The Development of Visual Event-Related Potentials in Autism

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Based on earlier findings of abnormal P3 amplitudes in autism, it was hypothesized that these abnormalities may be related to abnormalities in attentional processes preceding this processing stage.

Methods: Eighteen autistic children of about 10 years of age and 14 healthy control children and 10 autistic adolescents and 13 controls of about 19 years of age, performed a visual selective attention task during which the electroencephalogram was measured. Subjects were required to respond with a button press whenever a designated target stimulus was presented. The resulting Event-related Potentials (ERPs) were compared on three attention related peaks (FSP, SN and N2b) and were entered in an overall analysis to test for other effects, not related to selective attention.

Results: It was found that young autistic patients showed smaller occipital P1 and much smaller posterior P3 amplitudes than their matched controls. Adolescent autistic subjects mainly showed larger N2b amplitudes than autistic children.

Conclusions: Early abnormalities in visual processing seem to be present in childhood autism and the most prominent effects found in this study are not related to selective attention. Furthermore, the electrophysiological abnormalities observed in childhood autism seem to differ from those seen at adolescence.
Autism is a severe pervasive developmental disorder, which is characterized by disturbances in social interaction, language and speech development and stereotyped behaviour. The autistic syndrome has been extensively studied in many fields of research. An important number of studies suggest a neurobiological basis for autism [Bailey et al. 1996]. It is thought that important deficits in autism are those in perception and cognitive processing of sensory information [Minshew 1996]. Neuroimaging methods like Positron Emission Tomography (PET), Single Photon Emitting Tomography (SPECT), functional Magnetic Resonance Imaging (fMRI) and Event-Related brain Potentials (ERPs) provide valuable insight in how this processing takes place in the brain. Despite their relatively low spatial resolution, ERPs have the advantage over the other methods of having a superior temporal resolution and of being a direct measure of neural activity. This allows for following the time course of information processing in great detail.

Many ERP studies in autism have focused on the P3, a large positive wave starting around 300 milliseconds after a stimulus is presented. Abnormal P3 responses have been found in both the visual [Ciesielski et al. 1990; Courchesne et al. 1989; Kemner et al. 1994; Verbaten et al. 1991] and auditory modalities [Ciesielski et al. 1990; Courchesne et al. 1984; Courchesne et al. 1985; Courchesne et al. 1989; Kemner et al. 1995]. Except for Kemner et al., (1994, 1995) and Verbaten et al. (1991), these studies were carried out in adults or adolescents.

P3 abnormalities could serve as an index for the abnormalities in later stages of cognitive processing of sensory information. However, other defects in processes on the sensory or attentional level preceding the P3 could be responsible for such a P3 abnormality. Courchesne [Courchesne 1987] argued that there might be an active process interfering with earlier stages of processing, attenuating a normal flow of sensory information to later stages of processing. These early stages of information processing can be studied using a selective attention paradigm.

In selective attention tasks, a subject typically has to attend to one of two channels of information. Within these channels, frequently presented (standard) stimuli and rarely presented (deviant) stimuli are present. The subject is required to respond only to deviant stimuli within the attended channel. Selective visual attention to specific stimulus features, like colour selection, is characterized by a number of typical peaks in the ERP, which are thought to be functionally distinct. In adults, four different attention related components are distinguished in the difference wave resulting from subtracting unattended from attended standard stimuli. First, a frontal positivity, known as the frontal selection positivity (FSP) with an onset between 140 and 160ms post-stimulus [Kemmans et al. 1993]. Second, an occipital selection negativity (SN) is observed [Hillyard and Anllo-Vento 1998; Smid et al. 1997] with an onset latency of around 150-200ms. Third, around 200-250ms a central-frontal N2b occurs [Wijers et al. 1996]. Finally, a P3 (or P3b) occurs which is maximal over the parietal scalp and has an onset latency of 300-700ms [Picton 1992].
In autism, one selective attention study in adult autistics has been reported [Ciesielski et al. 1990]. This study used a combined visual and auditory task, in which the subjects had to attend to the visual and ignore the auditory stimuli or vice versa. In the visual modality, no attention effects were found on the N270 (comparable to the N2b) in the autistic group, while they were present in the control group. The authors did a separate test on the N270 of the four best performing autistic subjects who had task performances comparable to those of controls, but this test yielded the same results. Thus, the absence of attention effects on the N270 in autistic subjects could not be explained by differences in task performance. However, the interpretation of these effects are problematic, since attended and unattended channels stem from different experimental blocks and the study followed a cross modal design.

In the present study, we tested for the presence of diagnosis related differences in FSP, N2b and SN in children and adolescents, using a visual selective attention task as described by Jonkman [Jonkman et al. 1997]. To our knowledge, the present study is the first to study the developmental course of differences pertaining to selective attention between control and autistic groups. Furthermore, a more elaborate statistical design was used to test for the presence of additional differences between controls and autistic subjects.

Method

Subjects: School age children

The total initial sample consisted of 19 controls and 25 autistic children. From the control group, four children were excluded because of poor task performance (>50% omissions in three cases and 67% false alarms for the unattended deviant in one case) and one because of poor EEG quality. From the autistic subjects, three were excluded because of poor task performance (50% omissions in two cases, one subject with 47% omissions), one child was excluded on the basis of a known medical condition, one because of unclear diagnosis and two children were unable to complete the EEG recording session. The final clinical and control groups consisted of 18 and 14 subjects, respectively. The controls were all boys; one girl was included in the clinical group. There was no significant age difference between groups, mean ages 10.96 (sd 1.86, range 8-14.5) and 10.44 (sd 1.11, range 9.2-12.2) years for the clinical and control groups, respectively. The clinical subjects were recruited from the Department of Child and Adolescent Psychiatry at the Utrecht Academic Hospital. Controls were recruited from elementary schools in and around Utrecht.

All subjects were administered the Wechsler Intelligence Scale for Children, revised Dutch edition (WISC-RN). For autistic subjects, all diagnoses were based upon DSM-IV criteria and were made by a child psychiatrist (HvE) after extensive diagnostic evaluation, including a review of prior records (developmental history, child psychiatric and psychological observations and tests and neurological investigations). Furthermore, all autistic subjects were administered the Autism Diagnostic Interview Revised (ADI-R) [Lord et al. 1994] by a trained rater. Five subjects did not meet all the ADI-R cutoff
criteria for autism, but they did however meet the criteria for PDD-NOS as indicated by the psychiatrist. All subjects were medication free and had no significant neurological history.

The study was approved by the medical ethical committee of the Academic Hospital and all parents or caretakers gave written informed consent prior to participation. Furthermore, the child’s assent was obtained and it was pointed out that participation in the experiment could be stopped at any time and for any reason by the child or the accompanying adult.

*Table 2-1: Mean IQ scores for autistic and control groups. Standard deviations in parentheses, range in italics.*

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Performance</th>
<th>Verbal</th>
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<tbody>
<tr>
<td><strong>young groups</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>control</td>
<td>98.2 (9.68); 81-116</td>
<td>103.2 (13.15); 73-120</td>
<td>93.3 (9.04); 81-114</td>
</tr>
<tr>
<td>autistic</td>
<td>97.2 (14.03); 62-119</td>
<td>100.6 (19.88); 59-133</td>
<td>95.5 (14.26); 68-118</td>
</tr>
<tr>
<td><strong>adolescent groups</strong></td>
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<td></td>
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<tr>
<td>control</td>
<td>109.5 (8.19); 96-120</td>
<td>115.7 (9.76); 94-126</td>
<td>103.6 (7.99); 89-114</td>
</tr>
<tr>
<td>autistic</td>
<td>96.9 (10.91); 80-112</td>
<td>100.7 (13.25); 78-118</td>
<td>95.1 (11.13); 77-107</td>
</tr>
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*Subjects: Adolescents*

Clinical subjects were recruited from a residential institution for autistic adolescents (the Dr. Leo Kanner house). Control subjects were recruited from a secondary school in Utrecht. The total initial sample consisted of 13 subjects in both clinical and control groups. From the autistic group, 3 subjects were excluded on the basis of poor task performance or because of technical problems. Thus, the final sample consisted of 10 autistic subjects and 13 controls. One female was included in the clinical group; the controls were all males. There were no significant differences in age between the groups; mean ages 19.0 (sd 3.37, range 15.2-24.5) and 18.2 (sd 0.74, range 17.2-19.6) years for clinical subjects and controls. All controls were administered the Wechsler Adult Intelligence Scale (WAIS), Dutch edition. For one autistic subject, the Wechsler Intelligence Scale revised Dutch edition (WISC-RN) was used. All autistic subjects were extensively diag-
nosed by psychiatrists at the Leo Kanner house. The ADI-R was administered to all subjects in the clinical group by a skilled rater and all subjects met the ADI-R criteria for autism. All subjects were extensively informed about the experimental procedures prior to participation. All subjects gave written informed consent. For subjects who were not of legal age, parents or caretakers were also asked to give written consent.

Although care was taken to match IQ scores between clinical and control groups, the autistic groups had significantly lower total and performance IQ than controls (TIQ; F(1,53)=4.28, p=0.043; PIQ; F(1,53)=4.54, p=0.038). The means suggest that the differences are especially large in the adolescent groups (see table 2-1). Post-hoc, analyses of IQ scores for each age group separately confirmed that the differences in total and performance IQ were significantly different in the adolescent groups (TIQ; F(1,21)=10.1, p=0.005; PIQ; (F(1,21)=9.79, p=0.005), but not in the young groups (all F<.26).

**EEG and EOG recordings**

Electroencephalic activity was recorded from 62 tin electrodes by means of an electrocap. Electrodes were placed on the scalp according to the 10% system of the American Electroencephalographic Society [1991]. An electrode attached to the left mastoid was used as reference. Horizontal EOG was recorded from tin electrodes attached to the outer canthus of each eye by means of adhesive rings. Vertical EOG was measured from infra- and supraorbitally placed electrodes at the left eye. A ground electrode was placed at the middle of the forehead. Impedances of the ground and reference electrodes were kept below 5 kOhms. All signals were amplified with a time constant of 10 seconds by a Sensorium EPA-5 amplifier (Sensorium inc., Charlotte, VT, USA). All signals were digitized on-line by a computer at a rate of 256 Hz and stored as a continuous signal. After sampling, signals were epoched off-line starting 100 ms before stimulus onset, and lasting for 1s. After epoching, all signals were filtered with a 30Hz, 24dB/octave digital low pass filter.

**Task**

The task consisted of 300 stimuli, 150 red and 150 yellow rectangles. The rectangles subtended a length of 4.5 degrees of arc and a width of 3.7 degrees of arc. They were presented for 50 ms each, with an inter-stimulus interval (ISI) randomized between 1750 and 2150 ms. Total task duration was about 10 minutes. During each recording session, three other tasks were presented, which will be discussed elsewhere. The order of presentation was balanced across subjects.

The stimulus attribute to define relevant and irrelevant channels was colour (i.e., yellow or red). Standards or deviant stimuli were defined by the orientation (to upper left \ or upper right //, respectively) of thin, black diagonal bars in the rectangles. Within each colour, 20% were deviant and 80% were standard stimuli. Which orientation was deviant or standard was balanced across subjects, as was the relevant colour. Stimuli were presented in the centre of the visual field on a computer monitor positioned approximately 70 cm from the subject’s eyes. The instruction was to press a button, which was
held in the preferred hand, as fast as possible to rectangles of one colour in which the orientation of the bars was deviant.

**Procedure**

A parent or caretaker always accompanied children who participated in the study. The autistic adolescents were in most cases accompanied by a supervisor. On arrival, they were familiarized with the procedure. After the electrocap and EOG electrodes were attached, a teeth mould was made which was used in the measurement of electrode positions after EEG recording (see below). The subject was then seated in a dentist’s chair in an acoustically shielded room. The chair was adjusted so that the subject’s head was approximately parallel to a computer monitor, positioned slightly above and in front of the subject. After attachment of the electrocap to the amplifiers and a check of the signals, the test session was started. Instructions for the visual task were given orally, and the subject had to perform a short practice series during which the experimenter gave feedback. When the experimenter was convinced that task requirements were met, the subject was instructed to move as little as possible during the task and to keep his eyes fixed on a fixation cross on the computer screen. The experimenter then left the room, closed the door and dimmed the lights. During the task, EEG was monitored on a computer screen. With children, in most cases the accompanying person was seated behind the child during recordings.

After the recording session was completed, the electrode positions were digitized by means of a Polhemus IsoTrak digitizer. When all experimental procedures were completed, children were rewarded with a toy, while adolescents were paid for their participation.

**Signal analysis**

EEG and EOG data were analysed off-line using the SCAN software package (Neuroscan Inc, El Paso TX, USA). All signals were baseline corrected on the basis of the 100ms pre stimulus interval. All epochs containing artifacts like saturation of the A/D converter, flat lines or amplitudes larger than +/-125 µV were removed. The EEG was corrected for EOG artifacts by subtracting vertical and horizontal EOG from EEG epochs by a regression method in the time domain [Kenemans et al. 1991].

ERPs were computed by averaging all remaining trials with correct performance for each subject in four stimulus categories (attended deviants, attended standards, unattended deviants and unattended standards) per lead. Thus, only attended deviants with hits and standards and unattended deviants with no response were included (see table 2-2). The resulting waveforms are shown in figure 2-1.

**Statistical analysis**

Repeated measures MANOVAs were performed for ERPs and task performance (proportions of omissions and false alarms and reaction times) separately. The significance level for all tests was set at p < 5%, two-tailed.
Table 2-2: Means and standard deviations (in parentheses) of behavioural measures for all groups. Upper row schoolaged groups, bottom row adolescents. The adolescent groups made no errors in the unattended channel. RT = Reaction Time (in milliseconds); FA = False Alarms (proportion); Att Std = Attended Standards; Unatt Dev = Unattended Deviants; Unatt Std = Unattended Standards.

<table>
<thead>
<tr>
<th></th>
<th>RT</th>
<th>Omissions</th>
<th>FA Att Std</th>
<th>FA Unatt Dev</th>
<th>FA Unatt Std</th>
</tr>
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<tbody>
<tr>
<td>Young groups</td>
<td></td>
<td></td>
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<tr>
<td>Autistic</td>
<td>752 (128)</td>
<td>0.10 (0.07)</td>
<td>0.07 (0.10)</td>
<td>0.004 (0.01)</td>
<td>0.004 (0.008)</td>
</tr>
<tr>
<td>Control</td>
<td>705 (148)</td>
<td>0.06 (0.07)</td>
<td>0.03 (0.05)</td>
<td>0.005 (0.01)</td>
<td>0.0006 (0.002)</td>
</tr>
<tr>
<td>Adolescent groups</td>
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</tr>
<tr>
<td>Autistic</td>
<td>571 (165)</td>
<td>0.02 (0.03)</td>
<td>0.02 (0.02)</td>
<td>- (-)</td>
<td>- (-)</td>
</tr>
<tr>
<td>Control</td>
<td>530 (77)</td>
<td>0.02 (0.03)</td>
<td>0.005 (0.007)</td>
<td>- (-)</td>
<td>- (-)</td>
</tr>
</tbody>
</table>

For FSP, N2b and SN, analyses were done on difference waves constructed by subtracting the ERPs to unattended standards from those to attended standards. These analyses included a factor Diagnosis (autistics vs. controls) and Age (school age vs. adolescent) as between-subjects factors. In the school age group, the time windows used for these tests were 175-275 ms for FSP, 250-450 ms for N2b and 150-200 ms for SN. In adolescents, the windows were adjusted to 150-250 ms for FSP, 200-350 ms for N2b and 150-300 ms for SN. Mean area amplitudes were scored in these windows. FSP was scored on electrode Fz, N2b was scored on Cz and SN on Oz. Since these comparisons are also a test of the efficacy of our manipulation of attention, attention effects are also reported when they do not interact with diagnosis. Difference waves representing FSP, N2b and SN are shown in figure 2-2.

From 50 to 350 ms the ERPs were divided in 12 segments of 25 ms in which the mean area amplitude was computed. In the 350-750 ms time range, four 100 ms segments were used. The mean amplitudes in these segments on electrodes Fz, Cz, Pz and Oz were entered in an overall analysis which was done for each time segment separately, with Diagnosis and Age as between-subjects factors and Channel (attended and unattended), Stimuli (standards and deviants) and Leads (Fz, Cz, Pz and Oz) as within-subjects factors. This analysis was included to test for any other differences between the groups present in the data. Since the effects of attention are already covered by the FSP, SN and N2b analyses, and to limit the number of tests, only interactions with diagnosis and age x diagnosis are now considered for further analysis. Also, from 50-350 ms, sub-
sequent tests were only done when two or more adjacent segments showed significant interactions. These measures were taken as protection against the increased probability of type I errors when performing multiple ANOVA.

**Results**

**Performance**

Three performance measures were obtained for each age group: percentage omissions, percentage false alarms and mean reaction time to hits. False alarms were divided into three categories; false alarms to attended standards, unattended deviants and attended standards. The young groups showed significantly longer reaction times ($F(1,53)=26.1$, $p=0.000$), more omissions ($F(1,53)=16.35; p=0.000$) and false alarms to the attended standard ($F(1,53)=5.96, p=0.018$) than the adolescent groups. Means and standard deviations per group for these measures are given in table 2-2. No effects of Diagnosis were found.

**FSP, N2b and SN**

All groups showed a significant FSP ($F(1,51)=13.39, p=0.001$) and N2b ($F(1,51)=28.35, p=0.000$), thus demonstrating the efficacy of our manipulation of selective attention. An Age x Diagnosis effect for N2b ($F(1,51)=4.97, p=0.03$) indicated that adolescent autistic subjects showed larger N2b amplitudes than young autistics ($F(1,26)=4.343, p=0.047$). The effect for SN was less straightforward: SN showed a main effect of Diagnosis ($F(1,51)=5.13, p=0.028$). Further analysis indicated that the autistic groups showed a significant SN ($t(27)=-3.449, p=0.002$), whereas controls did not.

**Overall analysis**

From 75-125 ms significant Leads x Age x Diagnosis interactions were found ($F(3, 49)=3.942, p=0.01; F(3, 49)=7.547, p=0.000$), the young autistic groups showed smaller P1 amplitudes than controls on electrode Oz ($F(1,30)=6.16, p=0.019; F=8.27, p=0.007$). In the segment from 100-125 ms, this group also showed smaller amplitudes on electrodes Fz ($F=5.74, p=0.023$) and Cz ($F=7.17, p=0.012$).

Next, from 225-650 ms the autistic groups as a whole showed smaller amplitudes on electrode Oz (all $F(1,53) > 7$, all $p<0.01$), as indicated by significant Leads x Diagnosis interactions (all $F(3,49) < 3.212$, all $p<0.031$). From 450-650 ms, smaller amplitudes in the autistic group were also noted on electrode Pz ($F=8.93, p=0.004; F=7.49, p=0.008$).

**Discussion**

**Attention effects**

In the present study a visual selective attention task was used in which subjects had to identify target stimuli based on a conjunction of colour and orientation of a superimposed grating. In adults, such a task usually elicits three different attention related peaks: A frontal selection positivity (FSP), a central selection negativity (N2b) and an occipital
selection negativity (SN). In the present study, significant main effects were found for FSP and N2b in both age groups, indicating a successful manipulation of attention. No overall significant SN was found. However, we did find an effect of Diagnosis on SN, which is discussed below.

**Group Comparison**

No group differences were found with respect to the FSP, but there were group differences in N2b and SN. Adolescent autistic subjects showed larger N2b amplitudes than young autistic subjects. A similar age difference was not observed in the control groups. Although little is known about the functional process associated with N2b, it has been suggested that it reflects a feature non-specific attention process which is similar for attention to colour, location or conjunctions [Lange et al. 1998]. N2b would reflect covert orienting of attention to stimuli classified as relevant by earlier attentional processes [Rugg et al. 1987].

At first sight, the difference in SN between controls and autistics seems quite remarkable, since controls do not show a significant SN whereas autistic subjects do. Figure 2-2 shows that the young controls group even shows a positivity in the SN time-range. However, the particular relevance of this finding is unclear. It could be that in autistic subjects this stage of information processing has matured more rapidly or differently, since SN is usually reliably found in older age groups only [van der Stelt et al. 1998]. However, it then remains puzzling that the adolescent control groups do not show SN. Another explanation might be that the presence of SN in autistic subjects, and the absence thereof in controls, reflects a different selection strategy in autism. In a recent functional Magnetic Resonance Imaging (fMRI) study [Ring et al. 1999] using the Embedded Figures Task, it was found that where normal control subjects showed elevated activation of prefrontal brain regions associated with working memory, autistic subjects showed more ventral occipitotemporal activation associated with object feature analysis. The authors concluded that in autism, a different cognitive strategy is used to solve the task. A final possible explanation for the absence of SN in controls could be latency jitter in these groups.

In the overall analysis, apart from two isolated effects on Fz and Cz, the most notable group effects were seen on the posterior Pz and Oz leads in the autistic groups. The young autistic group showed a smaller P1 amplitude on Oz (75-125ms), independent of attention or stimulus type (figure 2-2). No such difference was found in the adolescent groups. P1 is a sensory-evoked, exogenous component which originates bilaterally in extrastriate cortex [Ossenblok et al. 1994], most likely from the fusiform gyrus [Heinze et al. 1998]. From flash-visual evoked potentials (FVEPs), it is known that the developmental course of the P1 amplitude shows an U shape, with amplitudes decreasing from 4-16 years of age and again increasing from 60 years onward [Dustman et al. 1996]. It has been suggested that this increase of P1 amplitude in older age might be a consequence of a decrease in inhibitory interneurons in the visual cortex [Diaz and Amenedo
Figure 2-1: Event-related potentials for all stimulus types, diagnostic- and age groups at four midline leads. Att dev = Attended deviant; Att std = Attended standard; Unatt dev = Unattended deviant; Unatt std = Unattended standard.
Figure 2-2: Difference wave of attended minus unattended standards at the four midline leads for all groups.
1998; Man’kovskii et al. 1978]. Extending this suggestion to childhood, the smaller P1 amplitudes in autistic children could be an indication of larger numbers of interneurons in autism and/or a more developed inhibitory function. Larger numbers of neurons could be compatible with reports of larger brain size in autism [Piven et al. 1995] [Piven et al. 1996a; Woodhouse et al. 1996]. Interestingly, Courchesne et al. reported a study, which indicated that in autism brain size was larger in childhood only; at early adolescence the volumes were comparable to controls [Courchesne et al. 2001]. Since the origins of P1 in healthy subjects are known and since P1 is a rather focused and circumscribed peak, localization of its electrical sources will be very feasible. Hopefully, this will enable us to shed light on the question whether the P1 in autism originates from the same or different brain structures as in healthy subjects. It could be that the locations of the sources of P1 in autism are normal, but that the amplitudes are reduced as a result of poorer propagation of electrical signals due to different skull thickness, larger brain size or disordered neuronal organization. Electrical source localizations by means of realistic individual head models take some of these differences into account and may help to answer these questions.

A very striking result emerges when the P3 amplitude is considered (figure 2-1). The autistic groups, especially the young autistic subjects, show a marked reduction of P3 amplitude on electrodes Pz and Oz. [Ciesielski et al. 1990] and [Courchesne et al. 1989] also found reduced P3 amplitudes to visual stimuli (although smaller P3s were not reported in an earlier study [Courchesne et al. 1985]). However, these studies differed from the present study in terms of the task used. Also, none of these studies considered the Oz electrode in their analyses. This site proved to be the electrode with the most prominent abnormalities in the present study, as well as in the studies by [Kenemans et al. 1991] and [Kemner et al. 1995]. As can be seen in figure 2-1, the P3 amplitude reduction is much larger in the young autistic group than in the adolescents. On the other hand, autistic adolescents showed larger N2b amplitudes. It may be that this enlarged N2b reflects a compensatory process, normalizing the P3 abnormalities present from childhood. Since P3 amplitudes are most dramatically reduced in autistic children, paired with normal amplitudes of peaks related to selective attention in this group, we conclude that these reduced P3 amplitudes are not the result of abnormal selective attention.

To our knowledge, the present paper represents the first study concerning the development of visual selective attention in autism. Due to the use of ERPs, the flow of information could be followed with high temporal resolution. This high temporal resolution allowed the demonstration of abnormal information processing in childhood autism, first occurring around 100ms after stimulus onset. The finding of smaller occipital P3s in autism is consistent with the findings of Verbaten et al. (1991) and Kemner et al. (1995) with visual oddballs. To date, reports on visual ERPs in autistic adolescents have been less consistent [Novick et al. 1979; Courchesne et al., 1989, 1985; Ciesielski et al., 1990]. Our finding of clear P1 and P3 abnormalities in childhood autism and abnormal
N2b in autistic adolescents provides new and exciting insights in the pathophysiology of autism. In autistic children, abnormalities seem to originate before 100ms after stimulus processing, which underlines the value of the high temporal resolution of ERPs and indicates basic abnormalities in visual processing. These early abnormalities need to be corroborated by further research aimed at dissecting the circumstances in which these phenomena occur. One next step will be the accurate anatomical localization of the abnormal P1 by means of advanced source localization techniques. More definitive answers regarding the apparent dissociation between ERP amplitudes in childhood and adolescence can only be found in subsequent longitudinal studies.

Acknowledgements
We would like to thank Maretha de Jonge and Judith Timp for collecting the ADI-R data and Gert Camfferman and Marijke Kellaert for their skilful assistance. The research described in this paper was financially supported by the Janusz Korczak foundation.