

**Asymmetric frontal EEG activity to another person's gaze:  
A comparison study between autistic and typically  
developing children.**

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Direction of gaze is a powerful social signal that has been associated with motivational tendencies of approach and avoidance. Recently, it has been found that another person's perceived direct and averted gaze can also activate the approach-avoidance motivational brain systems. Direct gaze of a person elicited relative greater left-sided frontal activation associated with approach-related motivation, whereas averted gaze elicited relative greater right-sided frontal activation associated with avoidance-related motivation.

The present study investigated frontal EEG asymmetry to different stimulus conditions in children with autism and typically developing children. The age of the participants ranged from 8 to 16 years. Three different face stimuli (direct gaze, averted gaze and eyes closed) and a control stimulus were used. Participants' gazing behaviour during stimulus presentation was recorded in order to be sure that the participants were looking at the stimuli. The participants' subjective evaluations of arousal and valence to different stimulus conditions were also investigated. Based on earlier studies with adults, we expected that the direct gaze would elicit left-sided frontal activation, whereas the averted gaze would elicit right-sided frontal activation in typically developing children. It was also hypothesized that if the autistic children experience eye contact with another person over-arousing, the direct gaze would elicit reduced left-sided or even greater right-sided frontal activation, whereas the eyes averted condition would elicit reduced right-sided or even relative left-sided frontal activation. Furthermore, we assumed that participants' subjective ratings of emotional valence and arousal would differ between different stimulus conditions and between children with autism and typically developing children. We expected that the direct gaze would be experienced as more arousing and less pleasant than other face stimuli conditions and that these differences would be more robust in children with autism.

Contrary to our expectations the asymmetry scores did not differentiate between different stimulus conditions or between the two groups of children. Left-sided frontal asymmetry was measured to all four stimulus conditions. In valence ratings the results revealed that direct gaze was evaluated as less pleasant than eyes closed. In arousal ratings, the direct gaze was evaluated as more arousing than averted gaze or eyes closed. Again no differences between children with autism and typically developing children were found. The gazing behaviour during different stimulus conditions did not differ between children with autism and typically developing children. The present study did not find support for the notion that another person's direct and averted gaze activates the approach-avoidance motivational brain systems in children with autism and typically developing children. In future studies the influence of age to these phenomena should be investigated. In addition, it should be noted that not all children with autism experience eye contact aversive. Therefore it would be interesting to divide children with autism into different groups based on their deficits in social interaction.

**KEY WORDS:** Autism, eye contact, gaze direction, EEG asymmetry, approach-avoidance motivation

INTRODUCTION .....	1
Autism and face perception .....	1
Perception of gaze and eye contact .....	3
Approach and avoidance related motivation and frontal EEG asymmetry .....	6
Aim of the study.....	7
METHOD .....	9
Participants .....	9
Stimuli .....	10
Design and procedure.....	10
EEG data acquisition.....	12
Data analysis .....	12
RESULTS .....	13
DISCUSSION.....	16
REFERENCES .....	21

## **INTRODUCTION**

Gaze has several important functions in social communication and it serves various functions during interpersonal interaction. These functions include regulating interaction, exercising social control, expressing intimacy, providing information, and facilitating communication (Kleinke, 1986). The direction of gaze and eye contact in special has a powerful role in social interaction. Eye contact can be seen as communicating information about threat or approach whereas averted gaze conveys information about submission or avoidance (Emery, 2000; Kleinke, 1986). In addition, the direction of eye-gaze gives information of whether a person is attending to you or whether the attention is directed to another person or to your surroundings. Studies conducted with newborns also give an insight of the importance of gaze and eye contact. Even newborns have the ability to detect the direction of gaze (Farroni, Johnson, & Csibra, 2004) and they also prefer faces with direct gaze (Farroni et al., 2004; Farroni, Menon, & Johnson, 2006; Hains & Muir, 1996). Studies suggest that the ability to detect gaze direction might be innate.

### **Autism and face perception**

The autism spectrum disorder is a neurodevelopmental disorder characterized by restricted repetitive and stereotypic behaviour and by qualitative impairments in social interaction and in communication (DSM-IV; APA 1994). The deficiencies in social interaction consist of difficulties in utilizing eye contact in nonverbal communication and deficits in social and emotional reciprocity. Abnormalities in the timing and quality of social gazing behaviour have also been found in individuals with autism (Willemsen-Swinkles, Buitelaar, Weijnen, & van Engeland, 1998). Individuals with autism tend to look less at others as compared to typically developing children (Hutt & Ounsted, 1966; Kasari, Sigman, & Yirmiya, 1993; O'Connor & Hermelin, 1967; Osterling & Dawson, 1994; Swettenham et al., 1998; Volkmar & Mayes, 1990) and spend more time looking at non-social stimuli than typically developing children (Swettenham et al., 1998; Klin, Jones, Schultz, Volkmar, & Cohen, 2002). Autistic individuals also have difficulties in understanding the information provided by the face. An example of this difficulty is the deficit in understanding facial expressions (Hobson, 1986; Weeks & Hobson, 1987; Tantam, Monaghan, Nicholson, & Stirling, 1989). Joint attention behaviour is also impaired in autistic individuals; this applies to both the production (Charman et al., 1997; Osterling & Dawson, 1994) and comprehension of joint attention behaviour (Dawson et al., 2004; Warreyn, Roeyers, Oelbrant, & De Groote, 2005).

Moreover, autistic individuals show difficulties in face recognition tasks (Howard et al., 2000; Klin, et al., 1999; Tantam et al., 1989), and in face memory tasks for both familiar and unfamiliar faces, but there are no deficits in recognition memory for non-social stimuli (Hauck, Fien, Maltby, Waterhouse, & Feinstein, 1998). Autistic individuals tend to look more to the mouth area than typically developing individuals when performing face recognition tasks (Langdell, 1978; Neumann, Spezio, Piven, & Adolphs, 2006) or when judging the emotional expression (Spezio, Adolphs, Hurley, & Piven, 2007) and they fixate less to the eye region than typically developing individuals (Hutt & Ounsted, 1966; Klin et al., 2002; Neumann et al., 2006; Pelphrey et al., 2002). It has been suggested that individuals with autism process faces differently from typically developing individuals (Joseph & Tanaka, 2002; Langdell, 1978).

Even though autistic children have abnormalities in face processing and in joint attention behaviour; they still prefer social stimuli over other stimuli (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2002; O'Connor & Hermelin, 1967). Although not all behavioral studies have found differences in face recognition (Hobson, Ouston, & Lee, 1988; Volkmar, Sparrow, Rende, & Cohen, 1989) and in fixation times to different parts of the face (van der Geest et al., 2002; Willemsen-Swinkels et al., 1998), it could be, as suggested by Deruelle and colleagues (2004), that different cognitive and neural processes are used by individuals with autism and typically developing individuals.

Studies concerning brain activation have also supported the notion that autistic individuals process faces differently as compared to typically developing individuals (Bailey, Braeutigam, Jousmäki, & Swithenby, 2005; McPartland, Dawson, Webb, Panagiotides, & Carver, 2004). These studies have found abnormal neural activation while perceiving faces (Pierce, Müller, Ambrose, Allen, & Courchesne, 2001), identifying faces (Dawson et al., 2002) and processing of emotional facial expressions (Critchley et al., 2000). Some studies concerning brain activation have supported the notion that autistic individuals process faces in the same way as objects (Bailey et al., 2005). Dawson et al. (2002) measured event-related brain potentials and found that young children with autism did not show differential brain activation to familiar and unfamiliar faces, but they did show differential activation to familiar versus unfamiliar objects, whereas typically developing children showed differential brain activation to both familiar and unfamiliar faces and objects. Activation also differs between autistic individuals and typically developing individuals in the Fusiform Face Area (FFA). FFA is found to be active in typically developing individuals when viewing faces (McCarthy, Puce, Gore, & Allison, 1997; Pierce et al., 2001; Tong, Nakayama, Moscovitch, Weinrib,

& Kanwisher, 2000), but studies conducted with autistic individuals have shown weak or no activity in FFA when viewing faces (Pierce et al., 2001). Dalton et al. (2005) showed that the activation of the fusiform gyrus was regulated by the time autistic individuals spent on looking at the eyes. Thus, the weak activation in the fusiform gyrus may be explained with diminished gaze fixation. Abnormal activation has also been found in the amygdala of autistic individuals. The results are in part conflicting since some studies have found decreased activation of the amygdala (Pierce et al., 2001) and other studies have found increased activation (Howard et al., 2000), but researchers are of one mind that the activation in the amygdala is abnormal in autistic individuals.

### **Perception of gaze and eye contact**

Gaze expresses the intensity of feelings and affects the physiological arousal (Kleinke, 1986). Many studies have shown that when seeing a person from straight ahead, people are very accurate at discriminating whether the person is looking toward or whether the gaze is averted (Anstis, Mayhew, & Morley, 1969; Gamer & Hecht, 2007). As mentioned, even newborns are able to discriminate between direct and averted gaze (Farroni et al., 2004). Individuals with autism are also capable of making overt eye-gaze direction discriminations (Kylliäinen & Hietanen, 2004; Leekam, Baron-Cohen, Perret, Milders, & Brown, 1997). In both autistic and typically developing individuals seeing an averted gaze triggers automatic shift of visual attention (Chawaraska, Klin, & Volkmar, 2003; Kylliäinen & Hietanen, 2004). There are also studies that have not found the gaze cueing effect in autistic individuals (Ristic et al., 2005), but this may be due to the fact that Ristic and colleagues used schematic faces with static averted gaze whereas studies that have found gaze cueing effect used real faces with static gaze (Kylliäinen & Hietanen, 2004) or real faces with blinking eyes followed by a movement of the eyes to either side (Chawaraska et al., 2003).

There is a wealth neurophysiological evidence suggesting that there are areas specialized to the eye-gaze processing. Superior temporal sulcus (STS) has been found to activate when processing information of eye movements (Akiyama et al., 2006; Engell & Haxby, 2007; Pelphrey, Singerman, Allison, & McCarthy, 2003; Pelphrey, Viola, & McCarthy, 2004; Pelphrey, Morris, & McCarthy, 2005; Puce, Allison, Bentin, Gore, & McCarthy, 1998). Hoffman and Haxby (2000) showed that gaze direction discrimination task produced a stronger response in the STS than identity task, whereas identity task elicited a stronger response in the inferior occipital gyri (IOG) and fusiform gyri (LFG) than did the gaze direction discrimination task. Amygdala is also involved in the processing of gaze direction. Kawashima et al. (1999) found that the left amygdala was activated to

the same extent both in situations with or no eye contact, whereas the right amygdala was activated more strongly in situations with eye contact.

Typically developing individuals show enhanced performance in face recognition when the face has a direct gaze as compared to averted gaze (Hood, Macrae, Cole-Davis, & Dias, 2003) even though they do not have any explicit goal to commit targets to memory (Mason, Hood, & Macrae, 2004). Categorizing according to gender is also enhanced when the target has a direct gaze (Macrae, Hood, Milne, & Rowe, 2002). Autistic individuals also detected the direct gaze faster and more efficiently than averted gaze in situations where they saw the whole face and also in a situation where they saw the eye area alone (Senju, Kikuchi, Hasegawa, Tojo, & Osanai, 2008), but it seems that in a situation where direct gaze is presented in the context of laterally oriented faces, autistic individuals have difficulties in the efficient detection of direct gaze (Senju, Hasegawa, & Tojo, 2005). The superiority to detect faces with direct gaze is only perceived when the faces are presented upright and diminished when the faces are presented upside-down in typically developing individuals (Senju et al., 2005; Senju et al., 2008). In individuals with autism the face inversion did not influence their performance (Senju et al., 2008). These results suggest that children with autism rely on featural information in the detection of direct gaze, whereas typically developing individuals use configural processing to detect direct gaze. Hood and colleagues (2003) suggested several explanations for this enhanced performance when seeing faces with a direct gaze. One explanation is that this effect emerges through mutual gaze with so-called mutual gaze detectors that facilitate the encoding. Another explanation is that the processing of faces with averted gaze is not so efficient due to the gaze cueing effect. This explanation is unlikely because the visual shifts of attention can be seen as early as in the first 200ms of processing and in these studies the stimuli appeared visible for much longer. It could also be that the enhanced performance in situations where faces display direct gaze is associated with the heightened arousal of the participant.

Many studies have supported the notion that direct gaze can result in heightened physiological responses. Electroencephalographic (EEG) arousal (Gale, Spratt, Chapman, & Smallbone, 1975) and skin conductance responses (Nicholas & Champness, 1971) have been found to be higher for direct gaze than for averted gaze. Gale et al. (1975) also found that the EEG arousal weakened as a function of distance, but the arousal for direct gaze was always higher than the arousal for averted gaze. Gaze has been found to increase the heart rate in a condition where the participants played a competitive game and the experimenter stared at them as compared to a condition with no-gaze during playing (Kleinke & Pohlen, 1971). There are also studies that have found only marginal effects (Donovan & Leavitt, 1980) or no effect of direct gaze on physiological arousal (Kylliäinen

& Hietanen, 2004). The differences in the results might be explained by the fact that studies that did find heightened arousal used live person as a stimulus, whereas studies that did not find any differences in the arousal between direct and averted gaze used images of faces (Hietanen, Leppänen, Peltola, Linna-Aho, & Ruuhiala, 2008). According to Hietanen et al. (2008) the feeling of being observed by another person is an important factor in initiating the self-awareness processes and that these self-awareness processes are different as compared to when seeing pictures of a person.

Autistic individuals show qualitative impairments in gaze behaviour. They engage less in eye contact (Hutt & Ounsted, 1966; Phillips, Baron-Cohen, & Rutter, 1992) and have fewer initiates for eye contact (Yirmiya, Pilowsky, Solomonica-Levi, & Shulman, 1999) than typically developing individuals. Those deficits in eye contact in autistic individuals can be traced back to the first years of life with retrospective studies (Osterling & Dawson, 1994; Zwaigenbaum et al., 2005). One explanation of this atypical eye contact behaviour is that autistic individuals avoid eye contact because they experience it over-arousing (Hutt & Ounsted, 1966; Kylliäinen & Hietanen, 2006). Kylliäinen and Hietanen (2004) found that the skin conductance responses (SCR) were higher to direct gaze than to averted gaze in autistic children, but no such difference between direct and averted gaze was found in typically developing children. Dalton et al. (2005) also showed that the activation of the amygdala was positively correlated with the time spent on fixating the eye region in autistic individuals. These results suggest that gaze fixation might be associated with heightened emotional response in individuals with autism and one hypothesis of the results is that individuals with autism might find eye contact aversive. Another explanation of atypical eye contact behaviour is that individuals with autism have difficulties in understanding the information provided by the face, that they do not see the eyes as meaningful or salient (Baron-Cohen, Baldwin, & Crowson, 1997; Weeks & Hobson, 1987). The fact that autistic individuals have difficulties in recognizing complex mental states especially when they see the eyes alone (Baron-Cohen et al., 1997) and that they rely more on the information from the mouth area for emotional judgement (Neumann et al., 2006) support the notion that autistic individuals have difficulties in perceiving the eyes as meaningful. Amygdala is said to be involved in establishing the reward value of the stimuli (see Baxter & Murray, 2002). Hence, the abnormal activation of the amygdala while rest and to face perception tasks (Howard et al., 2000; Pierce et al., 2001) also supports the notion that autistic individuals have difficulties in utilizing the information provided by the face because they do not experience them as rewarding.



Behavioural studies have connected eye-gaze direction to approach and avoidance motivation. Adams and Kleck (2003) have shown that the direction of gaze influenced the time it took for the participants to label pictures of faces according to their expression. They found that approach-oriented emotions of anger and joy were categorized faster when they were presented with direct gaze, whereas avoidance-oriented emotions of fear and sadness were categorized faster when presented with averted gaze. Adams and Kleck (2005) extended the findings of their previous study by showing that faces with direct gaze were labelled more often as experiencing anger or joy. They also found that direct gaze increased the perceived intensity of approach-oriented emotions, whereas averted gaze increased the intensity of avoidance-oriented emotions.

### **Approach and avoidance related motivation and frontal EEG asymmetry**

Asymmetric frontal EEG activity in the alpha band has been connected to positive and negative emotions and to approach and avoidance related motivation. The relative greater left-sided activation is associated with positive emotions and approach related emotions, whereas relative greater right-sided activation is associated with negative emotions and avoidance related emotions (e.g. Davidson, 1992; Harmon-Jones, 2003). It seems that these individual differences in EEG asymmetry are relative stable over time (Tomarken, Davidson, Wheeler, & Kinney, 1992) and it seems that the lateralization of approach and avoidance emotions is also present at infants (Davidson & Fox, 1989).

The studies of frontal EEG asymmetry have mainly measured EEG in a resting state. Only a few studies have measured frontal asymmetry to different stimuli. For example, a study conducted by Gable and Harmon-Jones, (2008) measured frontal asymmetry to pictures of dessert and to neutral pictures and found that emotive tendencies measured with liking the dessert or greater time since eaten resulted in greater left-sided activation when viewing pictures of dessert but not when viewing neutral pictures. Recently, it has been found that seeing another person's direct and averted gaze can also activate the frontal EEG asymmetry. Hietanen et al. (2008) have shown that in adults the direct gaze of a person seen from straight ahead elicited left-sided frontal activation, whereas averted gaze elicited right-sided frontal activation. These effects on EEG asymmetry were only observed in a condition where the participant viewed an actual person through a voltage sensitive liquid crystal shutter, not when the participants viewed pictures of the same person. They also measured skin conductance response (SCR) and participants' subjective ratings of arousal and valence. They found that both direct and averted gaze in the live condition elicited stronger autonomic responses than when the participants viewed pictures of the same person. In live condition direct gaze elicited

stronger responses than did the averted gaze. Thus, the direct gaze was more arousing than the averted gaze. Subjective ratings supported the results of frontal asymmetry. They revealed that the live face condition was evaluated as more arousing than the pictures of face stimuli and control object or the control object in the live presentation. In addition in the live presentation the direct gaze was evaluated as being more arousing than the averted gaze. In concordance with other studies, the results of Hietanen et al. (2008) support the notion that frontal asymmetry is in fact related to motivational tendencies and not to emotional valence of the stimulus (Harmon-Jones & Sigelman, 2001; Harmon-Jones, 2004; van Honk & Schutter, 2006). Therefore frontal asymmetry can be seen as a valuable method in the investigation of children's motivational tendencies to eye contact.

Only one study published, as far as we know, has measured frontal asymmetry in children with autism (Sutton et al., 2005). They measured resting EEG and social behaviour in autism. Social behaviour and symptoms of autism were measured with three different rating scales which were rated by the participants and by their parents. They found that children with autism who exhibited right-sided asymmetry had more severe symptoms of autism, whereas the children with autism who exhibited left-sided asymmetry had fewer problems in social interaction. As a conclusion, they suggested that children with autism who exhibited left-sided frontal asymmetry may have greater motivation to interact with others as compared to children with autism who exhibited right-sided or intermediate asymmetry. Contrary to their expectations they found that on average children with autism exhibited left-sided frontal activation, whereas typically developing as well as children with learning disabilities exhibited on average right-sided frontal activation. According to Sutton et al. (2005) it may be due to the experience of social anxiety that influenced the results. In typically developing children the greater social anxiety was related to right-sided frontal asymmetry, whereas in children with autism the greater social anxiety was related to left-sided frontal asymmetry, but more research is needed on that issue.

### **Aim of the study**

The aim of the study was to find out whether asymmetric frontal activation would differ as a response to another person's direct and averted gaze and whether the asymmetric frontal activation would differentiate between typically developing children and children with autism. We were especially interested whether children with autism react to eye contact differently as compared to typically developing children. To this end, we measured hemispheric asymmetry in the frontal

electroencephalogram (EEG) to different stimulus presentations. The relative greater left-sided frontal activation has been associated with positive and approach-related emotions while greater relative right-sided frontal activation has been associated with negative, avoidance-related emotions (e.g. Davidson, 1992; Harmon-Jones, 2003). Three different face stimuli and a control stimulus were used in the study. The face stimuli were faces with direct gaze, averted gaze and eyes closed. The control stimulus was a vase which was used in order to study whether some of the effects might be related to the mere perception of a face, independent of gaze direction.

Autistic individuals have been suggested to look less to the eye region than typically developing individuals (Hutt & Ounsted, 1966; Klin et al., 2002). Therefore, in the present study after every stimulus presentation the children were asked whether the model gazed straight, sideways or whether the eyes were closed. This way it was ensured that the children paid attention to the stimuli. The gazing behaviour of the children was also recorded in order to compare the time they spent on watching the stimuli. In this study the participants were viewing a person sitting opposite to them so the situation was made as realistic as possible corresponding to everyday gazing behaviour.

Based on earlier studies with adults (Hietanen et al., 2008) it was hypothesised that the direct gaze would elicit relative greater left-sided frontal activation, whereas the averted gaze would elicit relative greater right-sided frontal activation in typically developing children. It was hypothesized that if the children with autism experience eye contact with other person over-arousing the direct gaze would elicit reduced left-sided frontal activation or even greater right-sided frontal activation, whereas the eyes averted condition would elicit reduced right-sided frontal activation or even relative left-sided frontal activation. Furthermore, it was hypothesized that participants' subjective ratings of emotional valence and arousal would differ between different stimulus conditions and between the two groups. Thus, direct gaze would be experienced as more arousing and less pleasant than other gaze conditions and the difference would be more robust in children with autism. Regarding the gazing behaviour of the participants no specific hypotheses were formed beforehand because the results are to some extent conflicting stating that in some situations the gazing behaviour between the two groups does not differ (van der Geest et al., 2002; Willemsen-Swinkels et al., 1998) and on the other hand there is a wealth of evidence suggesting that individuals with autism have qualitative deficits in eye gaze behaviour (Hutt & Ounsted, 1966; Klin et al., 2002; Neumann et al., 2006; Pelphrey et al., 2002).

## METHOD

### Participants

Twenty-three autistic children and twenty-one normal control children participated in this study (mean age = 12,0 years, range 8-16 years). The participants received two movie tickets for their participation. 7 participants were excluded from the analysis due to EEG abnormalities (n = 3), low alertness (n = 2), migraine (n = 1) and one of the participants had fewer. Thus, the data were analysed from seventeen autistic children and twenty typically developing control children (Table 1). Children with autism were recruited from Child Psychiatry Clinic of Tampere University Hospital. All the children in the autistic group were diagnosed as having autism spectrum disorder by clinical procedures using ICD-10 classification. The diagnoses were F 84.0 Infantile autism, F 84.1 Atypical autism and F 84.5 Asperger's syndrome. Exclusion criteria included the presence of depression or anxiety diagnosis and IQ lower than 70. The parents of autistic children had been interviewed with 3Di-interview (Developmental, Dimensional and Diagnostic Interview; Skuse et al., 2004), which assesses the presence of autistic symptoms. Control children were volunteers and had no history of mental and neurological disorders. All the participants were tested with WISC-III (Wechsler Intelligence Scale for Children, Third edition). There were no significant differences between the clinical and control group in chronological age, full scale IQ, verbal IQ and performance IQ (Table 1).

Table 1. Participant characteristics

	Group	
	Children with autism	Typically developing children
N	17	20
Sex ratio	13 boys, 4 girls	16 boys, 4 girls
<b>CA (years)</b>		
Mean (SD)	11; 9 (2;1)	11;1 (2;1)
Range	8;0- 15;1	8;5- 15;1
<b>Full IQ</b>		
Mean (SD)	98 (13)	101 (15)
Range	72-118	75-127
<b>Verbal IQ</b>		
Mean (SD)	103 (20)	104 (19)
Range	69-145	71-137
<b>Performance IQ</b>		
Mean (SD)	93 (15)	99 (14)
Range	71-119	66-122

CA: chronological age, IQ: intelligence quotient

## Stimuli

Two women modelled for the facial stimuli. The direction of the gaze was either direct, averted (left and right) or the eyes were closed. In every condition the face bore a neutral expression and the model tried to avoid blinking. In the averted gaze condition the gaze was directed 30° to the left or right. A vase was used as a control stimulus. The control stimulus was 30 cm high. The stimuli were presented through a voltage sensitive liquid crystal shutter (LC-TEC Displays AB) (30 cm width x 40 cm height) which was attached on a white panel between the participant and the model (Figure 1). The shutter could be changed between opaque and transparent state within millisecond range. The participant sat in a chair 70 cm away from the shutter and the model sat in a chair 40 cm away from the shutter. Thereby the distance between the participant and the model was 110 cm. The control stimulus was located at the same height as the facial stimulus.



*Figure 1.* Participant and the model behind the voltage sensitive liquid crystal shutter.

## Design and procedure

The experiment consisted of two different blocks of stimuli. One block contained the facial stimuli and the other block contained the control stimuli. In the block of facial stimuli, 18 trials were presented. Each three conditions (direct gaze, averted gaze and eyes closed) were presented six times in random order. The model for the facial stimuli was the same through the whole experiment. Six trials of the control stimulus were presented in the second block. In total the participant saw 24 trials in the experiment. Each trial lasted 5 seconds and the inter-stimulus-interval (ISI) varied from 20 to 35 seconds. During the ISI the voltage sensitive liquid crystal shutter was opaque. The

presentation of the stimuli was controlled with NeuroScan Stim software which was controlled by PC. The experimenter initiated every trial by pressing a button in a remote control. In this way the experimenter was able to stop the experiment in any time without the experiment to fail. Before each trial the experimenter said "Let's look at the following!" This was done in order to ensure that the participant directed his or her attention towards the shutter and that the model could be prepared for the opening of the shutter. After each facial stimulus the experimenter asked from the participant whether the model gazed straight, sideways or whether the eyes were closed. The question was asked in order to ensure that the participant was looking at the facial stimuli and that he or she distinguished the different stimulus conditions. During the control stimulus block, the participants just viewed the stimuli.

First the model settled herself at the same height with the participant. During the experiment the experimenter sat behind the participant so that she was able to make observations of the participant's possible movements and also of the possible movements and blinks of the model. The eye movements of ten autistic children and seventeen normal children were recorded and saved by using a video camcorder. The recordings were used to compare whether the time the children viewed the stimuli differed between children with autism and typically developing children. A half of the children with autism as well as typically developing children took part first in the facial stimulus presentation followed by the control stimulus presentation, whereas a half of the children with autism and typically developing children executed the experiment in reversed order.

Before the experiment, the laboratory was introduced to the participants with cartoon pictures and together with their parent they signed a written consent. The participants were told that the experiment would measure the electric field of the brain while the participants would be performing a task in which they would view the face of the model behind the window. After that two nurses prepared the participants to the EEG data acquisition. Also skin conductance response (SCR) and electrocardiogram (ECG) were measured in addition to electroencephalogram (EEG) but they are not reported here. Before starting the experiment some background information was asked from the participants, like date of birth and handedness. Before each phase, the events of the experiment were gone through with cartoon pictures with the participants. The participants were asked to avoid large-scale movements during the experiment and to view the stimuli when presented. The experiment started with a 4-minute baseline recording of resting EEG. During that 4-minute period the participant was asked in turns to close his or her eyes or to keep the eyes open for 30 second at a time. After that the participant viewed the facial stimulus presentation and the control stimulus presentation. Before each section, the instructions were told to the participants and an example was

given from that section by opening the shutter. There were no breaks between the sections. After the experiment, the electrodes were removed and a break was kept.

After the break the participants evaluated how pleasant or uncomfortable they felt while seeing the different stimulus conditions and how calm or agitated they felt during each stimulus condition with 9-point self evaluation form (Self-Assessment Manikin, SAM) (Bradley & Lang, 1999). The participants were given four pieces of paper on which they were supposed to evaluate different stimulus conditions (direct gaze, averted gaze, eyes closed and control stimuli). In total, the experiment lasted about an hour for one participant.

### **EEG data acquisition**

Continuous EEG was recorded from the left and right frontopolar (Fp1, Fp2), midfrontal (F3, F4), lateral frontal (F7, F8), central (C3, C4) and parietal (P3, P4) sites. EEG signals were referenced to linked ears. Skin was gently abraded and electrode paste was used in order to reduce the electrode impedances below 5 k $\Omega$ . Eye movements were recorded in order to remove artifacts from the EEG. Vertical eye movements were recorded with the electrodes placed below and above of the participants left eye. Horizontal eye movements were recorded with electrode pairs placed at the external canthi of each eye. The EEG signal was amplified with SynAmps amplifiers with a gain of 5000 and a 1-200 Hz band-pass filter (50-Hz notch filter enabled). The continuous signal was digitized at 1000 Hz and stored on a computer disk for off-line analyses.

### **Data analysis**

The continuous EEG was corrected for blink artefact using a regression-based blink reduction algorithm (Semlitsch, Anderer, Schuster, & Presslich, 1986). Other visible artefacts were eliminated by visual inspection. Every artefact-free 5-second stimulus period was segmented into eight 1.024-ms epochs with 50% overlap between adjacent epochs. For each epoch a spectral power was calculated using Fast Fourier Transform (FFT) with a 10% Hanning taper. The power spectra obtained were averaged over all artefact-free epochs within each trial and over separate trials within each condition. The trials that had less than 50% artefact-free epochs were excluded from the data analysis. For average power spectra within each condition, power density values ( $\mu\text{V}^2$ ) within the alpha band (8-13 Hz) were calculated and natural ln-transformed to normalize the distribution. Asymmetry scores were calculated by subtracting the ln-transformed power density values for the

left site from the right site for each electrode pairs at frontal (ln F8-ln F7, ln F4-ln F3), central (ln C4-ln C3), and parietal (ln P4-ln P3) scalp regions (Allen, Coan, & Nazarian, 2004). The analyses concentrated on electrode pairs F4- F3 and F8- F7.

Clinical neurophysician analysed the baseline EEG data from all the participants and according to the analysis the children who exhibited abnormal EEG were excluded from the data analysis. At the same time the alertness of the participant was analysed and trials where the alertness was low were also excluded from the data analysis.

The gazing behaviour during stimulus presentation was coded with Queen's video coder –program (Baron et al., 2001). Each stimulus trial was rated frame by frame (0 = not looking at the stimulus, 1 = looking toward the stimulus). 30 % of the videos were rated by two independent researchers in order to calculate interrater reliability.

The statistical analyses were conducted with analysis of variance (ANOVA). For the analysis of variance, the degrees of freedom were corrected with Greenhouse-Geisser correction when necessary.

## RESULTS

The results of the hemispheric asymmetry scores are presented in Table 2. Hemispheric asymmetry scores were analyzed with a two way split-plot design ANOVA having group (children with autism vs. typically developing children) and condition (direct gaze vs. averted gaze vs. eyes closed vs. control stimulus) as factors. For the electrode pair F4/F3 the ANOVA did not show a significant main effect for condition  $F(3, 102) = 0.76, p > .05$  or group  $F(1, 34) = 0.570, p > .05$ , nor a significant interaction between the group and condition  $F(3, 102) = 0.13, p > .05$ . No significant differences were either found for electrode pair F8/F7. All stimulus conditions elicited left-sided frontal activation.



*Table 2.* Mean frontal EEG asymmetry scores for different stimulus conditions in children with autism and typically developing children. Positive values indicate left-sided activation and negative values indicate right-sided activation. The values express the difference in the EEG alpha power between pairs of electrodes F4/F3 (ln F4- ln F3).

Stimulus	Group		Total
	Children with autism	Typically developing children	
Direct gaze	0,091	0,132	0,111
Averted gaze	0,086	0,143	0,115
Eyes closed	0,111	0,128	0,119
Control stimulus	0,088	0,121	0,105

Subjective ratings of arousal and valence were analyzed with a two way split-plot design ANOVA (Group x Condition) (Figure 2). For the valence ratings the ANOVA showed that the main effect of condition was statistically significant,  $F(3, 80) = 4.427$ ,  $p < .05$ . The group had no significant main effect  $F(1, 33) = 0.436$ ,  $p > .05$ , and no significant interaction between the group and condition,  $F(2, 80) = 0.666$ ,  $p > .05$ , was found. Further analysis (averaged across groups) showed that the valence ratings were significantly higher for eyes closed condition ( $M = 7.3$ ) than for direct gaze condition ( $M = 6.2$ ,  $p < .05$ ). The averted gaze condition ( $M = 6.7$ ) and the control stimulus condition ( $M = 7.2$ ) did not differ from the eyes closed condition or from any other conditions in the valence ratings.

For the arousal ratings the ANOVA revealed a statistically significant main effect of condition,  $F(2, 78) = 6.410$ ,  $p < .05$  (GG corrected). There was no significant main effect of group  $F(1, 33) = 0.053$ ,  $p > .05$ , nor a significant interaction between the group and condition,  $F(2, 78) = 0.609$ ,  $p > .05$ . Pairwise comparisons showed that arousal ratings were significantly higher for direct gaze ( $M = 2.6$ ) than for averted gaze ( $M = 2.1$ ,  $p < .05$ ), or eyes closed ( $M = 1.7$ ,  $p < .05$ ) condition. The control stimulus condition ( $M = 2.0$ ) did not differ from the other stimulus conditions and the averted gaze and eyes closed conditions did not differ from each other

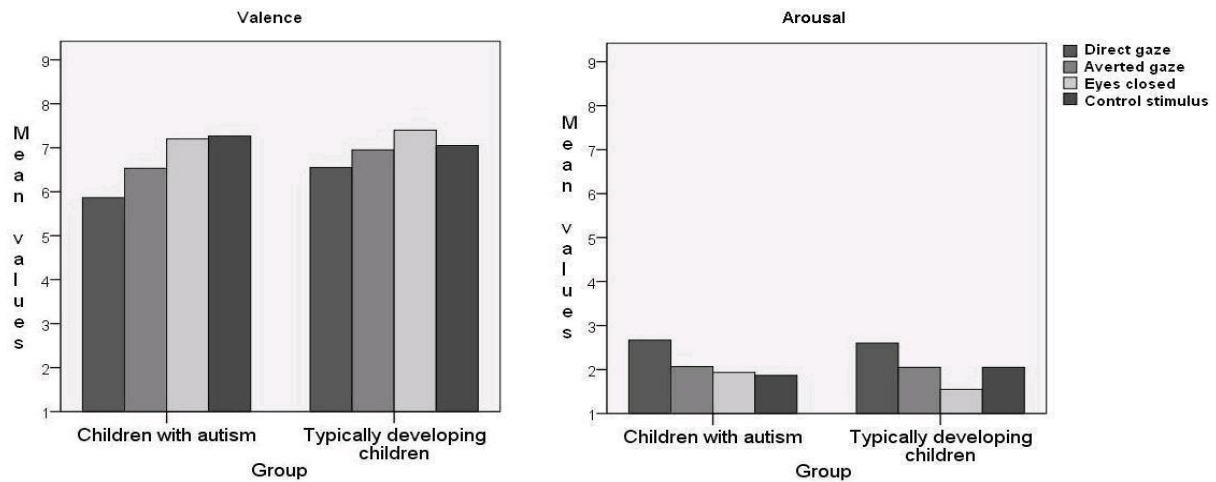


Figure 2. Mean SAM-scores of valence and arousal for each stimulus condition in children with autism and typically developing individuals.

Note. Valence: 1 = very unpleasant, 9 = very pleasant. Arousal: 1 = Very calm, 9 = very arouse

The results of the time spent on looking at different stimuli were analysed with a two way split-plot design ANOVA (Group x Condition). The ANOVA did not show a significant main effect for condition  $F(3, 42) = 0.417, p > .05$  or group  $F(1, 14) = 0.804, p > .05$ , nor a significant interaction between the group and condition  $F(3, 42) = 0.643, p > .05$ . The mean values of the looking times are presented in Table 3. The interrater reliability was analysed with bivariate correlations. The correlations revealed a significant correlation between the ratings of the two independent researchers,  $r = .956, p < .05$ . The correlations varied from .812 to 1.000 among participants.

Table 3. The mean values of the looking times to different stimuli in children with autism and typically developing children. Each stimulus appeared for 5 seconds at a time.

Stimulus	Group		Total
	Children with autism	Typically developing children	
Direct gaze	4,451	4,718	4,585
Averted gaze	4,465	4,667	4,566
Eye closed	4,603	4,760	4,681
Control stimulus	4,634	4,608	4,621

## DISCUSSION

In the present study we investigated whether seeing another person's direct and averted gaze would elicit differential asymmetric activation in the frontal areas in children with autism and in typically developing children. Participants viewed different face stimuli through a liquid crystal shutter at the same time as we measured EEG activity from frontal channels (F4/F3 and F8/F7). Participants also evaluated their subjective arousal and valence to different stimulus presentations. In addition, the gazing behaviour during stimulus presentation was recorded.

Based on studies conducted with adults (Hietanen et al., 2008) we expected that left-sided frontal asymmetry would be obtained to direct gaze and right-sided frontal asymmetry would be obtained to averted gaze in typically developing children. In children with autism we expected reduced left-sided or even right-sided frontal asymmetry to direct gaze and reduced right-sided or even left-sided frontal asymmetry to averted gaze. Contrary to our expectations the asymmetry scores did not differentiate between different stimulus conditions or between the two groups of children. In all four stimulus conditions (direct gaze, averted gaze, eyes closed and control stimulus) we measured left-sided frontal asymmetry which is supposed to reflect the activation of the neural systems associated with motivational tendencies of approach. The left-sided activation was perceived both in typically developing children and in children with autism.

Furthermore, we assumed that the subjective ratings of emotional valence and arousal would differ between stimulus conditions and between children with autism and typically developing children. We expected that the direct gaze would be experienced as more arousing and less pleasant than other stimulus conditions and that the difference would be more robust in children with autism. In valence ratings, direct gaze was evaluated as less pleasant than eyes closed. In arousal ratings the participants evaluated the direct gaze condition as more arousing than the conditions averted gaze or eyes closed. The results showed that the subjective ratings of arousal and valence did not differentiate the direct gaze from the control stimulus. There were no differences between the ratings of arousal and valence in children with autism and typically developing children. The results from the arousal ratings are consistent with studies that have measured skin conductance responses (SCR) to another person's gaze and found that direct gaze produced stronger response than averted gaze (Hietanen et al., 2008; Nicholas & Champness, 1971). EEG arousal has also been found to be

higher for direct than averted gaze (Gale et al., 1975). In situations with profound eye contact heart rate has also been found to increase (Kleinke & Pohlen, 1971). Because the subjective ratings of arousal were performed after the physiological recordings, this study also showed that like adults (Hietanen et al., 2008), children with autism and typically developing children are capable of forming a memory trace of the level of arousal during stimulus presentation. The memory trace of the arousal was also precise enough to differentiate between different stimulus conditions. It should also be noted that the ratings of emotional valence for direct gaze were still closer to pleasant than unpleasant. Hence, it cannot be concluded from the results that the direct gaze elicited negative emotions.

No hypotheses were formed beforehand concerning the gazing behaviour of children with autism and typically developing children due to contradictions in previous research. The gazing behaviour during stimulus presentations did not differ between children with autism and typically developing children. They spent the same amount of time on looking at the different stimuli. This is consistent with other studies that have found that the gazing behaviour between autistic individuals and typically developing individuals does not differ (van der Geest et al., 2002; Willemsen-Swinkels et al., 1998). All the participants answered correctly to the experimenter's questions concerning where the stimulus person was gazing. Consistent with other studies high functioning children with autism were able to make overt eye-gaze direction discriminations (Kylliäinen & Hietanen, 2004; Leekam et al., 1997). In the present study children were given alternatives of the direction of gaze. Therefore, it is possible that deficits are found in more complex tasks where individuals with autism have to use the information gathered from the eyes (Pelphrey et al., 2005).

One possible reason for why the differences in frontal asymmetry to direct and averted gaze were found in the study of Hietanen et al. (2008), but not in this study, may be the differences in the experimental design as compared to Hietanen et al. (2008). In both studies the stimulus was shown through a voltage sensitive shutter and it appeared for 5 seconds at a time. However, in the study of Hietanen et al. (2008) the participants just passively viewed the different stimuli without interacting with the experimenter, whereas in this study the experimenter said: "Let's look at the following!" before initiating every trial, and after each stimulus presentation the experimenter asked whether the model gazed straight, sideways or whether the eyes were closed. This was done in order to make sure that the participants' attention was directed to the shutter at the time of the stimulus presentation and that he or she distinguished the different stimulus conditions. Perhaps this interaction with the experimenter produced the feeling of being observed by the experimenter and

this feeling was stronger than the feeling of being observed by the face stimuli model. Contingently, in the present study the participants felt like being observed by the experimenter.

Differential asymmetric frontal activation to direct and averted gaze has so far been found only in adults (Hietanen et al., 2008). It is possible that the gaze direction does not elicit differential asymmetric activation related to motivational tendencies of approach and avoidance in children. Participants' age ranged from 8 years to 16 years, whereas in the study of Hietanen et al. (2008) the age of the participants ranged from 20 to 40 years.

The eye movements of the participants were recorded using a video recorder, so it is impossible to say whether the participants actually looked at the eye region of the model or whether the gaze was fixated for example to the forehead, nose or mouth. Thus, it is possible that the children only glanced toward the eye region of the model in order to answer the question of the experimenter and this lack of actually looking toward the eye region influenced the results. This could have influenced the results especially in children with autism because they have been found to look less at the eye region than typically developing individuals (Hutt & Ounsted, 1966; Klin et al., 2002; Neumann et al., 2006; Pelphrey et al., 2002).

Even though the participants were viewing a person sitting opposite to them, the experimental setting was still slightly artificial and not corresponding to usual social situation and interaction. For example the duration of continuous gaze was 5 seconds and during that time the participants did not have any interaction with the stimulus person. One of the participants even burst into laughter when seeing the stimulus face with a direct gaze. Furthermore, 5 seconds is a long time to be silent in normal social interaction and the only interaction during stimulus presentation was with the experimenter.

One might speculate that the stimuli used in the study did not evoke sufficient emotional or motivational tendencies. However, this is unlikely because the stimuli used in the study were actual persons sitting opposite to the child. The model was sitting only about a meter away from the participant and the model was gazing the child at the same height as the child was seated. Thus, the model gazed straight to the child's eyes.

Several studies have shown that there are abnormalities in the EEG characteristics of autistic individuals (Chan, Sze, & Cheung, 2007; Harrison, Demaree, Shenal & Everhart, 1998). Chan et al.

(2007) found that autistic individuals exhibit higher relative delta and lower relative alpha when compared to typically developing individuals. Dawson et al. (1995) found that children with autism exhibited reduced EEG power in frontal and temporal regions and that these differences were more robust for the left hemisphere. As described in methods, the baseline EEG data was analysed from all the participants in the study so EEG abnormalities of children with autism could not have influenced the results.

On the grounds of the study, the results cannot be generalized to all children with autism spectrum disorder, because the children with autism who participated in the study were high-functioning children. It may also be that children with autism react heterogeneously to eye contact based on their impairments in social interaction. Hence, it is possible that children with more profound deficits in social interaction would experience eye contact aversive and children with autism who have only mild or moderate problems in social interaction do not experience eye contact aversive or otherwise differently as compared to typically developing children. Sutton and colleagues (2005) have shown that there are differences in the asymmetric EEG activation of children with autism and that this asymmetric activation correlates with the severity of social impairments.

In the future, it would be interesting to re-execute the study by dividing the children with autism into different groups based on their degree of difficulty in social interaction. Therefore the groups of children with autism would be more homogeneous and perhaps these differences in frontal asymmetry to direct and averted gaze would be obtained. Children with different ages should also be studied to find out whether the differences in frontal asymmetry are found in other age groups. According to Donovan and Leavitt (1980) when measuring physiological responses to gazing behaviour the sex of the stimulus figure and the sex of the participants should be considered. Hereby, in future studies models of both sexes should be used and the effect of the familiarity of the model should also be studied

In conclusion, the present study did not find support for the association between perception of gaze direction and frontal hemispheric asymmetry in reflecting motivational tendencies related to approach and avoidance in children with autism and in typically developing children. According to the study it seems that autistic children may not experience eye contact differently as compared to typically developing children, but more research is needed of the influence of age to these phenomena. Even though no differences in frontal asymmetry to direct and averted gaze were found in this study, it is interesting to speculate whether it is due to methodological reasons or whether

gaze direction does not activate the mechanism responsible for motivational tendencies in children. In future studies the experiment should be executed without the need of interaction between the participants and the experimenter. The eye movements of the participants should also be accurately recorded for example with the eye movement camera in order to find out whether the behaviour between autistic children and typically developing children differs during stimulus presentation.

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