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Looking at Images with Human Figures: Comparison Between Autistic and Normal Children

J. N. van der Geest,[1,2,4] C. Kemner,[2] G. Camfferman,[3] M. N. Verbaten,[3] and H. van Engeland[2]

Based on clinical observations of abnormal gaze behavior of autistic children, it has been suggested that autistic children have a problem in processing social information. Several studies on eye movements have indeed found indications that children with autism show particularly abnormal gaze behavior in relation to social stimuli. However, the methodology used in such investigations did not allow for precise gaze analysis. In the present study, the looking behavior of autistic children toward cartoon-like scenes that included a human figure was measured quantitatively using an infrared eye-tracking device. Fixation behavior of autistic children was similar to that of their age- and IQ-matched normal peers. These results do not support the notion that autistic children have a specific problem in processing socially loaded visual stimuli. Also, there is no indication for an abnormality in gaze behavior in relation to neutral objects. It is suggested that the often-reported abnormal use of gaze in everyday life is not related to the nature of the visual stimuli but that other factors, like social interaction, may play a decisive role.

KEY WORDS: Autism; gaze behavior; eye movements; social information processing.

INTRODUCTION

Autism is a rare, but severe, developmental disorder. One of the more striking symptoms of the autistic syndrome is the marked social impairment of autistic individuals. This impairment is often developed at a very young age and continues into adulthood (Baranek, 1999). Numerous studies have reported abnormal looking behavior of autistic children toward social stimuli, such as faces. For instance, it has been observed that autistic children look less frequently toward the face of others (Hutt & Ounsted, 1966; Rutter & Schopler, 1987; Volkmar & Mayes, 1990). However, Sigman, Mundy, Sherman, & Ungerer (1986) and Willemsen-Swinkels, Buitelaar, Weijnen, & van Engeland (1998) found that autistic children look at faces as much as do normal children but showed abnormal timing of their gaze behavior. The incongruence in results might be related to the methodology that was used. In the aforementioned studies, looking behavior was measured by scoring videotapes, a method that does not allow for precise analysis of eye movements and looking behavior.

Several studies have been conducted on the question of whether abnormalities in looking behavior of autistic individuals are the result of a general problem in visual processing, affecting eye movements to all kinds of stimuli. In a study in which the looking behavior

[1] Department of Physiology, Erasmus University Rotterdam, Rotterdam, the Netherlands.
[2] Department of Child and Adolescent Psychiatry, Utrecht Medical Center, Utrecht, the Netherlands.
[3] Department of Psychopharmacology, Utrecht Institute for Pharmaceutical Sciences (UIPS), University of Utrecht, Utrecht, the Netherlands.
[4] Correspondence should be addressed to J. N. van der Geest, Department of Physiology, Erasmus University Rotterdam, PO Box 1738, 3000 DR Rotterdam, the Netherlands; e-mail: vandergeest@fys.fgg.eur.nl

to both social and neutral stimuli was studied, evidence was found that children with autism are particularly impaired in their ability to orient to social stimuli (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998). Also, in a study by Swettenham, Baron-Cohen, Charman, Cox, Baird, Drew, Rees, & Wheelwright (1998) in which the spontaneous looking behavior of young autistic children of age 20 months was observed during play sessions, it was found that autistic children spent less time looking at people than did control children and more time looking at objects. Furthermore, they observed that these young autistic children shifted their gaze less between objects than did normal children. Therefore, there are indications that the abnormalities in gaze behavior in autistic individuals are indeed related to the social content of the stimuli. Again, the methods used in these studies did not allow for the precise measurement of looking behavior. In the present study, the fixation behavior of autistic individuals to social stimuli was studied by means of an infrared eye tracker, allowing a reliable, quantitative measurement of the looking behavior of autistic children. Such real-time eye movement recordings, with a relatively high spatial and temporal resolution, are a valuable source of information on the way the brain processes the visual environment. In normal situations, a presented visual stimulus will elicit a pattern of consecutive points of regard, called *fixations*, which are directed toward parts of the stimulus. This pattern, called a *scanpath* (after Noton & Stark, 1971), consists of fixations with intermittent short-duration shifts, *saccades*, which rapidly change the position of the fixation to another location. Precise information about the parts of the stimulus viewed and about the properties of the scanpath, such as the direction of first fixation, the length of the scanpath, and the total number of fixations, can provide important insight into the way in which subject views and processes the visual environment. In other words, such recordings might reveal his or her looking strategies and interests. This technique has been used in assessing the eye movements of, for example, schizophrenics. Manor, Gordon, Williams, Rennie, Bahramali, Latimer, Barry, & Meares (1999) observed in persons with schizophrenia that some aspects of the pattern of eye movements toward faces differed from that of normal control subjects; for example, the total length of the total scanpath was much shorter in schizophrenic patients than in normal control subjects. The authors suggest that this "may reflect suboptimal processing of face stimuli, that may predispose these individuals to dysfunctional interpretation of facial communication cues" (Manor *et al.*, 1999).

In the present study, pictures containing neutral objects as well as a human figure were presented to normal and autistic children, and both the number of fixations and the fixation time were computed. The eye movement recordings of normal human adults viewing such a static picture reveal that normal subjects will fixate mostly on the people in the pictures and, specifically, on their faces. Furthermore, in most cases the first fixations will be directed to the figures in such pictures (see, e.g., Buswell, 1936; Yarbus, 1967).

The first question is whether autistic children look less than do their normal control peers at the information in the picture, reflecting a more general information-processing problem in autism (Minshew, Goldstein, & Siegel, 1997; Happe, & Frith, 2001; Happe, Briskman, & Frith, 2001). Such a problem will be reflected by overall shorter time spent looking at an image, an overall smaller number of fixations, an overall shorter scanpath length, or a combination.

The second question is whether autistic children do not show the normal preference for the human figure, indicating a specific problem related to social stimuli. Such a specific problem will be reflected by deviant looking times for the human figure and by deviant timing of the first fixation toward the human figure, which might be preceded by more fixations on other neutral objects in autistic children than in normal children.

METHODS

Subjects

Sixteen autistic children and 14 normal children participated in the experiment. The mean age of the autistic children was 10.6 years (*SD*, 2.1 years). The mean age of the normal children was 9.9 years (*SD*, 1.5 years). Total IQ scores were 92.8 (*SD*, 17.3) for the autistic children and 96.9 (*SD*, 9.9) for the normal control children as estimated by the full Wechsler Scale of Intelligence.

All diagnoses of pervasive developmental disorder (PDD) were based on the *DSM-IV* criteria and were made by a child psychiatrist (H. van E.) after extensive diagnostic evaluation, including a review of prior records (developmental history, child psychiatric and psychological observations and tests, and neurological investigations), a parent interview, and a child psychiatric observation.

Furthermore, 15 of the 16 autistic children who participated in this experiment were also examined with use of the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994). According to the rating algorithm of the ADI-R, 10 children met the full criteria for autism, 4 children fell 1 point short on the domain of Restricted/Repetitive Behaviors, and for 1 child, the age of onset of the abnormalities could not be firmly determined. All children scored well above the criteria for the domains of Social Interaction and Communication, so the children were diagnosed as having Autistic Disorder (AD, $n = 10$) or Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS, $n = 5$). In accordance with recently proposed diagnostic rules for PDD-NOS (Buitelaar & van der Gaag, 1998; Buitelaar, van der Gaag, Klin, & Volkmar, 1999), the children with PDD-NOS who were included in the present study met at least three of the diagnostic criteria for Autistic Disorder, including one of the criteria of the social interaction domain.

Clinically, all 16 autistic children exhibited the profound social disturbance characteristic of autism. Each subject participated in a series of experiments, of which the present experiment was one. All children had normal visual acuity, without glasses or contact lenses.

Apparatus

In this experiment, the subject sat upright in a dentist chair while his head was held steady using a vacuum cushion, which reduced head movements. Stimuli were displayed on a 21-inch computer screen that was positioned approximately 1 m in front of the eyes of the subject. The display size was 640×480 pixels.

Eye movements were recorded by means of the Iview Remote Eye Tracking device provided by SensoMotoric Instruments, with a sample rate of 50 Hz and an accuracy of less than 1 degree of visual angle, both horizontally and vertically. This device was positioned in front of the subject just below the monitor.

Stimulus Material

Each stimulus was a full-colored cartoon-like image with a human figure. Each image was one of the following scenes: a boat, a farm, a house, a town's square, and a forest. To avoid a possible left-right asymmetry in visual scanning, on each of these scenes there were five positions where a human figure could be located: top left corner, top right corner, bottom left corner, bottom right corner, and the center of the image. Each stimulus was a unique combination of scene and position, resulting in a total of 25 different stimuli. On each stimulus, several objects were present, such as cars, flowers, boxes, and so on. The type and number (7–9) of the objects differed across stimuli (see Fig. 1 for an example). Each image fitted the whole computer screen and, hence, had dimensions of 640×480 pixels.

Design

The order of stimuli was chosen randomly, with the restriction that two consecutive stimuli never depicted the same scene and that two consecutive stimuli never had the human figure in the same position. The stimuli were divided into two blocks. The first block contained 12 stimuli, and the second block contained the remaining 13 stimuli. Each subject received the same order of stimuli and, hence, the same order of blocks.

Procedure

The two blocks were separated by at least one other experiment that the subject had to perform. For each block of the present experiment, the following procedure was used. The subject was told that cartoon-like drawings would be presented and was instructed to carefully look at each image. Before actually beginning the experiment, the eye movements of the subject were calibrated using a nine-point calibration routine. This calibration was checked and recorded, and on successful completion of the calibration, the experiment was started. Before each stimulus, a small fixation cross was shown on the center of the screen for 2 seconds. After the disappearance of the fixation cross, each stimulus was displayed for 10 seconds. Then, the fixation cross was shown again.

Analysis

The raw data were analyzed for fixation points. A fixation point was extracted from the raw data if the mean deviance of five or more consecutive raw data points (i.e., 100 ms) was less than 1 degree of visual angle. For each of the 25 stimuli, regions were created around the human figure and around the 7 to 9 other items depicted in each scene (see Fig. 1). The number of fixations and the fixation-time for each region were calculated. Two types of objects were defined: the object "human figure" and the object "other."

The number of fixations for the object "human figure" was calculated as the average of number of fixations on the region around the human figure over all 25 stimuli. The number of fixations for the object "other item" was first calculated per stimulus as the total number of fixations to the regions around the other items divided by the number of other items defined

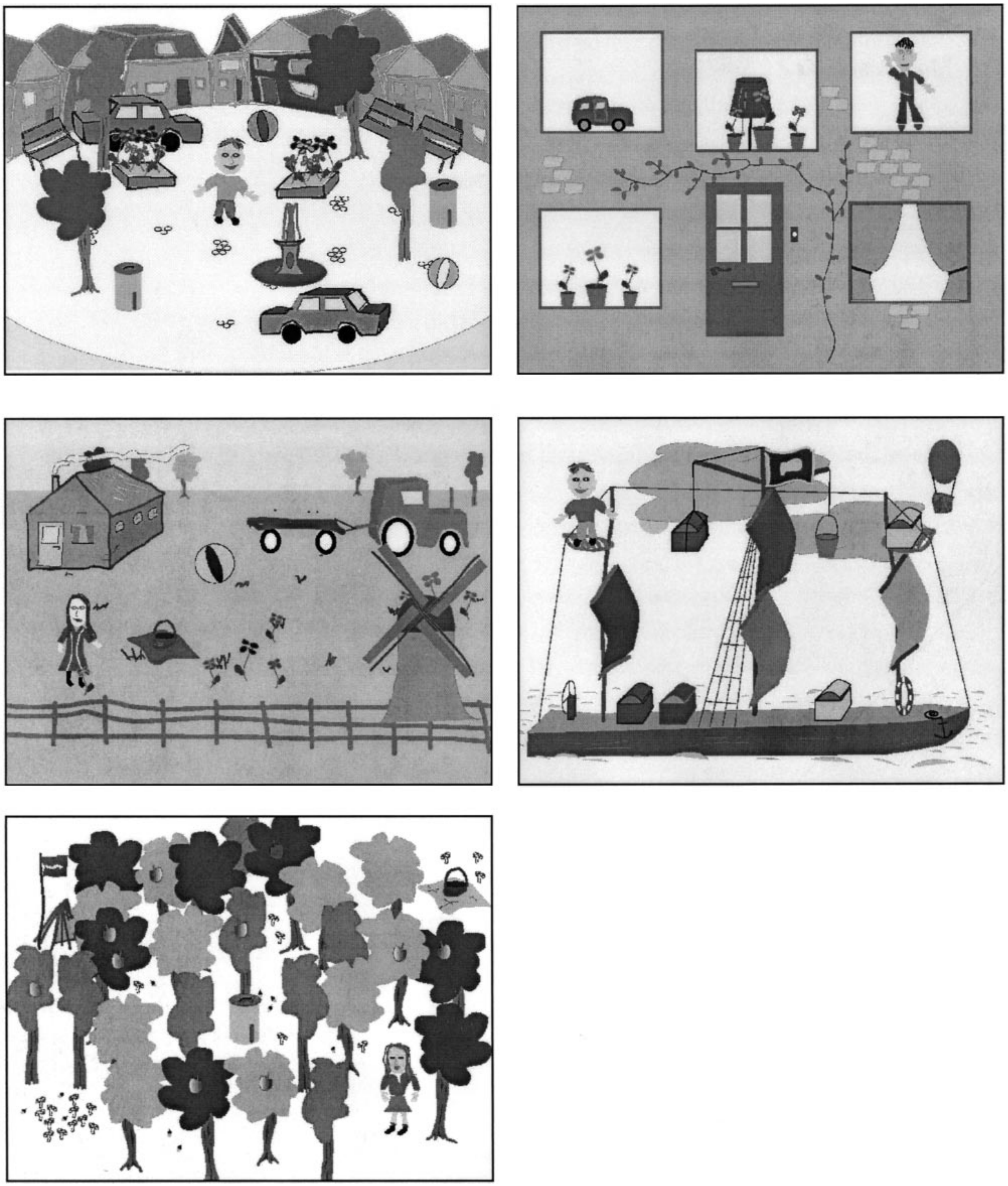

Fig. 1. Five images depicting all scenes used in the study.

in that stimulus. The average numbers of fixations for other objects in each stimulus were averaged over the 25 stimuli. The same calculation was made for the fixation times.[1]

Multivariate analyses were carried out for the fixation times and the number of fixations, with each containing two factors: "Group" with two levels (autistic vs. control children) and "Object" with two levels ("human figure" vs. "other item"). Furthermore, four parameters describing the looking strategy or scanpath were calculated. The first parameter was the latency between the onset of the stimulus and onset time of the first fixation toward the human figure. The second parameter was the fixation time of the first fixation directed toward the human figure. The third parameter was the total distance traveled by the eyes while viewing the picture (total scanpath length), and the fourth parameter was the average distance between two fixations (mean scanpath length). These four parameters were averaged over the 25 stimuli and compared between the autistic group and the control group.

RESULTS

The mean fixation time and the number of fixations for the two types of objects (the human figure and "neutral items") for the two groups (autistic and control children) are given in Table I.

With respect to the fixation times, the effect of "Group" and the interaction of "Group" × "Object" were not significant. The effect of "Object" was highly significant, indicating that the human figure was fixated longer than the other items [on average, 1882 vs. 1007 ms, respectively; $F(1, 28) = 40.3$, $p < .0001$].

With respect to the number of fixations, the effect of "Group" and the interaction of "Group" × "Object" were not significant. The effect of "Object" was highly significant, indicating that the human figure was fixated more often than the other items [on average, 3.2 vs. 2.2 times, respectively, $F(1, 28) = 38.4$, $p < .0001$].

With respect to the analysis of the looking strategy, the total number of fixations and total fixation time for the whole stimulus, the latency until the first fixation on the human figure and the length of this first fixation, and the total (TSL) and mean (MSL) scanpath lengths for the two groups (autistic and control children) are given in Table II.

The total number of fixations and the total fixation time for the whole stimulus, averaged over the 25 stimuli, did not significantly differ between the autistic and the control group [$t(28) = 1.11$ and $t(28) = 0.54$, respectively]. The latency for the human figure (i.e., time between onset of the stimulus and the first fixation on the human figure) and the fixation time of the first fixation on the human figure, averaged over the 25 stimuli, did not significantly differ between the autistic and the control children [$t(28) = 0.30$ and $t(28) = 0.46$, respectively]. The average distance traveled between two fixations (average scanpath length) and the total distance traveled between all fixations (total scanpath length) did not significantly differ between the two groups [$t(28) = 1.03$ and $t(28) = 1.36$, respectively].

Table I. Fixation Time and Number of Fixation Mean and *SD* Values[a]

		Human figure		Another item	
Group	*N*	NF	Time (sec)	NF	Time (sec)
Control	14	3.1 (0.6)	1.7 (0.4)	2.2 (0.2)	1.0 (0.2)
Autistic	16	3.4 (1.1)	2.0 (1.0)	2.3 (0.2)	1.0 (0.1)

[a] NF, number of fixations; Time, average fixation time.

DISCUSSION

The present study dealt with the looking behavior of autistic and normal control children toward images that contain neutral objects and a human figure. Looking behavior was studied by measuring fixations and scanpaths by means of an infrared corneal reflection technique. The results of the present study show that all children look longer and more often to the human figure than to the neutral objects, replicating the results from earlier studies (see, e.g., Buswell, 1936; Yarbus, 1967).

The first question was whether autistic children show a general looking problem, reflected in a different overall fixation time, a different amount of fixations, or different scanpath lengths. The results show that autistic children spent the same amount of time inspecting the pictures, have the same total number of fixations, and have similar average and total scanpath lengths. This suggests that autistic children put the same effort in inspecting the pictures as do normal controls and that they show no evidence of a general processing abnormality in this task.

[1] Note that this procedure may violate the assumption of equality of variances, but it is unlikely that this influenced the results obtained in the present study.

Table II. Results of the Scanpath Parameters, With Mean and *SD* Values[a]

Group	*N*	NF	FT (sec)	Latency (sec)	First FT (sec)	MSL (deg)	TSL (deg)
Control	14	21.0 (1.7)	9.4 (0.5)	0.62 (0.16)	1.3 (0.6)	6.5 (1.0)	136 (20)
Autistic	16	20.1 (2.6)	9.3 (0.8)	0.60 (0.18)	1.2 (0.6)	6.1 (0.9)	125 (22)

[a] *N,* number of subjects; NF, total number of fixations; FT, total fixation time; Latency; time from onset of stimulus until the first fixation on the human figure; First FT, length of the first fixation on the human figure; MSL, mean scanpath length; TSL, total scanpath length.

The second question was whether autistic children have a specific problem related to social stimuli, reflected in fixation parameters. The results show that the autistic children spend the same amount of time and the same number of fixations toward the human figure as do their normal peers. Also, the timing of the first fixation toward the human figure and the time spent during the first fixation on the human figure were the same for the two groups. Recently, in a functional magnetic resonance imaging study by Schultz, Gauthier, Klin, Fulbright, Anderson, Volkmar, Skudlarski, Lacadie, Cohen, & Gore (2000), it was shown that autistic persons show abnormal activation during face discrimination. The autistic activation pattern was interpreted as that autistic persons process faces in the same way as normal subjects process neutral objects. However, in the present study, no evidence was found for this suggestion, because autistic children showed the same preference for social objects (the human figure) over neutral objects as did the normal control children.

It has to be noted that the present study has some limitations. First, the advantages of the setup that was used, namely a highly controlled laboratory situation, can also pose a disadvantage, because it is not an ecologically valid environment. It might be that the observed abnormalities in gaze behavior in daily life are more related to the demands of social interaction, as suggested by Rutter (1978): "it is not so much the amount of eye-to-eye gaze (which may be abnormal) but rather the way eye-to-eye gaze is used." Also, the social validity of the full-color cartoon-like images might be questioned. However, both normal control and autistic subjects spent more time looking at the human figure than at any other object, indicating that this stimulus has a special (probably social) meaning. This finding is congruent with the looking behavior for photographs of social scenes (see, e.g., Yarbus, 1967).

The second limitation of the present study involves the characteristics of the autistic group in the present experiment. The autistic group consisted of high-functioning individuals, to prevent confounding of the results by mental retardation. At the same time, however, the high level of functioning puts limits on the generalizability to the whole autistic population, because many autistic individuals are also mentally retarded.

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