children's joint attention abilities, Pearson product- moment correlations was conducted both across and within diagnostic groups.

When correlations were performed across groups several significant associations was found. First, the two quantitative measures, frequency and duration of gaze were significantly negatively correlated. More frequent looks to an experimenters face was moderately associated with longer duration of looks across groups: $r = .34$, $n = 48$, $p < .018$.

a) Frequency of looks was also negatively correlated with clinical evaluations of children's unusual use of gaze: $r = .403$, $n = 48$, $p < .01$, response to joint attention (RJA): $r = -.285$, $n = 48$, $p < .05$, and initiation of joint attention (IJA): $r = -.392$, $p < .01$. Children looking more frequently at the experimenters face during the selected four minute recordings of symbolic play in ADOS-G, were also judged by clinicians to display normal levels of eye-contact and better joint attention abilities during the whole ADOS assessment.

b) Duration of looks (but not frequency of looks) towards the experimenters face was also positively related to parental reports of children's use of direct gaze in the ADI-R interview, $r = .34$, $p < 05$. Long duration of looks was associated with normal use of direct gaze. As previously mentioned, because ADI-R previously was not part of the assessment protocol for controls participating in the ABC-study, only 10 out of 12 controls were included in the latter analysis. Results are thereby mostly based on scores obtained by children with ASD and MR ($n = 38$), and care must be taken when interpreting its meaning.

As table 7 shows, however, correlations coefficients between these measures within the total ASD-group (HF- and LF-ASD) were generally small and non- significant.

Table 7

Correlation coefficients between frequency and duration measures of eye-gaze, parental and clinical reports of eye-gaze, responsive- (RJA) and initiating- (IJA) joint attention abilities, IQ and symptom intensity within the group of children with Autism spectrum disorders (ASD)

	1) Frequency	2) Duration	3) IQ	4) Symptom intensity	5) Parental report	6) Clinical report	7) RJA	8) IJA
1) Frequency	-	.39	.16	-.23	-.25	-.03	-.00	-.30
2) Duration		-	-.04	-.03	-.21	-.12	-.15	-.12
3) IQ			-	-.56**	-.15	-.24	-.63**	-.55**
4) Symptom intensity				-	-.03	.54**	.35	.85**
5) Parental report					-	-.06	.30	.18
6) Clinical report						-	.04	.38
7) RJA							-	.27
8) IJA								-

*. p < .05 (2-tailed)

**.p < .01(2- tailed)

3.5 The impact of reciprocal interaction in play for initiation of eye-gaze

3. Does degree of reciprocal interaction in play influence on the amount of eye-gaze initiated by children with ASD, MR and TD?

Types of play which encourage more reciprocal interaction between playmates was assumed to elicit more frequent and longer sustained eye-gaze than free play where children was encourage to play alone. The results disconfirmed this assumption. Mixed between- within subjects analysis of variance was conducted to assess the impact of two different types of play ("Free play" and "Interactive play") on children's a) frequency and b) duration of eye- gaze towards the experimenters face between the four diagnostic groups (LF- ASD, HF-ASD, MR and TD).

a) As predicted based on previously presented results, there was a substantial main effect for diagnostic group: $F(3, 44) = 4.35$, $p = .01$, partial eta squared = .23, but there was no significant interaction between type of play and group: Wilks' Lambda = .92, $F(3, 44) = 1.34$, $p= .28$, partial eta squared = .08, nor were there any main effect of the two different types of play: Wilks' Lambda = 97, $F(1, 44) = 1.55$, $p = .22$, partial eta squared = .03. These results suggest that higher degrees of reciprocal interaction between child and experimenter in play do not facilitate a higher frequency of eye- gaze initialized by children towards an experimenter in the ADOS.

b) Similarly, no significant interaction effect between types of play and diagnostic group (Wilk's Lambda = .87, $F(3, 44) = 2,37$, $p = .08$, partial eta squared = .14), nor any main effects of either type of play (Wilk's Lambda = .99, $F(1, 44) = .33$, $p = .57$, partial eta squared = .00) or diagnostic group ($F(3, 44) = 2,31$, $p = .09$, partial eta squared = .14) in duration of eye- gaze observed in the present population. However, there was a close-to significant tendency ($p =.08$) for cognitively low-functioning children (with MR and LF-ASD) to increase their duration of eye- gaze in interactive play, while the high- functioning children display shorter looks in more interactive play.

3.6 Differences in targets of gaze

4. Are children with ASD visually attracted by other targets of gaze than children with MR and TD?

Children's gaze could be targeted at different things dependent on their main focus of interest.

To explore whether children's targets of gaze differed between diagnostic groups (HF-ASD, LF-ASD, MR and TD) one- way between-groups ANOVA was conducted. The only significant difference shown was in the amount of looks towards the experimenter's body. Children with LF- ASD (M = 2.92, SD = 2.57) looked significantly more frequently and longer towards the experimenters body than children with MR (M = 0.67, SD = 0.65): $F_{(3, 44)} = 4.2$, $p = .01$, $F_{(3, 44)} = 4.2$, $p = .01$.

Interestingly, a close to significant difference was observed in frequency of looks toward parents between children with HF- ASD (M = 0.67, SD = 1.44) and LF- ASD (M = 4.00, SD = 3.64, $p = .06$), as well as between the HF- ASD and the MR- group (M = 4.00, SD = 4.00, $p = .06$). The mean differences between these groups are relatively large, but the standard deviations are also large, which might explain the lack of statistical significance.

4   Discussion

4.1   Variation in use of gaze within and between diagnostic groups

4.1.1 Frequency of eye-gaze

The main aim of the study was to investigate the variability in use of gaze among children with autism spectrum disorders (ASD). The results show that children with ASD are a rather heterogeneous group with relatively large individual differences in use of eye-gaze. As hypothesised, children with ASD tend to look less often at others face than children with mental retardation (MR) and typical development (TD). However, the within-group differences are as large among children with ASD as among children with TD. These findings can complement much previously presented research looking solely on between-group differences. On a between-group level the results support previous findings of lower frequency of eye- contact displayed by children with ASD compared to children with MR and TD (Osterling & Dawson, 1994; Wimpory et al., 2002; Jones et al., 2008). On a within group level the present findings are in line with Leekam and colleagues (1998) findings which showed that a large proportion of children with autism followed gaze spontaneously. In contrast to Leekam study, however, the quantitative measures of gaze in the present study rated initiation of eye gaze instead of gaze following which limits the comparability of these studies. Still, the observation of variation in eye-gaze among children with ASD observed in Leekam and colleagues study was supported by the present findings.

Surprisingly, children with mental retardation seem to be even more heterogeneous than the other diagnostic groups. This group was the only one with a variance of frequency scores statistically different from the distribution of eye-gaze scores in the two ASD- groups. This finding could possibly reflect the large variance in diagnoses and functioning within the group of children with MR. Similarly to the selected MR- groups in previous studies (Baranek, 1999; Leekam et al, 1997; 1998) the present selection of twelve children with MR consisted of subjects with mixed diagnoses, such as Down syndrome (2), Rubinstein Taybi syndrome (1) and idiopathic developmental delay with no specific syndrome or disorder identified (9). In addition, out of twelve children with MR, eight of them were also diagnosed

with co-morbid language impairments. Thus, it is not remarkable to find large individual differences in use of eye-gaze within such a heterogeneous group. At the same time it adds to the impression that use of eye-gaze is highly different in both clinical and non-clinical populations. Nevertheless, large individual differences within the MR- group might pose a threat to the validity of findings in between-group comparisons. Perhaps the diversity in this group makes it less appropriate as a comparison group for often more stringently selected ASD- groups. However, the results are not less interesting in the light of this potential diversity. Since lower levels of social orienting abilities are usually found in children with ASD compared to children with MR, it indicates that diagnostic ASD- features extends the influence of individual characteristics.

4.1.2 Duration of eye-gaze

Interestingly, though contrary to what was initially assumed, children with mental retardation generally displayed the longest looks to the experimenters face while children with high-functioning ASD displayed the shortest looks. Still, the variance in duration of looks towards the experimenters face was not statistically different which indicate that there are overlapping differences in the sustainability of eye-gaze between diagnostic groups. Looking at the frequency and duration scores together, it seems that cognitively low- functioning children (MR and LF-ASD) tend to stare more than children with higher cognitive functioning (HF-ASD and TD) whom might shift gaze more frequently. Maybe children with MR and LF-ASD need more time processing the information provided in the experimenters face than better intellectually functioning children. This is supported by the results obtained in Baraneks (1999) study were children with developmentally delay stared or fixated more on objects than children with autism and typical development. Still, in the present study children with HF-ASD looked less frequently at the experimenters face than children with MR, and the mean duration for children with LF-ASD tended to be shorter than for children with MR. This could be explained by the lack of interest or social orientation which diagnostically differentiates ASD from MR.

4.2 Use of eye-gaze and levels of functioning

Cognitive functioning was not related to use of eye-gaze neither within- nor between diagnostic groups. More frequent and sustained looks was expected in the high-functioning compared to the low- functioning ASD group, but this prediction was disconfirmed. This is surprising given the previous findings of normal rates of gaze- following (Leekam et al., 1998) and joint attention behaviours in high-functioning children with autism (Swettenham et al., 2003). However, since no previous studies have directly compared these groups, comparisons of results with previous findings are difficult. Furthermore, in Leekam's study IQ was only related to gaze- following in children with a mental age above 4 years. The present population was within the chronological age-range of 36 to 54 months, and specifically the ASD- selection's mean IQ was just within normal range (Mean IQ in the total ASD selection was 77) which implies that most ASD- children did not have a mental age above 4 years of age. Thus, it is not unlikely that IQ and use of eye-gaze could be related in groups of older children. Furthermore, estimates of IQ are based on subscale measures and one cannot disregard the possibility that more accurately full-scale IQ estimates could have yield different results.

Social functioning, operationally defined as ASD symptom intensity, on the other hand, was strongly related to frequency and duration of eye-gaze when correlation analyses were performed across groups. At face value, such a result could indicate that ASD symptom-intensity is a better predictor for differences in eye-gaze than IQ, but when correlations were made within groups these associations were not significant. A closer look at the between group differences in mean ADOS total score expectantly revealed significantly higher symptom intensity, indicating lower social functioning, among LF-ASDs than within the HF-ASD group. Unexpected, however, although the mean frequency of gaze was lower in the low-functioning group, this difference did not reach significance.

Since, neither clinicians nor parents reported differences in eye-contact between children with HF and LF- ASD, it seems that levels of functioning does not predict how often or long children with ASD gaze at others face. When it comes to coordinating visual attention between interactional partners and objects, however, levels of cognitive functioning may play a significant role.

4.3 Differences in joint attention behaviors between diagnostic groups

4.3.1 Joint attention and cognitive functioning

According to clinical reports, only low functioning children with ASD showed impaired IJA and RJA abilities. The RJA and IJA- scores obtained by children with high- functioning ASD are comparable to the normal scores of children with MR and TD, supporting previous findings (Leekam et al., 1998, Swettenham et al., 2003) even in younger, 3-4 year old children. Since children with MR show normal joint attention behaviour, the idea that children with mental retardation in general (autistic and non-autistic) have trouble shifting visual attention needs to be modified. Could it be that children with ASD have trouble disengaging from what they are currently occupied with, and thereby fail to respond to prompts of gaze switching, whereas children with mental retardation only needs more time to process the information given before they respond with gaze switching? The observation of longer duration of gaze in children with LF-ASD and MR compared to HF- ASD and TD children supports this assumption.

An alternative interpretation is that children with lower cognitive abilities have trouble coordinating use of gaze with gestures to communicate interest and needs. A look at the specific scores obtained by children with ASD strengthens this assumption. On measures of RJA, four children with LF-ASD failed to respond at all to gaze directing bids (indicated by the score 2), compared to only one child with HF-ASD. The remaining HF- ASD children all obtained normal scores (= 0), while three children with MR required an additional point to attend to the toy (score 1) Regarding IJA, more than half of the low functioning ASD children failed to direct the experimenters attention to reference a distal object throughout the ADOS-assessment (e.g. 7 LF-ASD children was given the score 2). In comparison, all high-functioning children initiated joint attention bids at least once, but half of them failed to integrate gaze switching with points or vocalizations (e.g. 6 HF-ASD children obtained the score 1). To summarize the results it seems that children with ASD are capable of social orienting to the extent that they initiate eye-contact in social interactions, but they fail to follow or direct others gaze to the targets of others or their own visual attention.

4.3.2 Joint attention and social functioning

However, it seems that not only cognitive functioning, but also social functioning, or ASD-symptom intensity, has a strong influence on variance in joint attention abilities within the ASD- group. First, lower levels of IQ were strongly associated with higher ASD symptom intensity, explaining the significant difference in ASD- symptom intensity- as well as supporting the differences in joint attention abilities between HF and LF- ASD groups. Thus, social functioning, as measured by symptom intensity, is related to cognitive functioning. Secondly, while cognitive functioning was significantly associated with both RJA and IJA, social functioning was only significantly correlated with IJA. This finding underlines the importance of distinguishing between RJA and IJA in studies of joint attention and ASD, and it supports the more consistent correlations observed in studies of social and affective symptom presentation in autism and joint attention abilities (Charman, 2004; Dawson et al., 2004; Hobson & Hobson, 2007 etc). However, due to the inappropriateness of conducting multiple regression analyses with small samples and skewed distributions (Pallant, 2007), analyses of the total and unique contributions of IQ and symptom intensity in explaining joint attention abilities is currently lacking. Replications of these findings in future studies with larger samples and more advanced statistical analyses could help clarify the contributions of these factors for differences in gaze and joint attention abilities among children with ASD.

4.4 Differences in targets of gaze and the impact of reciprocal interaction in play

Two interesting effects can be related to findings regarding levels of functioning, use of gaze and joint attention. Children with LF-ASD tended to look longer at the experimenter's body than children in the three other groups. Since they were also found to look the least towards the experimenters face, it suggest that they fixate more on other parts of the body than looking into the eyes of their interactional partner. These results can complement previous findings of preferential fixating away from the eyes in ASD- children compared to controls and children with developmental delays (Dalton et al., 2005; Klin et al., 2002; Pelphrey et al., 2002, Jones et al., 2008, Klin et al., 2008). On one hand, Jones and colleagues had the advantage of using much more precise measures of gaze than was available to this study. It is indeed probable that eye-tracking technology could have identified more deviant use of gaze among children with autism, for instance more looks toward the experimenter's mouth in the autism group.

46

On the other hand, in contrast to previous gaze monitoring studies, the present study had the strength of comparing ASD-children with different levels of functioning. This resulted in a revealed additional target of gaze (looks to the experiments body) used most frequently by low- functioning children with autism. Maybe children with LF-ASD spontaneously orient to others attention calling behaviour, but instead of fixating on the eyes, they merely cast a glance in that person's direction due to lack of interest, avoidance of eye-contact or other currently unidentified explanations. Furthermore, the tendency for children with LF-ASD to look more frequently in the direction of their parents than children with HF- ASD could perhaps be related to their impaired ability to engage in joint attention with the experimenter.

4.4.1 Causal interpretations

No causal conclusions can be drawn based on this study's correlation design. Nevertheless interpretations of the possible implications of these data could hopefully stimulate ideas for future research and interventions.

The developmental theories previously presented hypothesized that impaired social orientation reduces the amount of eye-gaze displayed by children with ASD. Presumably, impaired use of eye-gaze provides less social learning opportunities leading to lower levels of social functioning. The finding that children with ASD on average displayed lower amount of eye-contact than children in control groups could support this theory. However, it could not explain the equal within-group variances, and the fact that children with MR in this study were even more varied than the ASD children in use of eye-gaze. Furthermore, since no mean difference was found in the amount of eye-gaze displayed between subgroups of ASD, the idea that levels of cognitive functioning could be a moderating factor between these specific variables is weakened. If so, it suggests that other, currently unidentified factors could account for the lack of eye-contact often observed by children with ASD. If there are overlapping differences in use of gaze between children with ASD, MR and TD it indicates at least to possible explanations. Either social orientation impairment is not specific to children with ASD, but more severely expressed in this group, or perhaps many children with ASD are not born with social orientation impairment. The heterogeneity observed in spontaneous orientation to the eyes of others could support recent theories linking pathology of various kinds to similar underlying mechanism which causes impaired (Dadds et al, 2008; Itier & Batty, 2009; Klin, 2008, Jones & Klin, 2009).

At the same time it is likely that methodological factors inherent in the present study could help explain why some children with MR and TD displayed equal amounts of eye-contact as children with ASD. One possible explanation could simply be that some children were shy and uncertain during assessment which reduced the amount of eye-contact displayed during the four minutes recordings. The fact that free play and interactive play are the first two activities of the ADOS assessment and most children interacted with an unfamiliar experimenter makes it a plausible explanation. If so, the equal group variances in use of gaze between children with and without ASD could have different causes which are not distinguished in studies of eye-contact alone.

However, in line with Mundy and Sullivan's affect theory (2006) there seem to be a difference between the social use of spontaneous eye-gaze in social interaction and the ability to follow or direct gaze. While gaze- following abilities can be learned by others repeated bids for joint attention, the frequent initiations of eye-contact probably requires a motivational drive to do so which might be impaired in children with ASD. Since children with ASD on average looked less frequently to the eyes of others than children without ASD, it could be that these children have trouble understanding the reward value of eye-contact. However, the observed difference in joint attention abilities between subgroups of ASD could indicate that HF-ASD children might be better able to learn to follow and direct gaze than LF-ASD. In this view cognitive functioning could have a moderating effect on the relationship between possible social orientation impairments and social functioning.

This assumption goes well with the observation that intellectual disabled children (HF-ASD and TD) looked longer towards an experimenters face than the children with intellectually abilities within normal range (LF-ASD and MR). It could be that LF-ASD children both require more social learning experiences to learn to frequently and spontaneously orient to eye-gaze, but also need more time to process the information communicated by gaze. Developmentally delayed children without autism on the other hand, probably spontaneously seek facial information, but needs time to process it before responding with appropriate behaviour.

Since these interpretations are based on rather short observations of very few subjects one cannot understate the importance of treating these data and possible implications with care. Still, in case future studies would indicate some validity in these interpretations it could have important implications for treatment. It suggests the need to individually adapt

48

intervention programs to the child's intellectual and social level. Early training where the focus is to learn to frequently search for information in another person's face could probably be beneficial for all children with ASD. However, lower functioning children might be in need substantially more training than high-functioning children to obtain comparable effects. Moreover, it could perhaps be equally important that children with both HF and LF-ASD learn the purpose of social referencing, because only by understanding the rewarding value of eye- gaze one would be motivated to use it more often and sustained during social interactions.

4.5 Methodological strengths and limitations

The case-control design employed included control groups that enabled comparisons both within and between groups of age-matched children with different diagnostics and levels of functioning. Since very few previous studies have directly compared children with high and low functioning ASD in use of eye-gaze, our current knowledge on this matter is limited. More specifically, due to methodological issues, our knowledge is restricted to observations of average differences between primarily high-functioning ASD children and children with other developmental delays or typical development. The current study could just as well repeated this possibly misleading convention by reporting less use of gaze among children with ASD based on between-group analyses only. However, due to the exploration of within-group variance it is possible to show that children with ASD is not a uniform group nor are they any less different than typically developing children.

Nevertheless, as this and previous studies have shown, there is a tendency for children with ASD to be impaired in use of eye- gaze compared to children with typical development and children with MR. Such an impairment implies a loss of valuable information given in the facial expressions of others, and possibly limited opportunities for social learning experiences of various kind (including language and theory of mind abilities). Many children with ASD could thereby require additional support to help compensate for these impairments. However, as the present study show, not all children have impaired initiation of eye-gaze or gaze following abilities, but most children have trouble directing gaze to the targets of their visual attention. Since the ability to initiate joint attention are later developed than mutual gaze and RJA, IJA- behaviour (Sally & Dixon, 2007), impaired IJA might not be as easily detected for caregivers as the lack of mutual gaze or response to visual attention bids. If so, the potential

problem facing children with autism who display normal or close to normal rates of eye-gaze could be postponed identification and diagnosing. Without the focus on individual differences within the autism spectrum (as well as in other populations) one risk the chance of adding to much weight to the lack of eye-gaze as a significant marker of autism, thereby failing to diagnose actual affected cases. Although high-functioning individuals with ASD might function well on a cognitive and behavioural level as well as appearing relatively socially oriented, as pointed out in DSM-IV one should not underestimate the impact of their social difficulties (APA. 2000). According to C. Lord (personal communication, January 5th, 2010) treatment offers the potential of moving development faster, but factors such as parental engagement, scaffolding, popularity among friends etc. might be just as important for outcome. One of the many benefits of early identification of ASD could perhaps be to advice parents and other caregivers from early on, on how to optimize use of eye-gaze and joint attention abilities in children which could further increase the child's development of social skills.

However, although strong tendencies were observed, this study did not have the strength of testing possible mechanism and causalities. Thus, one can speculate about the possible implications of these observations, but the importance of taking the methodological limitations of this study into account cannot be understated.

4.5.1 Limitations

The main challenge facing the reliability of results in the current study is the small group sizes (low n) which consequentially limits statistical power, increases the chance of making type 2 errors and threaten the external validity of findings.

Because no differences were observed in results obtained with parametric and non-parametric approaches, parametric statistics was chosen to optimize statistical power. However, several close to significant effects were found indicating that some results are threatened by type 2 errors (the failure of rejecting a null hypothesis when it is in fact false, Pallant, 2007). For instance, there was a non-significant tendency ($p = .08$) for cognitively low-functioning children to increase duration of eye-gaze in interactive play compared to free play, while high-functioning children displayed the opposite pattern. Some statisticians suggest adjustments of alpha level, setting a cut-off of .10 or .15 instead of .05, to compensate when groups sizes are less than n= 20 (Stevens, 1996 in Pallant, 2007). By following these

50

guidelines the interaction analyses of type of play and duration of eye-gaze would have reached significance. Thus statistical interaction effects could perhaps be obtained by analyzing larger samples.

With regards to correlation analyses the small n was compensated for by collapsing the two ASD- groups into one, resulting in 24 subjects. Few studies investigating symptoms of autism has the advantage of high availability of ASD subjects. Therefore, it is not uncommon for studies investigating gaze in autism to study groups of less than 30 subjects. Nevertheless, the generalizability of findings is impaired by small samples and interpretations must be done with care. On the other hand, the robustness of actual significant effects when comparisons and correlations are made with small groups cannot be underestimated. In the present study this is especially evident in the overall large effect sizes of differences in mean frequency and duration of eye-gaze, joint attention abilities and symptom intensity.

An important factor to consider when interpreting the results is the fact that the quantitative ratings of eye- gaze are based on four- minute's segments only. The frequency and duration scores obtained could in worst case be quite arbitrary, and to base strong conclusion on such small samples of behaviour are indeed problematic. Replications of this study using much longer recordings and preferably other contexts for comparisons are highly warranted before the validity of these findings can be established. Still, the multiple informants and instruments used to measure eye-gaze yields consistent results which indicate that these four minutes recordings have adequately captured the children's typical use of eye-gaze. The qualitative ratings of eye-gaze conducted by experienced clinicians are based on almost 40 minutes observations of the selected children. Although one can question the compatibility of four minutes and 40 minutes observations, the degree of consistency between informants indicate quite high reliability between different measures of gaze. Furthermore, these measures are consistent with parent's ratings of their children's typical use of eye-gaze in everyday life. Presumably, this latter fact can argue in favour of the ecological strengths of this study as well. The consistent ratings of use of gaze across informants indicate that children were relatively familiar and comfortable with the ADOS- activities chosen for coding.

Potential selection biases also affect the possibility of generalizing findings to other populations. As previously discussed, to find an appropriate criterion to distinguish subgroups of children with ASD with the purpose of measure within-group variation is challenging. The

present study used level of IQ to distinguish between HF and LF- ASD children in accordance with the criteria employed in the ASD- literature. However, these groups were also shown to differ in symptom intensity and IQ and symptom intensity was highly correlated. Since symptom intensity could actually explain more of the variance in IJA than IQ, perhaps symptom intensity is a better criterion for distinguishing between HF and LF- functioning ASD than IQ. Certainly, it would be more in accordance with the tendency for HF-ASD children to be diagnosed with sub-threshold or atypical symptomatology leading to diagnoses of PDD- NOS and Asperger syndrome instead of autistic disorder which is most common among low-functioning children with ASD.

An alternative way of measuring the influence of IQ on use of eye-gaze could be to match subjects one-by-one on level of IQ instead of using a group-wise matching strategy (selection based on IQ $><$ 70) prior to subject selection and then later control for levels of IQ using regression analyses. Although, the benefits and disadvantage of matching was thoroughly discussed prior to participant selection it was eventually omitted due to the main purpose of this study and recommendations made in recent meta-analytic studies of matching strategies in autism research (Mottron, 2004). Matching subjects on too many variables, including IQ, creates the risk of restricting range (Breaugh & Arnold, 2007; Eilertsen, personal communication, 2009) which limit the actual within-group variance under investigation.

The material used to rate gaze could be criticized on several matters. First, as already mentioned ratings of use of eye-gaze cannot possibly be done with the same precision based on DVD-recordings as that is possible using eye-tracking methodology. Although "The Observer" allows viewing frame by frame to see exactly when a gaze is shifted, these ratings are still dependent on subjective evaluations with perceptual flaws and contextual distracters being potential source of measurement error. Thus a replication of this study using more advanced technology is warranted. However, great care was taken to decrease the impact of this problem by ensuring high-quality data. These considerations together with the high inter-rate agreement indicate quite reliable results.

Another potential problem regarding the specific ADOS sequences used for rating of gaze is that not all children have been exposed to the same conditions. For many of the children with MR and LF-ASD coding of gaze were based on recordings of the ADOS-birthday party. This sequence is highly structured compared to the interactive play sequence

used to code higher functioning children, which might imply that the observed tendency for low functioning children to stare longer at the experimenters face is due to differences in task demands between ADOS activities more than levels of IQ. Due to this limitation as well as the problem with low n, and short recordings (= 2 min. of each ADOS-sequence), the results of interaction analyses between type of play and use of eye-gaze has not been discussed in further detail. However the tendencies observed makes it a topic of interest for future studies. It would be highly desirable if future studies could take these methodological factors into account and investigate impacts of reciprocal interaction in play on eye-gaze in autism by using more comparable measures and longer recordings than was possible here.

4.5.2 Concluding remarks

The main findings of the current study share interesting lights upon the common notion that individuals with autism use less eye-gaze than other non-autistic individuals in social interaction. Although as a group, children with ASD tend to look towards others face less often than children with MR and TD, in general they are as different and unique as typical developed children in the amount of eye-contact initiated in social interactions. In fact, the current study shows even larger variation among children with MR than children with ASD and TD. Together with the second main finding that level of cognitive and social functioning does not predict frequency and duration of eye-contact, but joint attention behaviour, there should be other currently unidentified factors explaining differences in use of gaze across and within diagnostic groups. Compared solely on a between-group level, as previous studies typically have done, children with ASD are found to be deviant in their use of gaze. However, a closer look at individual differences should perhaps be employed to avoid stereotypical misconceptions of a very heterogeneous group. Too much weight attached to little use of eye contact as a diagnostic criteria for ASD might be misleading, and could (in the worst case scenario) possibly result in unidentified ASD-cases and lack of proper intervention offered to affected individuals.

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