The psychophysiology of selective attention and working memory in children with PPDNOS and/or ADHD
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Chapter 4

ERP correlates of selective attention and working memory capacities in children with ADHD and/or PDD-NOS

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Abstract

Objective: We examined whether children (8-11 years) diagnosed with Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) or Attention-Deficit/Hyperactivity Disorder (ADHD) showing primarily hyperactive behavior, differed in selective attention and working memory (WM) abilities.

Methods: Healthy controls and children with ADHD, PDD-NOS or symptoms of both disorders (PDD/HD) (n=15 in each group) carried out a visual selective memory search task while their EEG was recorded from which event-related potentials were derived.

Results: Compared to the control group, all patient groups made more omissions while hyperactive children also exhibited more false alarms. Regarding the process of WM-controlled search, significant group differences in ERP data were found between the control group and each of the clinical groups.

Conclusions: The results point to less efficient WM-functioning in all patient groups. Whereas the clinical groups differed from each other at the behavioral level as measured by questionnaires, no distinction between the clinical groups could be made with respect to performance or ERP measures of WM capacity and selective attention.

Significance: The results suggest that a possible differentiation in selectivity and working memory capacities between PDD-NOS and ADHD is hard to find. This may agree with clinical practice, where differential diagnosis is a subject of discussion.
Introduction

Children with Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) show autistic-like behavior in that they have difficulties interacting in a social environment. They have problems communicating adequately with others and may show stereotyped patterns in behavior, interests or activities. Yet, their behavioral deviations are not severe enough to fulfill the diagnostic criteria of autism (American Psychiatric Association, 2000). In social situations, their handicap emerges as a deficiency in understanding so-called ‘social cues’ and in understanding what another thinks or feels. Furthermore, they adhere to regularity and get easily upset when a sudden change occurs in their daily routine. Apparently, these children are less able than other children in handling new information coming up to them. It may therefore be speculated that their problems originate from a deficiency in their information processing system.

The main symptoms of Attention-Deficit/Hyperactivity Disorder (ADHD) are inattentiveness, hyperactivity and impulsive behavior. These children often show high distractibility when faced with competing stimuli. Although PDD-NOS and ADHD are described as clearly distinct syndromes in the DSM-IV-TR (American Psychiatric Association, 2000), in clinical practice, it often appears difficult to discriminate the two disorders (Clark et al., 1999; Jensen et al., 1997). In a relatively large number of children with ADHD, deviations in social behavior have been demonstrated as well (e.g. Clark et al., 1999; Santosh and Mijovic, 2004). However, the social problems these children exhibit may have different causes. In ADHD, inadequate social functioning is likely to arise from their impulsive behavior, acting before taking notice of another person’s thoughts and feelings (Lahey et al., 1987). In the present paper it was examined whether different information processing deficits may be at the basis of ADHD and PDD-NOS.

Lying at the core of information processing, selective attention and working memory (WM) play essential roles in how we process the information that surrounds us. Traditionally, selective attention refers to the ability of the processing system to select certain (relevant) information for further processing and to ignore irrelevant information. Working memory is considered as a system for temporary storage and manipulation of information necessary for complex cognitive tasks (Baddeley and Hitch, 1974). In the multi-component model of working memory that was proposed by
Baddeley and Hitch, temporary storage of information is provided by two subsystems, i.e. a phonological loop for verbal information and a visuo-spatial sketchpad for visual information. These systems are controlled by the central executive component of WM, which is assumed to be an attention-controlling system.

**Working memory and selective attention in PDD-NOS and ADHD**

Every day social situations are constantly subject to change and many events occur at the same time. This complexity requires high flexibility and the ability to process several types of information simultaneously. In other words, social situations appeal strongly to WM. Because of the impairments in social functioning that autistic children typically exhibit, a deficit in WM capacity in these children has been proposed (e.g. Bennetto et al., 1996). The evidence for this assumption is, however, not conclusive in that some studies demonstrated a WM impairment in children with disorders in the autistic spectrum (Althaus et al., 1996; Althaus et al., 1999; Bennetto et al., 1996; Minshew et al., 1999; Ozonoff et al., 1991) while other studies failed to find such an impairment (Geurts et al., 2004; Ozonoff and Strayer, 2001; Russell et al., 1996).

With regard to selective attention, children with autism have been reported not to differ from healthy controls in their ability to inhibit responses to (Ozonoff and Jensen, 1999), or ignore irrelevant stimuli (1996; Althaus et al., 1999; Pascualvaca et al., 1998). Instead, they often show an overfocus on certain stimuli being less able to process additional information (Burack, 1994; Lovaas et al., 1979; Lovaas and Schreibman, 1971).

Children with ADHD, on the other hand, are generally described to have difficulties ignoring irrelevant information being easily distracted by other stimuli. Therefore, a selective attention deficit may be presumed in these children. However, while several studies point to a increased distractibility in children with ADHD (Booth et al., 2005; Brodeur and Pond, 2001; Carter et al., 1995; Jonkman et al., 2004; Jonkman et al., 1997a; Karatekin and Asarnow, 1998; Klimkeit et al., 2005), a few studies failed to find such a deficit (Huang-Pollock et al., 2005; Taylor et al., 1997). With regard to WM, the literature is equivocal too in that some studies found no robust evidence for a WM deficit (e.g. Geurts et al., 2004; Pennington and Ozonoff, 1996) while other, meta-analytic, studies do suggest an impairment (Martinussen et al., 2005; Willcutt et al., 2005). Employing the model of Baddeley and Hitch (1974),
Karatekin and colleagues (Karatekin, 2004) distinguished between temporary storage in WM and the Central Executive of WM in children with ADHD. Whereas the short-term storage system seemed to be intact, the Central Executive of WM was suggested to be impaired.

Many studies that aimed at examining selective attention and WM in clinical samples have made use of neuropsychological tasks examining measures of accuracy. However, the outcome of these studies may merely reflect the product of multiple neurocognitive processes, which complicates drawing general conclusions from the findings. Studies using reaction time paradigms allow a more thorough examination of the various stages of information processing. In the present study, we employed such a paradigm in combination with the method of visual event-related potentials (ERPs) to examine processes of selective attention and WM. The high temporal resolution of ERPs enables us to study stages in information processing that take place before an overt response is made.

**Psychophysiological correlates of information processing: ERPs**

In adult studies, several visual ERP components have been related to different stages of information processing. In relation to memory storage, a positive going slow wave has been found (Ruchkin et al., 1990; Ruchkin et al., 1992) showing a larger positivity when memory load is increased (Weber et al., 2005).

The effect of selectively attending to a specific stimulus category has been investigated by comparing the responses to relevant (to-be-attended-to) stimuli with the responses to irrelevant (to-be-ignored) stimuli. The resulting difference potentials have been described as an early frontal selection positivity (FSP) and an early, occipitally maximal, selection negativity (SN) (both between 150 and 200 ms) as well as a more central N2b (between 250 and 300 ms) (Harter and Aine, 1984; Hillyard and Anllo-Vento, 1998; Smid et al., 1999; Wijers et al., 1989a; Wijers et al., 1996; Wijers et al., 1989b). In children, these components have been demonstrated too, although showing a somewhat later onset and a slightly different scalp distribution (Van der Stelt et al., 1998).

The ‘target P3’ or ‘P3b’ (300- 800 ms poststimulus) is a widely studied component and has been suggested to reflect the use of resources at a more central level of information processing that are involved with event categorization (for a
review see Kok, 2001). This component is characterized by a large occipito-parietal positivity to target stimuli as compared to nontarget stimuli (Hillyard and Picton, 1979). In healthy adults, the P3b amplitude is larger in response to attended stimuli whereas its amplitude decreases when higher demands are made on WM (Kok, 2001; Mulder et al., 1984; Wijers et al., 1996). A later onset than in adults and a more occipito-parietal distribution for this component has been demonstrated in 7- to 9-year-old children (Van der Stelt et al., 1998).

In response to the controlled process of serial search that is carried out in WM, a negative going long latency wave (300-600 ms poststimulus), reaching a maximum at Cz, has been found (Okita et al., 1985; Wijers et al., 1989b). This search-related negativity (SRN) has been found in adults only for attended stimuli and is enhanced in situations of higher memory load.

In a preliminary study (previous chapter), using the same paradigm as in the current experiment, we investigated how the effects of memory load and selective attention could be visualized on event-related potentials in a group of healthy control children (n=18). In this group, that included the 15 control children from the current study, most ERPs described above could be demonstrated to occur in response to the task manipulations (Gomarus et al., 2006).

Visual ERP studies in pervasive developmental disorder and in ADHD

ERP studies of early attentional processing in pervasive developmental disorder (PDD) are scarce. To our best knowledge, to date, one study on early attentional filtering has been carried out in which normal controls demonstrated an enhanced negativity in response to attended targets, while for the autistic subjects this negativity was not significant (Ciesielski et al., 1990). Another study of visuospatial attention found delayed electrophysiological responses in autistic persons reflecting reduced attention to stimuli in the peripheral visual fields (Townsend et al., 2001). The findings from this latter study, along with other findings, have led several authors to propose that autistic persons show a deficit in especially the orientation and/or shifting of attention (e.g. Belmonte and Yurgelun-Todd, 2003; Goldstein et al., 2001).

Most studies of visual ERPs in children with a pervasive developmental disorder concentrated on the P3. Results from these studies have been rather consistent in
that the vast majority demonstrated smaller P3 amplitudes in nonretarded subjects with autism spectrum disorders (Ciesielski et al., 1990; Ciesielski et al., 1995; Courchesne et al., 1989; Kemner et al., 1999; Verbaten et al., 1991). However, other results have been reported as well. Earlier studies using visual oddball paradigms showed no deviant P3 amplitude in individuals with autism (Courchesne et al., 1985) or larger P3 amplitudes in response to novels for autistic children (Kemner et al., 1994). Finally, in studying processing capacity, control subjects demonstrated smaller P3 amplitudes to visual probes in a hard as compared to an easy condition, while higher functioning children with autism spectrum disorders did not (Hoeksma et al., 2004). The absence of the effect of task load in the autistic group was interpreted as a deficiency in the allocation of processing capacity.

Concerning ADHD, a relatively small number of ERP studies has concentrated on visual selective attention. Some of these found a smaller FSP in ADHD as compared to normal controls, suggesting deficiencies in early attention processes (Jonkman et al., 2004; Satterfield et al., 1994; Van der Stelt et al., 2001), while no abnormalities were found for the N2b. For the P3, the findings were inconsistent, demonstrating no differences in amplitude, a smaller amplitude or a deviation in scalp distribution (Jonkman et al., 2004; Jonkman et al., 1997b; Satterfield et al., 1994; Van der Stelt et al., 2001). Studies using other attention paradigms (e.g. continuous performance, oddball and choice reaction time tasks (see for a review Barry et al., 2003), however, have supplied rather conclusive evidence for smaller visually evoked P3 amplitudes.

In sum, several studies found reduced FSP amplitudes in ADHD, which can be taken as suggesting a deficit in selective attention. In autism, only one study reported a reduced psychophysiological response to attended stimuli, while several authors propose a deficit in the orienting of attention. Furthermore, a majority of ERP studies have demonstrated diminished P3 amplitudes in both ADHD and pervasive developmental disorder. With respect to the SRN, no studies have been conducted in ADHD and PDD.

**The present study**

Although the behavioral characteristics of both disorders might suggest 1) a deficit in WM capacity to be characteristic of PDD-NOS and 2) a selective attention deficit to
be typical of ADHD, the literature is equivocal. In fact, like with behavioral problems, 
the studies summarized above suggest some overlap in the cognitive problems that 
can be seen in children with PDD-NOS and in children with ADHD. This overlap may 
complicate differential diagnosis and stresses the importance of gaining more insight 
in the cognitive processes underlying behavioral problems. The aim of the present 
study was to examine the processes of selective attention and WM in PDD-NOS and 
ADHD with the aid of event-related potentials. Although earlier studies have 
investigated these abilities separately in the individual disorders, a direct comparison 
between PDD-NOS and ADHD while investigating both selective attention and WM in 
a single paradigm, has – to our best knowledge – not been carried out before. 

With respect to ADHD, the DSM-IV-TR distinguishes between three subtypes, 
i.e. children characterized by hyperactive/impulsive behavior, inattentive behavior or 
both. Recent studies indicate that different ADHD subtypes may show problems in 
different cognitive domains (Diamond, 2005; Nigg et al., 2002) which illustrates the 
importance of distinguishing between these subtypes when investigating cognition. In 
the current study, ADHD children of the hyperactive/impulsive or combined type were 
included.

Four groups of children carried out a visual memory search task in which both 
selective attention and memory load were manipulated. Memory load was 
manipulated by presenting the children either one or three letter(s) they had to store 
in memory (the ‘storage set’) and subsequently compare with four letters in the 
following display set (‘search set’). Selective attention was manipulated by depicting 
the search set in either the same (relevant) or in a different (irrelevant) color as the 
letter(s) the child had to remember. If the search set had been categorized as 
relevant, the subject was supposed to search for (one of) the target letter(s) in the 
display - hereby comparing each letter in the search set with the letters in the storage 
set until (one of) the target letter(s) is found. This search process is carried out in WM 
and is supposed to be controlled, capacity-limited and serial in nature (Schneider and 
Shiffrin, 1977; Shiffrin and Schneider, 1977).

Reaction times and errors were measured as well as the EEG from which 
event-related potentials were derived. With regard to these measures, overall 
Manova’s were carried out with Group as a between subjects factor. Apart from a 
healthy control group, a group of children with PDD-NOS and a group of children 
diagnosed with ADHD, we examined a group of children demonstrating symptoms of
both PDD-NOS and hyperactive/impulsive behavior. This latter group was included because the problems typical of PDD-NOS and of ADHD often occur together (e.g. Frazier et al., 2001).

As stated before, the aim of the current study was to examine whether children with PDD-NOS and children with ADHD differ in their information processing abilities of selective attention and working memory. We hypothesized that problems in selectively attending to a stimulus would become evident in a larger number of false alarms to, especially, irrelevant targets and/or nontargets. Less efficient functioning of WM might be found in a larger load-related increase in the number of errors and reaction times as compared to the control children. With respect to the ERPs, a less efficient functioning of the selective attention system would be reflected in smaller, or later occurring, effects of stimulus relevance on the SN, FSP and/or N2b. Finally, decreased WM capacity would become evident in smaller effects of memory load on the SRN and the P3.

**Methods**

**Participants**

Participants were fifteen healthy controls and 45 patients between eight and twelve years of age. The control group was composed of a subgroup of children from a study previously reported by Gomarus and colleagues (2006). These children were recruited from regular primary schools and were fully informed about the experiment. They had no history of major medical or psychiatric illness or special education. Their intellectual abilities were assessed with a short form of the WISC-RN (Dutch version) (Van Haasen et al., 1986), comprising the subtests Information, Similarities, Picture Arrangement and Block Design.

The patients were recruited from our out-patient clinic and were diagnosed by an independent expert clinician with either ADHD or PDD-NOS according to the criteria of the DSM-IV (American Psychiatric Association, 2000). All ADHD children that were included in our sample had received the DSM subtype diagnosis of primarily hyperactive/impulsive, which was verified with the aid of ADHD questionnaires (see below for a description). Considering the common male to female ratio of about 4:1 in the prevalence of ADHD problems as well as in problems in the autism spectrum, we included about four times as many boys as girls in our
study. The patients were administered the complete form of the Dutch version of the Wechsler Intelligence Scale for Children-Revised (WISC-RN) (Wechsler, 1974) in a separate test session. Furthermore, their parents and teachers filled in standardized questionnaires measuring social and hyperactive behavior. The patients were primarily assigned to one of the three different subject groups on the basis of their clinical diagnosis, while also taking into account their scores on standardized questionnaires measuring both social behavior and ADHD problems. The three subgroups that were constructed were mainly characterized by 1) behavior typical of PDD-NOS (“PDD-NOS”), 2) hyperactive/impulsive behavior (“ADHD”) or 3) behavior typical of PDD-NOS as well as hyperactive/impulsive behavior (“PDD/HD”).

Exclusion criteria were comorbid disorders other than PDD-NOS or ADHD, color blindness, estimated IQ scores below 75 and use of medication other than methylphenidate. All groups, including the control group, consisted of 15 children and were matched on age, IQ and gender (Table 1). All children had normal or corrected-to-normal vision and for each child, an informed consent was obtained.

**Behavior Checklists**

In order to assess social behavior problems, the parents of the patients were asked to complete the Dutch versions of the Child Social Behavior Questionnaire (CSBQ; (Hartman et al., 2006; Luteijn et al., 2001)) and the Child Behavior Checklist (CBCL (Achenbach and Edelbrock, 1983; Verhulst et al., 1990)). The CSBQ is a 96-item checklist that has been developed in order to describe behavioral problems in children with milder forms of pervasive developmental disorders. From the list, 6 subscales have been derived mainly covering social behavior problems: Not tuned to social context, Tendency to withdraw, Orientation problems, Not understanding social information, Stereotyped behavior, Resistance to/fear of changes. The CBCL assesses behavioral problems by means of 118 items to be scored on a 3-point scale. The list consists of eight syndrome scales and two broadband scales describing internalizing and externalizing behavior. From the syndrome scales, we employed Social Problems, Internalizing, Externalizing as well as the Total Items Score.
Table 1. Sample Characteristics: Mean score comparisons of each group: sex ratio, age, IQ and mean scores from the behavior questionnaires (A. Hyperactive/Impulsive behavior, B: Social behavior).

<table>
<thead>
<tr>
<th></th>
<th>Controls</th>
<th>PDD-NOS</th>
<th>ADHD</th>
<th>PDD/HD</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (girls)</td>
<td>15 (4)</td>
<td>15 (2)</td>
<td>15 (4)</td>
<td>15 (5)</td>
</tr>
<tr>
<td>Mean Age (sd)</td>
<td>10,15 (1,41)</td>
<td>10,25 (1,11)</td>
<td>9,82 (1,09)</td>
<td>10,13 (1,33)</td>
</tr>
<tr>
<td>Mean IQ (sd)</td>
<td>107,1 (15,6)</td>
<td>108,6 (17,5)</td>
<td>103,5 (10,2)</td>
<td>101,9 (14,0)</td>
</tr>
</tbody>
</table>

**A. Hyperactive/ Impulsive behavior: means (sd)**

- AVL attention deficit: 5,13 (4,75) 10,20 (7,05) 9,53 (6,56) 2,96 .063<sup>a,b,e</sup>
- AVL hyperactivity: 4,67(3,20) 12,33 (6,80) 13,20 (4,21) 13,37 .000<sup>a,b</sup>
- AVL impulsivity: 3,53 (2,83) 9,73 (7,20) 10,33 (5,25) 7,31 .002<sup>a,b</sup>
- Conners, acting out: 19,60 (4,34) 25,33 (7,41) 30,40 (7,51) 10,09 .000<sup>a,b</sup>
- Conners, hyperkinesia: 9,27 (3,20) 13,73 (4,56) 14,13 (3,29) 7,85 .001<sup>a,b</sup>

**B. Social behavior: means (sd)**

- CBCL social problems: 66,73 (9,23) 63,50 (8,53) 66,80 (16,50) 0,35 n.s.
- CBCL total: 67,53 (8,81) 66,00 (9,04) 65,47 (9,76) 0,20 n.s.
- CBCL internalizing: 67,93 (8,37) 57,64 (11,20) 67,27 (16,29) 3,08 .057<sup>c,d,e</sup>
- CBCL externalizing: 62,47 (11,69) 68,71 (10,32) 62,13 (13,87) 1,35 n.s.
- CSBQ not tuned: 10,47 (6,07) 11,71 (3,95) 12,80 (5,35) 0,75 n.s.
- CSBQ tendency to withdraw: 7,87 (3,74) 2,07 (2,09) 6,07 (2,58) 15,01 .000<sup>c,d</sup>
- CSBQ orientation problems: 6,33 (3,27) 7,14 (2,51) 7,47 (4,69) 0,39 n.s.
- CSBQ Not understanding: 6,73 (3,90) 4,50 (3,98) 5,40 (3,16) 1,35 n.s.
- CSBQ Stereotyped behavior: 3,67 (3,40) 2,29 (2,16) 3,07 (2,69) 0,88 n.s.
- CSBQ fear of changes: 2,67 (1,59) .71 (1,14) 2,47 (1,96) 6,40 .004<sup>c,d</sup>
- CSBQ Total: 37,73 (15,18) 28,43 (9,71) 37,27 (11,87) 2,51 .094<sup>c,d,e</sup>

Means, standard deviations (sd) and F-values are derived from univariate anova's carried out over two classes of variables (A and B). Simple contrasts were used to reveal how subject groups differed (PDD-NOS versus ADHD and PDD-NOS versus PDD/HD to examine hyperactive/impulsive behavior; ADHD versus PDD-NOS and ADHD versus PDD/HD to examine social functioning).

- <sup>a</sup>: PDD/HD > PDD-NOS
- <sup>b</sup>: ADHD > PDD-NOS
- <sup>c</sup>: PDD-NOS > ADHD
- <sup>d</sup>: PDD/HD > ADHD
- <sup>e</sup>: Tendential (.05 < p < .10)

With respect to hyperactive/impulsive behavior, the patients’ teachers filled out the Conners' Teacher Rating Scale (CTRS) (Blöte and Curfs, 1986; Conners, 1967; Conners, 1973) and a Dutch ADHD questionnaire (AVL) (Scholte and Ploeg, 1998).
The Conners’ Teacher Rating Scale consists of 39 items evaluating problem behaviors as reported by the teacher. Of the five subscales, we employed Acting Out and Hyperkinesia. From the items of the AVL - covering the DSM-IV criteria for ADHD behavior – three subscales can be constructed describing the main problem areas of ADHD: Inattention, Hyperactivity and Impulsivity (see Table 1).

Group characteristics are presented in Table 1, demonstrating that the groups did not differ in age, IQ or sex ratio. As was expected, the Table further shows that the groups can be differentiated from each other at the behavioral level. The ADHD group and the PDD/HD group differed from the PDD-NOS group in that they showed significantly higher scores on the scales describing hyperactive/impulsive behavior, while the PDD-NOS group and the PDD/HD group demonstrated significantly higher scores than the ADHD group on “Reduced contact and social interest” and “Fear of and resistance to changes”. Furthermore, the AVL ‘Attention deficit’ scale indicates that attention problems were present in both groups with ADHD symptomatology. Although, with respect to this scale, the effect of Group reached only near significance in the overall group Anova, the contrasts between ADHD and PDD-NOS and between PDD/HD and PDD-NOS did reach significance.

**Stimuli and Design**

The task consisted of 640 trials presented in twenty blocks containing 32 trials each. After each block a 40-seconds resting period followed. Halfway through the experiment, i.e. after ten blocks of trials, the subject was given a ten-minute break.

All stimuli were uppercase consonants presented against the black background of a computer monitor. Every block of trials was preceded by a white fixation cross appearing for 2000 ms in the middle of the screen. The first trial started with a *storage set* consisting of three consonants presented in juxtaposition for 1700 ms (see Figure 1). These letters were either red or blue and either all the same or all different, i.e. memory load was either one or three letters. The subject’s task was to memorize these letters and the color in which they were presented. After the storage set, the fixation cross reappeared and remained on the screen until the next trial. 700 ms after the reappearance of the fixation cross, it became accompanied by four consonants constituting the *search set*. These letters were either red or blue as well, and were presented in an imaginary square around the fixation cross. After 1500 ms
the search set disappeared and after another 1500 ms the next trial began. The search set contained either one target letter or none. If a target letter was present, the child was expected to respond by pressing a button only when the letters in the search set were depicted in the same (relevant) color as the storage set.

Our task manipulations resulted in three task variables: memory load was varied by displaying three letters in the storage set which were either all the same (“load1”) or all different (“load3”). Relevance was varied by depicting the storage set and the search set in either the same (relevant) or in different (irrelevant) colors. With the target being present or not (Target/Non-target (T/NT)), this led to eight stimulus categories, i.e. relevant target load1, relevant non-target load1, irrelevant target load1, irrelevant non-target load1, relevant target load3, relevant non-target load3, irrelevant target load3 and irrelevant non-target load3. These were all presented at random and equally often with the consequence that relevant targets occurred in only one out of four trials. Therefore, to prevent the children from developing a response bias for ‘no-responses’, no button had to be pressed in case no relevant target was present.

Figure 1. Time sequence of a trial. A: Example of a relevant target load1, B: Example of an irrelevant non-target load3.

Procedure
The experiment consisted of two sessions with at most one week in between. During the first session, the whole task was practiced to familiarize the child with the test situation and to minimize the effect of learning during the actual experiment. The experimental session started with a brief introduction after which the child practiced another three blocks of trials in the presence of the experimenter. As soon as the child performed at an adequate/optimal level, the electrodes were placed on the head
and connected to the measurement equipment. The child was asked to fixate at the center of the screen, to blink as little as possible and to respond fast but accurately. Furthermore, the subject was motivated by the prospect of being allowed to choose a small present at the end of the experiment if task performance was sufficient. Children who were on medication (methylphenidate) refrained from taking their medicine on the day of testing. IQ assessment took place in a separate session.

**Electrophysiological recording and processing**

Using the left earlobe as a reference, we recorded the electroencephalogram (EEG) with seven tin electrodes attached on the midline of the scalp (Fz, Cz, and Oz) and at parietal positions (P3, P4, P7, and P8) according to the official extended 10-20 system (American Electroencephalographic Society, 1994). The EOG was recorded with one electrode placed above the eyebrow and another on the outer canthus of the left eye. We placed the ground electrode at the breastbone and kept electrode impedance below 5 kOhm. Using a data acquisition system (developed by the Instrumentation Service of Psychology (IDP), University of Groningen), the EEG and EOG were amplified with a 10 seconds time constant and a 200 Hz low pass filter, sampled at 1000 Hz, digitally low pass filtered with a cut-off frequency of 30 Hz and online reduced to a sample frequency of 100 Hz. EEG recording was restricted to the task execution resulting in approximately 58 minutes of total EEG registration time.

The EEG signals were further processed using Brain Vision Analyzer to obtain ERPs. Trials in which a wrong response was given or in which reaction times were either exceptionally low (below 200 ms) or high (above 2500 ms) were excluded from further analysis. Furthermore, recordings with EEG deflections exceeding 200 μV or EOG deflections exceeding 500 μV were removed. The remaining trials containing eye movements were corrected using the regression procedure described by Gratton (1983).

The EEG signal was segmented in 2500-ms epochs encompassing the storage set and in 1600-ms epochs encompassing the search set, both starting 100 ms before the appearance of the storage set and the search set respectively. Being aligned to a 100-ms prestimulus baseline, the epochs covering the storage set and the search set were averaged for each subject, electrode position and stimulus category. Thus, ERPs were obtained for the ‘storage interval’, in which the storage
set presentation was embedded, for the load1 and the load3 stimulus categories. For the ‘search interval’, covering the presentation of the search set, ERPs were derived for each of the eight stimulus categories. The minimum accepted amount of trials for each stimulus condition was 20. However, in three children, less than 20 trials remained after artifact rejection in the following categories: for one ADHD child 14 trials remained in the load 1 relevant nontarget category, for one PDD/HD child 13 trials remained in the load 3 relevant target category, for one PDD/HD child 9 trials remained in the load 3 irrelevant target category. Because visual inspection of these ERPs learned that the relevant components could be clearly enough discerned, the data of these children were allowed to take part in the analyses. There were no meaningful differences in the averaged numbers of trials accepted for each group and for each stimulus category.

**Statistical analysis**

*Performance data*

Subjects had to respond only if a relevant target appeared. Responses to these stimuli were considered as hits if the button was pressed within the 350- (load1) or 450- (load3) to 4700-ms time window after stimulus presentation. For each load condition, the percentages of false alarms and omissions were computed, the first category being divided in false alarms to 1) relevant nontargets, 2) irrelevant targets and 3) irrelevant nontargets. Using Load as a within-subjects factor and Group (4 levels) as a between-subjects factor, the omissions and false alarms in response to relevant targets were analyzed in two separate repeated measures analyses (GLM SPSS). Furthermore, the false alarms in response to both irrelevant targets and irrelevant nontargets were analyzed in one design, using Target as an additional factor. The data were log-transformed in order to meet normality assumptions.

Mean reaction times were computed for responses to relevant targets in load1 and load3 separately and analyzed using Load as within-subjects factor and Group as a between-subjects factor.

*ERPs*

Based on inspection of the grand average waveforms and on findings from previous studies (Gomarus et al., 2006; Van der Stelt et al., 1998), we determined the time
intervals and electrode positions for which the statistical analyses were to be performed.

In order to investigate the effect of Load within the storage interval, repeated measures analyses (GLM SPSS) were carried out for each mean amplitude value of 50-ms time segments from the 0- to 2400-ms poststimulus time interval. For the midline electrodes (Cz and Oz) and for the parietal electrodes (P3, P4, P7, P8), separate analyses were performed using Load and Lead as within-subject factors along with Hemisphere for the analysis of the parietal electrodes.

Within the search interval, the early effects of Relevance were investigated in the 100- to 500-ms time range using smaller (20-ms) time segments because, in general, the effects of Relevance are short-lasting. For the FSP and SN, the analyses were confined to the Fz and Oz lead respectively, using Load and Relevance as within-subject factors. For the N2b, the analyses were carried out at Fz and Cz with Lead as an additional factor. The analyses were carried out on mean amplitude values belonging to nontarget stimuli because, in this stimulus category, the P3 component is expected to be of minimal amplitude and will therefore not interfere.

In order to examine the P3 and the SRN, 50-ms mean amplitude values from the 450- to 800-ms time range at Oz (P3) and 400- to 1300-ms range at Cz (SRN) were entered in the analyses. For the SRN, only amplitude values to nontarget stimuli were used because we expected the search process to be more elaborate in this category. Target, Load and Relevance were used as within subjects factors for the examination of the P3 while Relevance and Load were used for the analyses on the SRN.

For each of the analyses, we used Group as a between subjects factor. Whenever a significant interaction with Group was found, group contrasts were carried out in order to examine which groups differed from each other with respect to the task manipulations. If group contrasts were significant, separate group analyses were conducted in order to examine how the groups were affected by the different task manipulations. Results were reported only if significant effects were found in at least three consecutive time segments for the analyses in the storage interval and in two consecutive time segments in the search interval. The significance criterion for

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1 When conducting multiple analyses, the risk of capitalization on chance is increased. As 48 mean amplitude values were tested for the storage interval, a total number of $48 \times 0.05 = 2.4$ intervals was expected to show a significant effect by
one segment was set at 0.05. If significant effects in successive time segments were found, we reported the smallest and largest F-values with corresponding p-values. Further, effect sizes in terms of partial eta squared ($\eta_p^2$) will be mentioned as well in case near significant and meaningful effects are found.

Correlations

In order to examine possible relations between the effects of the task manipulations and behavioral data (i.e. data from questionnaires, performance data, age and IQ), correlations were computed between the obtained measures. If significant task effects were found on the ERPs, the differences between the amplitudes engendered by the task manipulations were computed in the intervals for which significant effects were found. For example, if a main effect of Load was found, the magnitude of this effect was calculated as the difference in amplitude values between load1 and load3, averaged over the time segments for which a significant effect was found. For the P3, we also calculated the magnitude of this component by averaging the amplitude values between 450 and 800 ms in response to relevant target stimuli in load1 and load3 separately. The obtained values were correlated with scores obtained from the questionnaires, reaction times, errors, age and IQ. In the Results section, only significant correlations will be summarized.

Results

Performance data

Reaction times. Mean reaction times are presented in Table 2. The overall ANOVA revealed a main effect of Load ($F(3,56) = 702.77, p < .001, \eta_p^2 = .93$). No main effect of Group was found. In addition, no interactions of Group by Load were found that might have pointed to a group difference in the load-dependent increase in reaction time.
Table 2. Mean reaction times (RT) and standard deviations (sd) in milliseconds to load1 and load3 stimuli for each group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Load1 RT</th>
<th>Load1 SD</th>
<th>Load3 RT</th>
<th>Load3 SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>862</td>
<td>152</td>
<td>1258</td>
<td>178</td>
</tr>
<tr>
<td>PDD-NOS</td>
<td>949</td>
<td>161</td>
<td>1302</td>
<td>160</td>
</tr>
<tr>
<td>ADHD</td>
<td>921</td>
<td>96</td>
<td>1246</td>
<td>130</td>
</tr>
<tr>
<td>PDD/HD</td>
<td>928</td>
<td>130</td>
<td>1298</td>
<td>206</td>
</tr>
</tbody>
</table>

False alarms. With respect to the number of false alarms to relevant nontargets, only a main effect of Group was found ($F(3,56) = 5.22, p = .003, \eta^2_p = .22$). Contrasts showed that both groups with ADHD symptomatology made significantly more false alarms to relevant nontargets than the control children and the children in the PDD-NOS group did (see Table 3).

As Figure 2 demonstrates, very few false alarms were made in response to irrelevant stimuli. No significant effects of Group were found within this category.

Omissions. The overall ANOVA demonstrated a main effect of Load ($F = 287.8, p < .001, \eta^2_p = .84$) indicating that more omissions were made in the Load3 condition than in the Load 1 condition. There was no significant interaction of Group by Load which indicates that the groups did not differ from each other with respect to the effect of Load.

Table 3. Statistics for the contrasts on the percentages of false alarms to relevant nontargets and omissions.

<table>
<thead>
<tr>
<th></th>
<th>False alarms to relevant nontargets</th>
<th>Omissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F$</td>
<td>$p$</td>
</tr>
<tr>
<td>PDD-NOS vs CNT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADHD vs CNT</td>
<td>7.66</td>
<td>.010$^1$</td>
</tr>
<tr>
<td>PDD/HD vs CNT</td>
<td>4.84</td>
<td>.036$^1$</td>
</tr>
<tr>
<td>PDD-NOS vs ADHD</td>
<td>10.10</td>
<td>.004$^1$</td>
</tr>
<tr>
<td>PDD/HD vs ADHD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PDD-NOS vs PDD/HD</td>
<td>7.12</td>
<td>.013$^1$</td>
</tr>
</tbody>
</table>

The group contrasts (df: 1, 28) were conducted after a main effect of Group was found in the overall group Anova’s on the percentage of false alarms to relevant nontargets and on the percentage of omissions.

1: Children with ADHD symptomatology made more errors than the other subject group in the comparison.

2: Children with PDD-NOS made more omissions than the control group.
Because a main effect of Group was found \( (F(3,56) = 4.67, p = .006, \eta_p^2 = .84) \), contrasts were carried out in order to examine which groups differed from each other. These contrasts revealed that all patient groups made significantly more omissions than the control children did with the contrast between controls and ADHD-children showing the largest effect (see Figure 2 and Table 3).

**EEG data**

**Storage interval: Effects of Load**

Overall, a main effect of Load was found in the analyses on Cz and Oz between 650 and 1900 ms \[ F_{\text{Load}}(1,56) = 7.58 - 34.20, p < .008 \]. As can be seen in Figure 3, the storage set containing three different consonants (load3) elicited a larger long-lasting positivity as compared to the set containing three identical consonants (load1). There was no interaction of Load by Group but the interaction of Lead by Group in the 1200- to 1900-ms interval \[ F_{\text{Lead} \times \text{Group}}(3,56) = 2.79 - 4.76, .005 < p < .05 \] suggests that the activity elicited by the storage set might be differentially distributed for each group. However, further analyses revealed no significant group contrasts with respect to task-related effects. Analyses on the data derived from the parietal electrode sites revealed no interaction of Group by Load either.
Search interval: effects of Relevance on FSP, SN and N2b

The overall analyses demonstrated a main effect of Relevance at Fz between 380 and 500 ms \( [F_{\text{Relevance}}(1,56) = 4.28 - 9.84, .003 < p < .043] \). In this time range, the relevant stimuli evoked a more positive amplitude than the irrelevant stimuli did (see Figure 4) which may be interpreted as a frontal selection positivity (FSP). The figure illustrates that each group showed a frontal selection positivity (FSP) with the relevant stimuli eliciting a larger positive peak than the irrelevant stimuli in the 200- to 380-ms time range. No signs of a selection negativity (SN) nor of an N2b were found in the overall group analyses. Furthermore, no significant interaction of Group by Relevance was found.
ERPs in Children with ADHD and/or PDD-NOS

Figure 4. Grand average ERPs at Fz for relevant targets and nontargets collapsed over load1 and load3 (black curve) and irrelevant targets and nontargets collapsed over load1 and load3 (grey curve).

Search interval: effects of Target, Relevance and Load on the P3

A clear P3 was visible for all subject groups (see Figure 5). The overall analyses on data from the Oz lead, showed main effects of Load, Relevance and Target (see Table 4). These effects indicate that relevant stimuli and target stimuli elicited larger P3-amplitudes than irrelevant and nontarget stimuli whereas the higher load condition evoked a suppression of the amplitude as compared to the load1 condition. The analyses also revealed significant two-way interactions of Load × Target, Relevance × Target, as well as an interaction of Group × Relevance. The latter group interaction was further explored by means of group contrasts. These revealed that the PDD/HD group differed significantly from the other groups in that they showed a smaller effect of Relevance [CNT-PPD/HD: $F(1,28) = 4.28 - 6.67, .015 < p < .048$; PDD-PDD/HD: $F(1,28) = 5.31 - 13.99, p < .051$; ADHD-PDD/HD $F(1,28) = 6.66 - 10.9, .003 < p < .015$]. This effect possibly reflects the same brain dynamics as
the effects mentioned in the description of the SRN below. For the other group contrasts, no significant effects were found. Finally, there was no main effect of Group in the overall ANOVA showing no group differences in the overall P3 signal.

![Oz ERP](image)

**Figure 5.** Grand average ERPs at Oz for each group in response to relevant targets. For each group, the P3 to load3 stimuli (black curve) was suppressed as compared to the P3 to load1 stimuli (grey curve).

**Table 4. Results from the group ANOVA on the P3.**

<table>
<thead>
<tr>
<th></th>
<th>Interval</th>
<th>F</th>
<th>p</th>
<th>df</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Load</strong></td>
<td>450-850</td>
<td>26.47-35.06</td>
<td>&lt;.001</td>
<td>1, 56</td>
</tr>
<tr>
<td>Load x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
<tr>
<td><strong>Relevance</strong></td>
<td>450-800</td>
<td>128.78-251.02</td>
<td>&lt;.001</td>
<td>1, 56</td>
</tr>
<tr>
<td>Relevance x Group</td>
<td>550-800</td>
<td>2.85-5.20</td>
<td>&lt;.05</td>
<td>3, 56</td>
</tr>
<tr>
<td><strong>Target</strong></td>
<td>450-800</td>
<td>39.84-131.57</td>
<td>&lt;.001</td>
<td>1, 56</td>
</tr>
<tr>
<td>Target x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
<tr>
<td>Load x Relevance</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>1, 56</td>
</tr>
<tr>
<td>Load x Relevance x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
<tr>
<td><strong>Load x Target</strong></td>
<td>450-700</td>
<td>19.50-46.99</td>
<td>&lt;.001</td>
<td>1, 56</td>
</tr>
<tr>
<td>Load x Target x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
<tr>
<td><strong>Relevance x Target</strong></td>
<td>450-800</td>
<td>14.90-52.39</td>
<td>&lt;.001</td>
<td>1, 56</td>
</tr>
<tr>
<td>Relevance x Target x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
<tr>
<td>Load x Relevance x Target</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>1, 56</td>
</tr>
<tr>
<td>Load x Relevance x Target x Group</td>
<td></td>
<td>n.s.</td>
<td></td>
<td>3, 56</td>
</tr>
</tbody>
</table>
Search interval: effects of Relevance and Load on SRN

A significant interaction in the overall analyses of Load × Relevance between 750 and 950 ms (see Table 5) indicates that, in the relevant category, a larger negativity was elicited in response to Load 3 stimuli than to Load 1 stimuli. Significant interactions of Load × Relevance × Group in the interval between 400 and 750 ms suggest that the groups might differ in this effect (see Figure 6). Subsequent group contrasts indeed revealed that the control children differed from each patient group regarding the interaction Load × Relevance. Additional analyses that were carried out for each group on the relevant nontargets and the irrelevant nontargets separately, demonstrated that for the control children, the effects of Load were confined to the relevant category [400-900 ms: $F_{\text{Load}}(1,14) = 6.28 - 16.27, .001 < p < .025$]. Whereas the PDD groups showed no effects of Load at all, near significant effects of Load were found for the ADHD group within both the relevant and the irrelevant category [relevant: $F_{400-550, 750-850}(1,14) = 2.56 - 3.82, .07 < p < .13, .154 \leq \eta_p^2 \leq .214$; irrelevant: $F_{500-700}(1,14)= 2.31 - 3.21, .1 < p < .19, .142 \leq \eta_p^2 \leq .186$. Although the effects are not significant, high effects sizes were found for both categories.

Correlations

Overall, age and IQ correlated negatively with reaction times in load1 ($r_{\text{age}, \text{rt}} = -.32, p = .01; r_{\text{IQ}, \text{rt}} = -.27, p = .04$). Furthermore, age was negatively correlated with the percentage of omissions ($r_{\text{age}, \% \text{miss}} = -.44, p < .001$).

Hyperactive as well as impulsive behavior, as measured with the behavior checklists, were positively correlated with the percentages of misses and false alarms (% omissions with AVL-Impulsivity scale and Conners-Hyperkinesia scale: $r = .34, p = .02$ and $r = .38, p = .01$; % false alarms with the AVL -Attention, AVL-Hyperactivity and AVL-Impulsivity, Conners-Acting out and Conners-Hyperkinesia: $r = .40, p < .01; r = .34, p = .02; r = .47, p < .01; r = .47, p < .01; r = .42, p < .01$). These correlations may, however, have become artificially significant due to the ADHD group showing more omissions and false alarms than the other groups. Therefore, separate correlations were carried out for each group revealing significant correlations within the ADHD group between the AVL-Impulsivity scale and the percentage of omissions in load3 ($r = .53, p = .04$) as well as between the Conners-Hyperkinesia scale and the
percentage of total omissions and the percentage of omissions in load3 \( (r = .66, p < .01; r = .58, p = .03) \).

In addition, false alarms to irrelevant stimuli were found to be correlated with ADHD-related behavior within the ADHD group (AVL-Hyperactivity: \( r = .62, p = .01 \); AVL-Impulsivity: \( r = .68, p < .01 \); Conners-Acting out: \( r = .76, p < .01 \); Conners-Hyperkinesia: \( r = .61, p = .02 \)). This suggests that ADHD features may be related to diminished selectivity.

With regard to the ERPs, no meaningful correlations were found.

![Grand average ERPs to relevant nontargets for load 1 (grey curve) and load 3 (black curve) stimuli at Cz.](image)

*Figure 6. Grand average ERPs to relevant nontargets for load 1 (grey curve) and load 3 (black curve) stimuli at Cz. Only the control children demonstrated significant main effects of Load pointing to a search-related negativity (SRN). In the ADHD group, the factor Load elicited high effect sizes in both the relevant and irrelevant category, but did not reach significance.*
Summary of main results

Summarizing, in the performance data, overall effects of load were found on reaction times and on the number of omissions. With respect to the number of omissions, each of the patient groups showed more omissions than the control group. However, the groups did not differ with respect to the effect of Load on either reaction times or the number of omissions. Furthermore, both groups with ADHD symptomatology made significantly more false alarms to relevant nontargets than the control children and the children in the PDD-NOS group did.

The ERP to the storage interval showed an overall effect of Load in which the groups did not differ from each other. In response to relevant stimuli in the search set, an overall early frontal selection potential (FSP) was present for which no group differences were found either. With respect to the P3, the PDD/HD group showed a smaller effect of relevance than the other groups. For the search-related negativity (SRN), significant group differences were found. Here, contrasts revealed that each patient group demonstrated a different pattern than the control group. Whereas for the control children the effect of Load was confined to the relevant category, the PDD-NOS group and the PDD/HD group showed no effect of Load at all and the ADHD group showed near significant effects with high effect sizes in both the relevant and the irrelevant category.

Discussion

The main research aim of the present study was to find an answer to the question whether children diagnosed with either ADHD or with PDD-NOS could be distinguished with respect to their information processing capacities of selective attention and working memory. In an effort to answer this question, electrophysiological brain responses as well as performance data were collected from four groups of children while they performed a visually presented task in which both selective attention and WM were manipulated. The data of these groups - a healthy control group, a group of children diagnosed with PDD-NOS, a group diagnosed with ADHD showing hyperactive/impulsive behavior, and a group of children with symptoms of both categories - were compared with each other using overall group Anova’s.
Although the analyses on the data from the questionnaires clearly suggest behavioral differences between the groups, the performance measures only partly corroborated these findings. With respect to the ability of selectively attending to relevant information, no differences were found in the number of false alarms to irrelevant stimuli. However, within the ADHD group, significant correlations between ADHD-related behavior and false alarms to irrelevant stimuli were found that do point to a relation between hyperactive/impulsive behavior and distractibility. Further, a higher level of impulsiveness in both hyperactive/impulsive groups might be reflected by a larger number of false alarms to relevant nontarget stimuli as compared to both the control group and the PDD-NOS group. Here, after having judged the search set as ‘relevant’, the hyperactive/impulsive children made a ‘yes’-response to nontarget stimuli implying a higher level of impulsivity in these children.

With respect to working memory, children with PDD did not differ from nonPDD children regarding a load-related increase in either reaction times or in the percentage of errors. Analogously, children with hyperactive/impulsive behavior did not differ from children without hyperactive/impulsive behavior. However, all of the patient groups made significantly more omissions than healthy children in both the load1 and load3 condition. The finding that task load did not seem to have a significant effect on this difference may imply that these children have a general problem in the allocation of working memory capacity rather than that they show a shortage of working memory capacity. A capacity-allocation deficit in children with ADHD has been suggested earlier by Sergeant and Scholten (Sergeant and Scholten, 1985) and in ERP studies by Jonkman and colleagues (2000) as well as by Sawaki and Katayama (2006). A shortage of working memory capacity would become especially evident in situations of higher task load. This may imply that the demands of the current task were not high enough to reveal possible group differences. Here, it must be noted that reaction times for nontargets were not recorded in our study, leaving no opportunity to compare reaction times in the most difficult task condition, i.e. a situation in which an exhaustive search had to be carried out. A study by Althaus and colleagues (1996) reported a larger load-related increase in reaction times in children with PDD as compared to control children that was larger to nontargets than to targets. This indicates that a shortage in capacity becomes more evident in situations of exhaustive search (i.e. nontarget situations).
On the other hand, problems in the allocation of processing capacity may have become more evident in the current task conditions. The rather low rate of stimuli the children had to respond to (25% of the trials) may have produced a low level of activation (Sanders, 1983) in especially the patient groups. This may have caused them to be less responsive leading to fewer false alarms and more omissions. The finding that the ADHD children missed many targets is in line with reports on studies using the Continuous Performance Test (CPT) in ADHD (see Losier et al., 1996 for a review) where it is commonly found that, apart from making more errors of commission, these children also make more errors of omission than normal children do. An explanation may be found in the task instruction at hand. Apart from responding as quickly as possible, we instructed the children to respond as accurately as possible which may have yielded a more conservative response strategy. The fact that the PDD-NOS children in our study also made more omissions, demonstrates that this effect is rather non-specific.

The fact that no load-related differences in the performance data were found between the patient groups may also be explained by these children using compensatory strategies. For instance, in an fMRI study using an n-back WM task with conditions varying in load, Koshino and colleagues (2005) found no impairment in task performance in higher functioning autistics, but they did find differences in activation patterns between these patients and normal controls. According to these authors, the data suggest that autistic persons use a different processing style with respect to WM. They hereby point to the fact that performance data may not reveal differences in the neurocognitive processes underlying an overt response. As the method of ERPs has proved to be a useful aid in identifying possible deficiencies in information processing (for a review, see Banaschewski and Brandeis, 2007), we used this method in addition to performance data.

The most interesting differences in the electrophysiological response patterns between the groups were found with respect to the SRN which is supposed to characterize the search process. The controlled process of serial search is expected to be more elaborate and exhaustive in nature when no target is present. Therefore, the effect of stimulus load in response to this process was analyzed within the condition where only nontargets were present. Usually, the amplitude of the SRN is enhanced under conditions of higher cognitive load, i.e. when the search process is
expected to be more extensive (Okita et al., 1985; Wijers, 1989). Thus, a larger negativity may imply that more resources are invested in the search process.

Regarding the SRN, a significant interaction of group with the task manipulations was found. This finding demonstrates that a covert measure of information processing in a nontarget situation may to some extent reveal differences that were left unnoticed by analyzing performance data in response to only target stimuli. As expected, the control children demonstrated a load-related effect that was confined to relevant nontarget stimuli, whereas each of the patient groups demonstrated a significantly different pattern. None of the patient groups demonstrated significant effects of Load, which may imply that for these children, the search process was as extensive in load1 as it was in load3. It may be speculated that the children showing psychopathology invested fewer or no extra processing resources in the high as compared to the low load condition which implies difficulties in the use of working memory capacity. It is, however, from these data not possible to infer whether this can be attributed to a difficulty in the allocation of working memory capacity or to a shortage of working memory capacity.

Although not significant, high effect sizes of Load were found in the ADHD group for both the relevant and the irrelevant category. Although the effects are not statistically significant, we still think it is worth mentioning these high effect sizes ($\eta_p^2$) because they are suggestive of a tendency to attend to both relevant and irrelevant stimuli, which would imply a deficit in selectively attending. While not significant in the current study, these high effect sizes suggest that a possible future study with larger sample sizes may demonstrate a significant effect of Load.

Finally, although the children who were on medication (methylphenidate) refrained from taking this medication on the day of testing, some after-effects may still have been present. As it was mostly the children with hyperactive/impulsive behavior who were medicated, it cannot be excluded that this may to some extent have distorted the results. Although we expect this to be of minimal effect, this may be another explanation for possible group differences not becoming evident.

In sum, the patient groups were found to differ from the control group with respect to their number of omissions, false alarms and the ERP component that has been related to controlled processing in working memory (SRN). Despite the fact that the behavior questionnaires clearly suggest a distinction at a behavioral level between the clinical groups, direct comparisons between these groups only revealed
a significant difference in the number of false alarms between the ADHD group and the PDD-NOS group. Further, the analyses revealed no significant differences in the information processing abilities of selective attention and working memory in either the performance data or the EEG data. Whereas each patient group differed significantly from the control group concerning the SRN, the results are suggestive of a dissociation in the way each patient group differed from the control group but the effects are not significant. Hence, significant differences - if present - in measures of selective attention and working memory between the clinical groups remain to be clearly identified. The fact that these differences could not be demonstrated, may partly be attributed to the commonly acknowledged overlap in symptomatology, as has often been observed in clinical practice (Clark et al., 1999; Jensen et al., 1997). Also, although studies on information processing in children with ADHD and PDD are still scarce, evidence for group differences in this respect has thus far proven hard to find (Goldberg et al., 2005; Happé et al., 2006). Further, as is discussed above, the question whether possible differences in working memory may become evident in conditions of higher task demands remains to be examined.