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Skin Conductance Responses to Another Person's Gaze in Children with Autism

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The effects of another person's gaze on physiological arousal were investigated by measuring skin conductance responses (SCR). Twelve able children with autism and 12 control children were shown face stimuli with straight gaze (eye contact) or averted gaze on a computer monitor. In children with autism, the responses to straight gaze were stronger than responses to averted gaze, whereas there was no difference in the responses to these gaze conditions in normally developing children. Thus, these results showed that eye gaze elicited differential pattern of SCR in normally developing children and in children with autism. It is possible that the enhanced arousal to eye contact may contribute to the abnormal gaze behaviour frequently reported in the context of autism.

KEY WORDS: High functioning autism; skin conductance responses; electrodermal activity; eye contact; gaze direction.

Eye contact is a powerful stimulus in social interaction. People are very accurate at discriminating whether another person is looking straight at them or whether the gaze is averted, especially when the other person's face is seen from straight ahead (Anstis, Mayhew, & Morley, 1969; Cline, 1967; Gibson & Pick, 1963; Masame, 1990; Wade & Jones, 1982; Vecera & Johnson, 1995). Gaze direction also serves many other important social functions: it provides information about attentiveness to communication, regulates interaction, facilitates communicational goals, and expresses intimacy and social control (Argyle, 1975; Kleinke, 1986). From early infancy, gaze behaviour has a special role in social development. Infants are known to preferentially fixate face-like stimuli (for a review, see Maurer, 1985), they prefer faces with eyes open (Batki, Baron-Cohen, Wheelwright, Connelan, & Ahluwalia, 2000) and especially faces with straight gaze (Caron, Caron, Roberts, & Brooks, 1997; Farroni, Csibra, Simion, & Johnson, 2002; Hains & Muir, 1996).

The significance of gaze behaviour in social development becomes evident in the case of developmental disorders such as autism, which is characterised by serious disturbances in communication and social interaction. Abnormalities in eye contact in autism have been reported since Kanner's (1943) original definition of the syndrome and it is still one of the diagnostic criteria for autism spectrum disorders (DSM-IV; APA 1994). In empirical studies of gaze behaviour in autism, research has concentrated on (i) possible lack of eye contact and (ii) on presumable deficits in the use of gaze to control social interaction. In studies concentrating on the amount of eye contact, the results have shown that individuals with autism *spontaneously* direct their own gaze to other people less than normally developing individuals (Hutt & Ounsted, 1966; Kasari, Sigman, & Yirmiya, 1993; Osterling & Dawson, 1994;

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Pederson, Livoir-Petersen, & Schelde, 1989; Phillips, Baron-Cohen, & Rutter, 1992; Tantam, Holmes, & Cordess, 1993; Volkmar & Mayes, 1990). Studies investigating the use of gaze in social interaction have, in turn, shown deficits in timing and quality of gaze behaviour (Baron-Cohen, Baldwin, & Crowson, 1997; Buitelaar, van Engeland, De Kogel, De Vries, & van Hooff, 1991; Mirenda, Donellan, & Yoder, 1983; Swettenham *et al.*, 1998; Willemsen- Swinkles, Buitelaar, Weijnen, & van Engeland, 1998).

It has been suggested that these abnormalities in gaze behaviour may arise because of a variety of reasons. For example, individuals with autism do not understand the mental significance of the eyes; they show impairments in recognising other people's complex mental states and intentions from the eyes (Baron-Cohen, Campbell, Karmiloff-Smith, Grant, & Walker, 1995; Baron-Cohen, Wheelwright, & Jolliffe, 1997). Studies measuring eye-movements during looking at facial images have shown that individuals with autism scan the mouth region more than the eye region of the face, a pattern of results which is opposite to that observed in normally developing individuals (Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Pelphrey *et al.*, 2002). Also, unlike normally developing children, children with autism rely in their face (identity) recognition more on the mouth region than on the eye region (Joseph & Tanaka, 2003). These findings have been explained by assuming that the perceptual bias to the mouth region observed in autism may reflect a strategy to improve the understanding of verbal information in social interaction (Klin *et al.*, 2002; Joseph & Tanaka, 2003). Recently, it has also been suggested that deficits in the neural mechanisms dedicated to the processing of another person's straight gaze (eye contact) might participate in the disturbances in development of social behaviour (Senju, Yaguchi, Tojo, & Hasegawa, 2003). It has been shown that both children (Senju *et al.*, 2003) and adults (Howard *et al.*, 2000) with autism have difficulties in recognising gaze stimuli with an eye contact among serially presented averted-gaze stimuli. That the deficit is specifically related to the processing of eye contact is supported by the findings that individuals with autism can make overt discriminations of where other people are looking (Baron-Cohen *et al.*, 1995; Kylliäinen & Hietanen, 2004; Leekam, Baron-Cohen, Perrett, Milders, & Brown, 1997; Tan & Harris, 1991) and that seeing of another person's averted gaze direction triggers an automatic shift of visual attention comparably in the clinical and control groups (Chawarska, Klin, & Volkmar, 2003; Kylliäinen & Hietanen, 2004; Senju, Tojo, Dairoku, & Hasegawa, 2004; Swettenham, Condie, Campbell, Milne, & Coleman, 2003).

In the present study, we were interested in investigating the effect of another person's direct gaze on children with autism. In the past, it has been suggested that the avoidance of gaze in autism reflects an unusual degree of arousal elicited by eye contact (Hutt & Ounsted, 1966; Tinbergen, 1974). As an important element in social interaction gaze, indeed, affects physiological arousal (Kleinke, 1986). There are studies showing that, in healthy adult subjects, EEG arousal (decreased alpha activity) is higher to eye contact than to averted gaze (Gale, Spratt, Chapman, & Smallbone, 1975). Also, in some studies, heart rate has been found to be higher in an eye contact condition compared to a condition without eye contact (Kleinke & Pohlen, 1971), and eye contact has been shown to elicit greater skin conductance responses than unreciprocated gaze (McBride, King, & James, 1965; Nicholas & Champness, 1971). However, there are also studies showing no difference in physiological arousal between eye contact and unreciprocated gaze. For example, Leavitt and Donovan (1979) reported that pictures of gazing and non-gazing infants presented on a television monitor did not result in differential skin conductance responses in observing mothers. Also in another study by Donovan and Leavitt (1980), there were only marginal differences in skin conductance responses between straight gaze and averted head (without eye contact) conditions. In the present study, we investigated the effects of *gaze direction* on skin conductance responses in normally developing children and in children with autism. Despite the early suggestions of increased arousal to eye contact in autism (Hutt & Ounsted, 1966; Tinbergen, 1974), physiological arousal to straight and averted gaze in autism has not actually been measured.

Skin conductance response (SCR) refers to momentary changes in the electrical resistance of the skin reflecting the functioning of the sweat glands controlled by the sympathetic nervous system (Andreassi, 2000, pp. 193–196). Skin conductance responsiveness has been interpreted to be a sensitive method for collecting physiological data on the stimulus significance, novelty, and its' emotional content to the subject, and it is generally believed to be a reliable accompaniment of psychological processes such as attention and orienting reflex (Dawson, Schell, & Filion, 1990). Skin conductance (phasic) responses to sensory stimuli in children with autism have been mostly studied using auditory stimuli (van Engeland, 1984; Palkovitz & Wiesenfeld, 1980; Stevens & Gruzelier, 1984) and more rarely using both auditory and visual stimuli (Barry & James 1988; van Engeland, Roelofts, Verbaten, & Slangen, 1991; James & Barry, 1984). Studies with auditory stimuli have produced somewhat conflicting results. In van Engeland's (1984) study, children with autism were split into two subgroups: high and low general arousal. The children in the high general arousal subgroup had higher mean amplitude in skin conductance responses than normally developing children. In the studies by Barry and James (1988, see also James & Barry, 1984), the mean SCR to auditory stimuli was found to be higher in the group of children with autism than in the group of normally developing children. On the other hand, other studies have found no difference in responsiveness to auditory stimuli between children with autism and normally developing children (Palkovitz & Wiesenfeld, 1980; Stevens & Gruzelier, 1984) nor between children with autism and mentally retarded children (Stevens & Gruzelier, 1984). The mental age of the children had no effect on these results. In studies using visual stimuli (simple geometric figures), there has been some evidence showing that high functioning children with autism are hyporesponsive (van Engeland *et al.*, 1991), whereas mildly or moderately retarded children with autism are hyperresponsive to visual stimuli as compared to normally developing children (Barry & James 1988; James & Barry, 1984).

Only a few electrodermal studies have used socially meaningful stimuli. Palkovitz and Wiesenfeld (1980) used a spoken sentence as a stimulus and failed to differentiate between the children with autism and control children. However, the authors argued that their stimulus sentence ("listen to me") was more commonly used with the children with autism than with control children and, therefore the significance of the stimulus might not have been comparable in both groups. Blair (1999) had three socially meaningful visual stimulus categories in his study; distressing (e.g., a crying face), threatening (e.g., a pointed gun), and neutral (e.g., a book) images. When the responses were averaged across all the stimulus categories, the children with autism did not differ in their responsiveness from the normally developing children or from the children with moderate learning difficulty. However, in a further analysis, it was found that only in the group of children with autism did the children have greater skin conductance responses to distress cues than to neutral stimuli, while there was no difference between responses to the threatening and neutral stimuli. Hirstein, Iversen, and Ramachandran (2001) studied relatively low-functioning children with autism and found that there was no difference in SCR between looking at their mother's face and looking at a paper cup. In a control group consisting of both children and adults, there were stronger SCRs to a face that to a cup.

In most of the previous studies, the general experimental procedure was quite simple. In studies using auditory stimuli, SCR was measured while the children heard sounds of different amplitude and frequency without any task, i.e., without a demand to respond in a certain way to different kinds of stimuli. In fact, the children were asked to ignore the tones they were hearing (van Engeland, 1984; Palkovitz & Wiesenfeld, 1980; Stevens & Gruzelier, 1984). In the studies using visual stimuli, children were usually asked to pay attention to the stimuli by either just encouraging to maintain their attention on the screen (Barry & James 1988; Blair, 1999; Hirstein *et al.*, 2001; James & Barry, 1984), by asking to fixate on the target stimulus, or by requiring the children to count the number of a certain type of stimuli (van Engeland *et al.*, 1991).

In the present study, skin conductance responses of high functioning children with autism and normally developing children were measured to face stimuli with straight gaze (eye contact) or averted gaze shown on a computer monitor. After the stimulus presentation, the children were asked whether the person looked straight at the child or whether the person's gaze was averted. Hence, in this study, the children were especially asked to pay attention to the stimuli. It was expected that if eye contact with another person is associated with an unusual degree of arousal in autism, perceiving another person with a straight gaze would elicit relatively stronger skin conductance responses in comparison to an averted gaze in children with autism than in normally developing children.

METHODS

Participants

Twelve school-aged children with autism took part in this study. All these children were clinically diagnosed to have an autism spectrum disorder. Additionally, the parents were administered the

Autism Diagnostic Interview -Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994) and all the children met ADI algorithm criteria for autism. Table I shows the scores of the clinical group on the three domains of the ADI-R, communication domain (cutoff score for diagnosis of autism is 8), social domain (cutoff score 10), and stereotypy domain (cutoff score 3). Normal gender- and mental-age-matched control children were volunteers and had no history of mental or neurological disorders. The groups were individually matched for mental age (WISC-R). There were no significant differences between the clinical and control groups in chronological age, mental age, and performance IQ, but the normal controls had a higher verbal IQ, $t(22) = 3.35$, $p \leq .003$, and full scale IQ, $t(22) = 2.79$, $p \leq .01$, than the clinical group (see Table I). The children were the same as in our previous study investigating reflexive gaze-cued attention orienting (Kylliäinen & Hietanen, 2004).

Table I. Subject Characteristics

	Group	
	Clinical	Control
N (sex)	12 (11M, 1F)	12 (11M, 1F)
CA (years; months)		
Mean (*SD*)	9;11 (1;10)	8;11 (2;10)
Range	7;4–14;1	6;1–16;0
MA(years; months)		
Mean (*SD*)	9;3 (2;11)	9;5 (2;10)
Range	6;8–16;0	6;6–16;0
Full IQ		
Mean (*SD*)	91 (17)	106 (7)
Range	67–122	101–124
Verbal IQ		
Mean (*SD*)	90 (19)	109 (8)
Range	69–124	94–123
Performance IQ		
Mean (*SD*)	95 (16)	102 (7)
Range	67–117	95–118
ADI-R Communication Domain		
Mean (*SD*)	14.1 (3.1)	
Range	8–18	
Social Domain		
Mean (*SD*)	18.7 (4.5)	
Range	11–24	
Stereotypy Domain		
Mean (*SD*)	7.3 (2.5)	
Range	3–12	

M: male; F: female; CA: chronological age; MA: mental age; IQ: intelligence quotient; ADI-R: Autism Diagnostic Interview-Revised.

Stimuli

Frontal views of a female and a male face with a neutral expression were filmed with a video camera. The models were asked to maintain straight gaze or gaze averted to the left or right. By using the zoom of the camera, an impression was created in which the faces appeared to be looming towards the subject (see Fig. 1). Moving images, particularly those which are known to be arousing, are associated with an increase in the magnitude of skin conductance responses, and they improve the viewer's attention to stimuli (Detenber, Simons, & Bennett, 1998; Simons, Detenber, Roedema, & Reiss, 1999). As measured from the computer monitor, the inter-ocular distance of the stimulus face subtended 5° and 13° in the first and last frames of the film clip, respectively. The film clips had duration of 6 s. The facial stimuli were presented on a 20-inch computer monitor (1024×768, 75 Hz, Apple Multiple Scan Display).

Physiological Measurements

The electrodes were coated with electrode gel and attached to the palmar surface of the medial phalanxes of the index and middle fingers on the children's left hand, which had been cleaned with an antiseptic liquid. Power Lab 400 equipment was used to measure the skin conductance. Data collection was controlled by Power Lab Chart v3.6 computer programme running on a Power Macintosh 7100/80 computer. The sampling rate was 100/s.

Design and Procedure

Children sat in a comfortable chair in front of a monitor at a distance of 70 cm. The cubicle was isolated with portable walls. The experimental procedure was carefully explained to the child with the aid of cartoon pictures showing the sequence of different events during the task. The children were asked to fixate in the middle of the screen and they were asked not to talk and to stay as still as possible.

In total, 12 face stimuli were presented in a random order, 6 faces with a straight gaze and 6 faces with an averted gaze. Half of the faces were female and the other half male. The inter-stimulus-interval (ISI) was 25–35 s. After the presentation of each face (during the ISI), the children were asked whether the person they had just seen had a straight or an averted gaze direction. This confirmed that the children had to look at the face on the monitor. The children's eye movements were also monitored using a

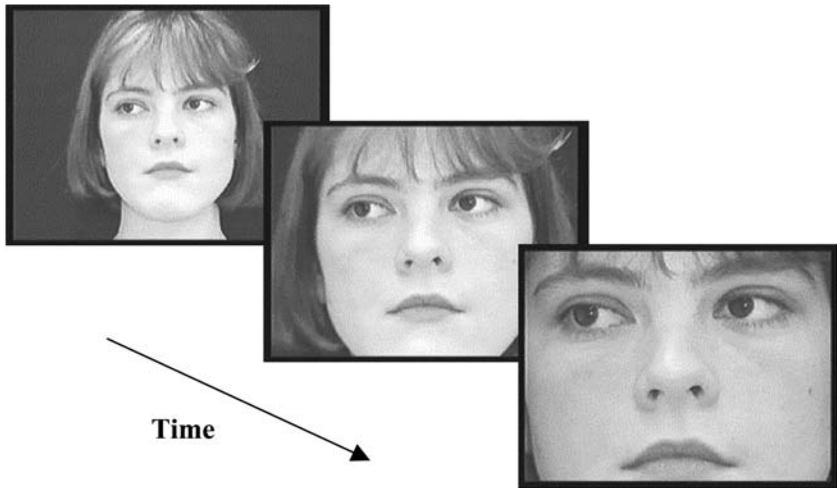

Fig. 1. By showing three separate pictures the figure illustrates the impression of a looming face which was created by using the zoom of the camera. The film clips had a duration of 6 s. Published with consent.

video-camera above the computer monitor. The children were rewarded with a token after the task completion. The experimental procedure lasted around 15–20 min.

Data Analysis

The experimental design included one within-subject variable: gaze direction (straight or averted) and one between-subject variable: group (clinical or control). The SCR was defined as the maximum amplitude change from baseline (defined at the stimulus onset) during a 5-s time window starting after 1 s from the stimulus onset till the end of the stimulus presentation. Responses contaminated by children's body movements or technical problems with the measurement were eliminated from subsequent analysis. Also, trials in which the child did not concentrate on the computer screen during the stimulus presentation were rejected. This evaluation was done by using the video tapes of the monitoring of the child's eyes. Because of all these reasons, 21% of trials were eliminated. There was no significant difference between the clinical subjects (24%) and controls (18%) in the mean percentages of the eliminated trials (Mann–Whitney, $U=55$, n.s.). After this, the mean value of SCR was computed across all stimulus presentations in the category including those without a measurable response as a zero response. This method of calculation results in the *magnitude* of the galvanic skin conductance responses; a measure that combines response size and response frequency (cf., Dawson *et al*., 1990). There was no significant difference between the clinical and control group in the number of non-response trials (Mann–Whitney, $U=59$, n.s.).

RESULTS

Regarding the behavioural data, there was no difference between the clinical subjects (97%) and controls (99%) in the mean percentages of correct responses to gaze direction (straight or averted) (Mann–Whitney, $U=65$, n.s.). For physiological data, the normality of the distribution was tested and it showed that the data were not normally distributed (Kolmogorov–Smirnov, $D(48)=.140$, $p=.02$). Square root and logarithmic transformations, which are commonly used with positively skewed distributions (e.g., Clark-Carter, 1997), did not remove the skewness of the distribution. Thus, all further analyses were performed using non-parametric tests.

Figure 2 shows the mean skin conductance responses as a function of gaze direction and group. The overall mean (averaged across straight and averted gaze conditions) of the skin conductance responses in the clinical group (mean = .29 μMho, $SD=.17$) was weaker than the mean responses in the control group (mean = .51 μMho, $SD=.37$). However, this difference was not statistically significant (Mann–Whitney, $U=48$, $p=.17$). The effect of gaze direction was tested separately in the clinical and control groups. Wilcoxon's signed ranks tests showed that the effect of gaze direction was significant in the

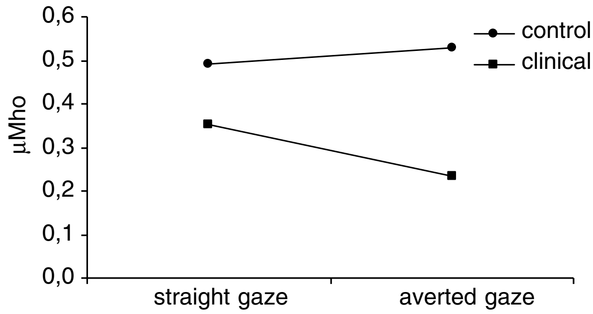

Fig. 2. Mean skin conductance responses as a function of gaze direction and group.

group of autistic subjects, $T = 11$, $p = .028$; the responses were stronger to straight gaze (mean = .35- μMho, $SD = .22$) than to averted gaze (mean = .24- μMho, $SD = .14$). However, in the control group, there was no difference in the responses between straight gaze (mean = .49 μMho, $SD = .41$) and averted gaze (mean = .53 μMho, $SD = .32$) conditions, $T = 31$, $p = .86$.

In order to analyse whether the skin conductance responses were affected by the children's intelligence, correlations between SCRs and verbal, performance, and full scale IQs were performed. There was no significant correlation between SCRs and any of the intelligence measures either in the clinical group or in the control group.

DISCUSSION

Skin conductance responses (SCR) to another person's gaze direction (straight and averted gaze) were measured in children with autism and in normally developing children. First, the present results showed that, although the overall SCR level seemed to be lower in the group of children with autism than in the control group, the difference was not statistically significant. This finding is in line with Blair's (1999) study in which the children with autism were only marginally ($p = .062$) hyporesponsive to meaningful visual stimulus categories (i.e., to neutral as well as to distressing and threatening stimuli) as compared to normally developing children. Secondly, and more importantly, in normally developing children, there was no difference in SCR between straight gaze (eye contact) and averted gaze conditions, whereas in children with autism the responses to straight gaze were stronger than those to averted gaze. In the following, we will separately discuss the findings related to the SCR to gaze direction in the normally developing children and in children with autism.

The results of this study revealed that there was no significant difference in SCR between eye contact and averted gaze in the normally developing children. In some previous studies with healthy adults, eye contact produced greater electrodermal activity than unreciprocated gaze (McBride, King, & James, 1965; Nicholas & Champness, 1971). In other studies, however, such a difference has not been found (Donovan & Leavitt, 1980; Leavitt & Donovan, 1979). In the early study by Nicholas and Champness (1971) with reasonable control of the stimulus conditions, the procedure, however, differed in two important ways from the present procedure. First, in the study by Nicholas and Champness, the stimulus person was actually sitting in the front of the subject, whereas in the current study computerised stimuli were used. Second, Nicholas and Champness collected data for alternating 10-s periods when the eye contact was held and when the eye contact was released. A period of released eye contact is not entirely comparable with the condition of averted gaze in the present study. This possible explanation for the differences between the results of the earlier studies and the present one is also supported by other previous studies. In their study with adults, Donovan and Leavitt (1980) found only a marginal difference in SCR between eye contact and averted head conditions and, in another study, they (Leavitt & Donovan, 1979) found no difference in SCR of mothers who were shown gazing and non-gazing infants. The data were collected, in both studies, during presentations of static computerised images separated by 25–45-ms long inter-stimulus-intervals.

As expected the pattern of SCR results was different in the children with autism than in normally developing children. In children with autism, the SCR was stronger to straight than to averted gaze suggesting, thus, that, in these children, a stronger level of arousal may be triggered by eye contact than by averted gaze. It has long been argued, without actually measuring physiological responses to gaze direction, that individuals with autism avoid eye contact with others in order to reduce their physiological arousal (Hutt & Ounsted, 1966; Tinbergen, 1974). Thus, the present data seem to fit with this suggestion. Recent studies using accurate measurements of eye movements have also provided evidence for that individuals with autism tend to look more at the mouth than eye region of the face, whereas the eye region is more commonly the focus of fixation in the normal face scanning (Klin *et al.*, 2002; Pelphrey *et al.*, 2002). Because, in the present study, the children were asked to answer to the question of where the person on the screen was looking at, they had to look at the eye region of the stimulus faces. This fact together with the special feature of the stimulus presentation (looming faces) might have contributed to the finding of stronger physiological responses to straight gaze (eye contact) than averted gaze in children with autism.

The higher arousal to eye contact than averted gaze in autism may reflect the interpretation of another person's direct gaze as a hostile signal or a signal expressing intimacy at a level which is experienced uncomfortable. In early infancy, the eye contact with a primary caregiver is very important in establishing affection bond between the child and a caregiver. This early gaze behaviour is not only for regulating social interaction but is thought to be also one of the precursors for later social development (Jaffe, Stern, & Perry, 1973). Thus, if the enhanced physiological arousal to eye contact is reflecting the fact that eye contact is experienced as uncomfortable in individuals with autism it is not surprising that eye contact is avoided. Followingly, this may contribute to the development of disturbances in social behaviour from very early on.

So far, the present results have been interpreted in light of giving support to our hypothesis that straight gaze elicits stronger SCR than averted gaze in children with autism in comparison to normally developing children. However, one could also argue our results showing that averted gaze elicited unusual low level of physiological arousal in the children with autism. In fact, further analyses of the results showed no significant difference in SCR in the straight gaze condition between the groups (Mann–Whitney, $U = 62$, n.s.), whereas a significant difference was found in SCR between the groups in the averted gaze condition (Mann–Whitney, $U = 36$, $p = .039$). The comparison between the groups is, however, very problematic. Although, in the present study, the overall SCR level was not statistically significant between the clinical and control groups, high functioning children with autism have been shown to exhibit generally lower responses to visual stimuli as compared to normally developing children (van Engeland *et al.*, 1991). Therefore, one should be cautious in interpreting between-group differences. In order to answer to the question of whether the differential SRC to straight and averted gaze in children with autism reflected enhanced responses to eye contact or attenuated responses to gaze aversion, our design would have necessitated a control stimulus. However, the choice of an appropriate control stimulus is not that straightforward. The experimental and control stimuli should be identical with respect to all stimulus features except that under investigation, i.e., the direction of gaze in this case (cf., Jonides & Mack, 1984, p. 31). Thus, one possible control stimulus to be used in a present type of a study would be a face with eyes closed. If the results of an experiment including such a control stimulus showed that (a) the SCRs to straight, averted, and closed eyes are indistinguishable in the group of control children, and (b) that, in the group of children with autism, SCRs to the control stimulus are at the level of responses either to straight gaze or averted gaze (or between them), it would be relatively straightforward to answer to the question of whether straight gaze produced enhanced responses or whether averted gaze produced attenuated responses (or both). However, if such an experiment showed a different pattern of results, it would lead to reasoning of whether a face with closed eyes was, after all, an appropriate control stimulus.

For the present time, regardless of the line of interpretation, the present results *did* show that eye gaze elicited differential pattern of SCR in normally developing children and in children with autism. It is obvious that the question of enhanced physiological arousal to eye contact (cf., Hutt & Ounsted, 1966; Tinbergen, 1974) in autism must be revisited by other studies using well-controlled experimental design and measurements. Meanwhile, the present study can be regarded as an opening on this interesting line of research.

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