Chapter 5

Do children with ADHD and/or PDD-NOS differ in reactivity of alpha/theta ERD/ERS to manipulations of cognitive load and stimulus relevance?

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Abstract

Objective: We examined whether the method of event-related (de-)synchronization (ERD/ERS) revealed differential effects of selective attention and working memory load in children (8-11 years) with pervasive developmental disorder – not otherwise specified (PDD-NOS) or attention-deficit/ hyperactivity disorder (ADHD).

Methods: 15 healthy controls and 3 equally large groups of children with symptoms of PDD-NOS, ADHD or both (PDD/HD) performed a visual selective memory search task. The EEG was recorded from which occipital alpha and frontal theta were derived.

Results: The effects of the overall task manipulations of task load, relevance and target/nontarget were clearly present in the overall analyses of alpha and theta ERD/ERS. However, no significant differences with respect to these manipulations existed between any of the subject groups.

Conclusions: The results supply no evidence for a distinction in information processing abilities of selective attention and working memory as reflected by alpha and theta ERD/ERS between children diagnosed with either ADHD, PDD-NOS or healthy controls.

Significance: Alpha and theta ERD/ERS are sensitive to manipulations of task load, relevance and target/nontarget, but supply no additional information on possible group differences in comparison to the more frequently used method of event-related potentials.
Introduction

Although Attention Deficit/Hyperactivity Disorder (ADHD) and Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) 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). The core problems of PDD-NOS are related to those of autism and lie in the domains of social interaction, communication and stereotyped behavior patterns whereas the main symptoms of ADHD are inattention, hyperactivity and impulsive behavior. Studies using questionnaires assessing either ADHD-like or autistic-like behavior have, however, repeatedly demonstrated that a relatively large number of children diagnosed with ADHD or hyperkinetic disorder also show problems in social behavior (e.g. Clark et al., 1999; Santosh and Mijovic, 2004). On the other hand, children diagnosed with PDD-NOS may show symptoms of ADHD, i.e. hyperactivity or inattentiveness (Goldstein and Schwebach, 2004; Sturm et al., 2004). This apparent overlap in symptomatology between ADHD and PDD-NOS may, however, be caused by different underlying mechanisms (Jensen et al., 1997).

Mechanisms that are generally accepted to play major roles in human information processing are selective attention and working memory (WM). Traditionally, selective attention is referred to as the ability of the processing system to select certain (relevant) information for further processing and to ignore irrelevant information. Working memory is commonly viewed as a limited capacity system that is capable of storing and manipulating information (Baddeley, 1986; Baddeley, 1996). Since selective attention and working memory are at the core of information processing, deficits in these areas may lead to serious problems in human functioning. The question is how these concepts are related to ADHD and PDD-NOS, and whether they are differentially affected in both syndromes.

In this respect, the frequently observed high distractibility (i.e. the failure to ignore irrelevant information) in children with ADHD may arise from a deficit in selective attention. In children with PDD-NOS, on the other hand, the problems with functioning in social situations, in which many events have to be processed simultaneously, may be ascribed to a working memory deficit (e.g. Althaus et al., 1996; Althaus et al., 1999; Bennetto et al., 1996). However, although the symptoms
of both disorders may suggest 1) a working memory deficit to be characteristic of PDD-NOS and 2) a selective attention deficit to be typical of ADHD, the literature is not conclusive (for a brief outline, see Chapter 4, published as Gomarus et al., 2009a).

In a former study, the results of which are described elsewhere (see Chapter 4, Gomarus et al. 2009a), we tried to shed more light on this matter by using event-related potentials (ERPs), with which more insight in the discrete processes preceding an overt response can be obtained. A direct comparison was made between children with an autism spectrum disorder and children with ADHD. Compared to the control group, all patient groups made more omissions than controls while hyperactive children also exhibited more false alarms. The results of the study revealed no significant differences between these groups of children with respect to their electrical brain responses related to either selective attention or working memory. Each patient group did, however, differ from the control group in the evoked response related to memory search and in the number of omissions. The latter effect was discussed in relation to the allocation of processing capacity which in turn may be modulated by state regulation. While in the time course of an ERP, the different computational processes in response to a given stimulus may be discerned, the time course of ERD/ERS shows a slower power change that may be considered to reflect processes that are longer-lasting, being more related to state. The aim of the current study was to explore whether the method of event-related desynchronization/synchronization (ERD/ERS) might give additional information to the use of ERPs in identifying possible differences in underlying cognitive processes among these patient groups.

Whereas the ERP reflects ‘stimulus driven’ or evoked activity that is both time- and phase-locked to the event, induced activity can be considered as rhythmic background activity that is modulated by external or internal events and is time-, but not necessarily phase-locked. Due to the averaging procedure in computing the ERP, non-phase locked activity is cancelled out of this measure. With the method of ERD/ERS this activity can be maintained because the amplitudes are squared before averaging (Bastiaansen and Hagoort, 2003). In ERD/ERS, an event-related change in power of a given frequency band is expressed as the percentage of the power in a specified reference period. A decrease of power is called event-related desynchronization (ERD) (Pfurtscheller, 1977; Pfurtscheller and Aranibar, 1977)
while an increase is referred to as event-related synchronization (ERS) (Pfurtscheller, 1992).

The frequency bands that have acquired most attention in ERD/ERS research are the theta (4-8 Hz) and alpha (8-12 Hz) bands, both of which have been found to be sensitive to variations in task demands (see Bastiaansen and Hagoort (2003); and Klimesch (1999) for a review), especially to manipulations of cognitive load. Theta activity has been reported to be most pronounced over midline frontal electrode sites (Gevins and Smith, 2000) and has repeatedly been related to processes involved in learning and (working) memory (Bastiaansen and Hagoort, 2003; Klimesch, 1999; Pesonen et al., 2006). Studies in humans indicating that the hippocampus mediates in the generation of theta activity (Arnolds et al., 1980; Halgren et al., 1978; Tesche and Karhu, 2000) corroborate this hypothesis as it is widely established that the hippocampus plays an essential role in learning and memory.

Although still little is known about the origin of alpha activity in the brain (Steriade, 2000), it has been hypothesized on the basis of animal studies and studies in humans (Feige et al., 2005; Steriade, 2000) that the alpha rhythm is related to thalamo-cortical activity. Alpha can be seen most clearly in an eyes-closed condition of relaxed wakefulness being most pronounced over occipito-parietal sites. A common finding is that alpha activity is suppressed in attention demanding tasks and it has been related to the allocation of attention, alertness and semantic processing (Boiten et al., 1992; Klimesch, 1999).

In the visual selective memory search task that we applied, both memory load and selective attention were manipulated in order to specify their effects on performance measures as well as on event-related alpha and theta power. In the first part of a trial (‘storage interval’), the children had to store one or three letter(s) in memory. In the second part (‘search interval’), four letters were presented containing either one or none of the letters from the storage set. Selective attention was manipulated by depicting these letters in either the same (relevant) or in a different (irrelevant) color as the letter(s) the child had to remember. The child had to search for (one of) the letters from the storage set only if both sets were presented in the same color. This process of controlled serial search is supposed to be carried out in working memory and therefore expected to load on working memory capacity.
In a former study (Gomarus et al., 2006) (Chapter 3), we examined how, in the same task paradigm, the manipulations of memory load and selective attention affected alpha and theta ERD/ERS in a group of healthy children (n=18). The results from this study were in line with findings described in the literature. For theta, a task-related enhancement was found to be most pronounced at the Fz electrode between 4 and 8 Hz. Theta ERS appeared to be sensitive to each task manipulation while it showed the strongest increase in response to the most difficult task condition that made high demands on working memory. Therefore, it was concluded that theta ERS might reflect the involvement of processes related to working memory. Alpha power, on the other hand, showed a task-related suppression with a clear peak between 8 and 12 Hz, which was most pronounced at the Oz lead. In contrast to theta ERS, alpha ERD was only slightly affected by the task manipulations of Relevance, Target/Nontarget and Load. The absence of strong, task-related effects may suggest that alpha ERD reflects brain activity involved in a general allocation of attention, as is suggested in the literature (see above). Attention processes, in turn, are thought to be influenced by the level of alertness or vigilance (Posner, 1993).

In the study described below, it was examined whether the method of ERD/ERS would reveal differences in selective attention and/or working memory processes between children with either ADHD-related behavior or children with PDD. The paper will put the main focus on the description of alpha and theta ERD/ERS. Only a short description of the performance data will be presented as these have already been described extensively in the foregoing paper.

**Methods**
In this paragraph, a shortened description of the applied methods is given. For a more detailed description, we refer to Gomarus and colleagues (2009a, Chapter 4).

**Participants**
Participants were fifteen healthy controls and 45 patients between eight and twelve years of age with mean IQ scores above 75 (WISC-RN) (Wechsler, 1974). The patients were diagnosed with either Attention-Deficit/Hyperactivity Disorder (ADHD) or Pervasive Developmental Disorder Not Otherwise Specified (PDD-NOS) according to the criteria of the DSM-IV (American Psychiatric Association, 2000) by an
independent expert clinician. Only ADHD children that were characterized by their clinician as hyperactive/impulsive were included in our sample. 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 parents of the patients were asked to complete the Dutch versions of the Child Social Behavior Questionnaire (CSBQ; (Hartman et al., 2006; Luteijn, 2000) and the Child Behavior Checklist (CBCL (Achenbach and Edelbrock, 1983; Verhulst et al., 1990)). The patients' teachers filled out the Conners' Teacher Rating Scale (CTRS) (Blöte and Curfs, 1986; Conners, 1967; Conners, 1973) and the Dutch ADHD questionnaire (AVL) (Scholte and Ploeg, 1998). Using the data obtained from these questionnaires in combination with the diagnosis given by the clinician, the patient group could be divided into three subgroups of 15 children each, which were mainly characterized by behavior typical of 1) PDD-NOS, 2) ADHD or 3) PDD-NOS as well as ADHD (“PDD/HD”).

All groups were matched on age, IQ and gender. An informed consent was obtained for each subject.

Stimuli and Design

The task consisted of 640 trials. Children had to memorize three letters (consonants) presented in red or blue (“storage set”). These letters were either all the same or all different, i.e. memory load was either one or three letters. After the storage set had disappeared, a fixation cross appeared followed by four consonants constituting the “search set”. If these letters appeared in the same color as the storage set, the child was to search among these letters for (one of) the target letters from the storage set and press a button when a target letter was present. 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 a different (irrelevant) color. With the target being present or not (Target/Nontarget (T/NT), this resulted in eight stimulus categories, which were all presented equally often and at random.
**Procedure**

After a practice session in which no electrophysiological recordings were made, the actual experiment took place at most one week later. Here, the child practiced again three blocks of trials after which the electrodes were placed on the head and connected to the measurement equipment. Children who were on medication (methylphenidate) refrained from taking their medicine on the day of testing.

**Electrophysiological recording**

For the measurement of ERD/ERS, the electrodes at the Fz and Oz positions (according to the official extended 10-20 system (American Electroencephalographic Society, 1994) were used. We used the left earlobe as a reference and recorded the EOG with one electrode placed above the eyebrow and another on the outer canthus of the left eye and the ground electrode was placed at the breastbone. Impedance was kept below 5 kOhm. Using the DAP data acquisition system (developed by Instrumentatiedienst Psychologie (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.

**Data processing**

The EEG signals were further processed using Brain Vision Analyzer in order to obtain ERD/ERS. 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 and colleagues (1983).

In agreement with the commonly accepted frequency ranges for theta and alpha we defined the theta frequency band as ranging from 4 to 8 Hz and the alpha band from 8 to 12 Hz. After artifact detection, the data were bandpass filtered for the specified theta and alpha frequency ranges, squared, and low pass filtered with a cut-off frequency of 4 Hz. The data were epoched and averaged for each stimulus.
condition separately. Finally, from the originally 5400 ms lasting trial, starting from stimulus onset, 18 segments of 250 ms were used for further analysis. For each of these, ERD/ERS was calculated as the percentage of increase or decrease in power relative to the reference interval using the 500-ms time window preceding each trial as the reference period. Positive values indicated ERS, whereas negative values indicated ERD.

**Statistical analysis**
In order to examine whether the task manipulations yielded differential effects among the groups, the data were submitted to overall ANOVAs with Group as a between-subjects factor. Whenever a significant main effect of Group or an 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 would be conducted in order to examine how the groups were affected by the different task manipulations.

**Performance data**
As subjects had to respond only if a relevant target appeared, mean reaction times could be computed only for responses to relevant targets in load1 and load3. The percentages of omissions to relevant targets and the false alarms to 1) relevant nontargets, 2) irrelevant targets and 3) irrelevant nontargets, were computed for each load condition.

**Theta and alpha power in the reference interval**
To investigate whether theta and alpha power in the reference interval differed among the groups, mean ln-transformed theta and alpha power in the 500-ms prestimulus reference period were entered into the analysis.

**ERD/ERS**
Alpha and theta ERD/ERS in response to the separate stimulus categories was computed for each of the 18 time segments and plotted in separate graphs for alpha and theta frequencies (Figure 2a-d). On the basis of visual inspection of these
graphs, it was decided for which time intervals statistical analyses were carried out. In this manner, we were able to reduce the number of comparisons made.

For theta in the storage interval, analyses were carried out on each 250-ms time segment, starting from the beginning of the trial, until ERD/ERS was no longer significant (tested against baseline (effect of Intercept)). With regard to theta ERD/ERS in the search interval, the search interval was subdivided into three larger segments (100-850 ms, 850-1600 ms, 1600-2100 ms) for which mean amplitudes were computed. Alpha ERD/ERS in the storage interval was strongest between 500 and 1750 ms. Therefore, mean alpha ERD/ERS was computed for this time range and entered into the analysis. For the same reason, mean alpha ERD/ERS in the search interval was computed for the 600- to 1100-ms and 1100- to 1600-ms intervals.

For the analyses on the storage interval, Load was used as a within-subjects factor and for the search interval, Load, Relevance and Target/Nontarget were used as within-subject factors. The \( \alpha \)-level was set at .05. We described the largest p-value along with the largest and smallest F-values. Effect sizes are mentioned in terms of partial eta squared (\( \eta_p^2 \)).

**Correlations**
If significant ERD or ERS was found in a specific time range (see above), mean ERD/ERS in this range was calculated for each subject. Furthermore, if significant task effects were found on ERD/ERS, 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 on alpha ERD in a specific time interval, 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. The obtained values were correlated with scores obtained from the questionnaires, reaction times, errors, age and IQ. Finally, in order to find out whether baseline theta and alpha power was related to reaction times, errors, age, IQ and behavior as described by the questionnaires, we carried out correlations between these latter measures and mean theta and alpha power in the reference interval. In the Results section, only significant correlations will be summarized.
Results

Performance data

In the following, a summary of the main findings from the analyses on the performance data is given. For a more elaborate description we refer to Chapter 4 of this thesis (published as Gomarus et al. 2009a).

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 Load effect on either reaction times or the number of omissions. Both the ADHD group and the PDD/HD group made more false alarms in response to relevant nontargets than the control group and the PDD-NOS group did.

EEG data

Spectral theta and alpha power in the reference interval

In Figure 1, mean ln-transformed theta (left panel) and alpha power (right panel) in the reference interval are depicted for each group. Neither for theta power, nor for alpha power, a significant effect of Group was found, although the effect of Group nearly reached significance ($p=.055$) in the analyses on alpha power.

![Figure 1. Ln-transformed values of mean theta (left) and alpha (right) power in the reference interval, presented for each group.](image-url)
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Theta ERS in the storage interval

In response to the storage set, overall theta synchronized significantly during the first 1000 ms [main effects of Intercept: $4.70 < F(1,56) < 86.38; .001 < p < .035$]. Further, an overall effect of Load was present between 250 and 1000 ms demonstrating more ERS for load1 stimuli than for load3 stimuli [$9.36 < F_{\text{Load}(1,56)} < 11.98; .001 < p < .003$]. No significant effects of Group were found.

Table 1. Significance effects ($p$-values) for the repeated measures ANOVAs on theta and alpha ERD/ERS in the separate time segments that were analyzed for the search interval. In this interval, no significant main effects of Group or interactions with Group were found.

<table>
<thead>
<tr>
<th>ERD/ ERS in the Search interval</th>
<th>Theta</th>
<th>Alpha</th>
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<tr>
<td></td>
<td>100 – 850 ms</td>
<td>850 – 1600 ms</td>
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<tr>
<td>Intercept$^a$</td>
<td>p &lt; .001</td>
<td>p &lt; .001</td>
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<tr>
<td>Group</td>
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<tr>
<td>Load × Group</td>
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<tr>
<td>Relevance</td>
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<tr>
<td>Relevance × Group</td>
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<tr>
<td>Target</td>
<td>p = .041$^c$</td>
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<tr>
<td>Target × Group</td>
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<tr>
<td>Load × Relevance</td>
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<tr>
<td>Load × Relevance × Group</td>
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<td>Load × Target × Group</td>
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<td>Relevance × Target</td>
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</table>

$^a$: Significant ERD/ERS tested against baseline.

$^b$: Load3 more ERD/ERS than load1 stimuli, relevant more ERD/ERS than irrelevant stimuli, target more ERD/ERS than nontarget stimuli.

$^c$: Nontarget more ERS than target stimuli.

Figure 2 (next page). Theta and alpha ERD/ERS presented for each of the subject groups. The first graph in each row represents ERD/ERS for the control group, the second for the PDD-NOS group, the third for the ADHD group and the last for the PDD/HD group. The upper two panels depict theta ERD/ERS at Fz in response to (a) load1 and load3 in the storage set, and to (b) each stimulus category in the search set. The lower two panels depict alpha ERD/ERS at Oz in response to (c) load1 and load3 in the storage set, and to (d) each stimulus category in the search set.
Figure 2
**Theta ERS in the search interval**

During the search interval, theta synchronization was significantly present in each of the analyzed time segments \[72.71 < F(1,56) < 101.89; p < .001\]. Significant main effects of Load, Relevance and Target/Nontarget as well as significant two-way and three-way interactions indicated that the relevant nontargets in load3 elicited most theta ERS, as Figure 2b clearly illustrates (see Table 1 for \(F\)- and \(p\)-values). There were no significant interactions with or main effects of Group.

**Alpha ERD in the storage interval**

Figure 2c shows that alpha desynchronized in response to the storage set which was significant \([F(1,56) = 32.11, p < .001]\) and did not differ between groups.

**Alpha ERD in the search interval**

In response to the search set (Figure 2d), alpha desynchronized as well \([F(1,56 = 71.10 and 63.87; p < .001]\). Further, significant main effects were found of Relevance during the entire interval \([F(1,56 = 16.70 and 10.65; p \leq .002]\) and of Target between 600 and 1100 ms after presentation of the search set \([F(1,56 = 5.74; p = .02]\). These effects indicate more alpha ERD for relevant as compared to irrelevant stimuli and for target as compared to nontarget stimuli respectively.

There were no significant effects of Group in the search interval.

**Correlations**

The amount of omissions was related to hyperactive/impulsive behavior within the ADHD group (see also Gomarus et al. 2009a, Chapter 4). For this group, significant correlations were found between the AVL-Impulsivity scale and the percentage of omissions in load3 \((r = .53, p = .041)\) as well as between the Conners-Hyperkinesia scale and the percentage of total omissions and the percentage of omissions in load3 \((r = .66, p = .007; r = .58, p = .025)\). This finding is in accordance with the results from the group comparisons on the errors described above; the ADHD groups showed significantly more omissions than the control children did. No meaningful correlations of behavioral data with any of the ERD/ERS measures were found.


Discussion

The study described above is a continuation of a former study that focused on identifying differences in ERP components related to selective attention and working memory among healthy controls and three clinical groups showing different types of developmental psychopathology. Whereas event-related potentials are commonly used because of their high temporal resolution, reflecting processes that are phasic in nature, ERD/ERS may be more related to the energetic mechanisms modulating a person’s cognitive state. This method may therefore be especially suitable for studying longer-lasting processes such as keeping attention to the task and investing effort in the process of extensive serial search, as was required in the current paradigm. In the study at hand, the method of ERD/ERS was used in order to examine whether it would supply extra information with regard to a possible distinction in the efficiency of neurocognitive processes related to selective attention and working memory in children with either PDD-NOS or ADHD.

The results of this study show that the different task manipulations of Relevance, Load and Target/Nontarget all significantly affected overall theta and alpha ERD/ERS. These effects correspond largely to the results from our earlier study on healthy controls (Gomarus et al., 2006). In response to the memory set, a significant effect of Load on theta ERS indicates that theta ERS was smaller for the stimulus set in which three different letters were presented (load3) as compared to the set containing three identical letters (load1). Here, the results of the current study deviate from those of the previous one where no such significant difference was found. Most probably, the higher power in the present study resulted in this different outcome (n=60 against n=15 in the previous one). The larger ERS for the load1 as compared to the load3 condition may be attributed to a more efficient encoding of the load1 memory set (Klimesch, 1999; Klimesch et al., 2001).

In response to the search set, the task manipulations of Load, Relevance and Target/Nontarget all affected theta ERS, with the relevant nontarget stimuli in the high load condition eliciting the largest synchronization. This increased theta ERS to relevant nontargets in the high load condition is probably achieved because only in the relevant category, a serial search is carried out which is exhaustive in nature when no target is present (nontarget category). Furthermore, as was formulated in
the introduction, theta activity has been found to increase under conditions of higher cognitive load (Gevins and Smith, 2000; Krause et al., 2000).

Considering that more intelligent subjects have previously been demonstrated to display more theta activity in response to cognitive load than less intelligent subjects (Doppelmayr et al., 2005; McEvoy et al., 2001), we propose that the enhanced theta ERS in response to the relevant nontargets in the high load condition reflects the efficient use of processing capacity involved in serial search. Consequently, it may reflect a more refined tuning of the individual’s physiological state to the task demands. In this line of reasoning, it may be expected that healthy subjects, who are supposed to show intact information processing, will show a clear interaction of Load by Relevance by Target/Nontarget, indicating a significant increase in theta ERS for relevant nontargets in the high load condition. This effect is most clearly illustrated by the first panel of Figure 2b, in which theta ERS for healthy control children is depicted. For children with developmental psychopathology on the other hand, who have repeatedly been demonstrated to show less efficient information processing, such an interaction may be less pronounced or absent. The last two panels of Figure 2b may indeed suggest that for children in the ADHD and PDD/HD groups this interaction is less pronounced. However, statistical analyses did not reveal significant group differences with respect to this effect. Therefore, no differences in information processing between the control group on the one hand and the patient groups on the other could be concluded from the data. Furthermore, no differences between each of the patient groups, i.e. among children showing different kinds of developmental psychopathology were found.

Alpha ERD, which has been related to processes of attention and alertness (Boiten et al., 1992; Klimesch, 1999), was thought to become differentially affected between children with attention problems on the one hand and children without these problems on the other. If present, such a distinction was thought to become most evident in the search interval, in which relevant stimuli would evoke more alpha desynchronization than irrelevant stimuli. However, here too, no significant effects of Group were found at all.

Thus, although the children could be assigned to different subject groups on the basis of their clinical diagnosis and the outcome of behaviour questionnaires, no significant group effects could be demonstrated with respect to specific psychophysiological measures that were thought to reflect state-related processes of
information processing. The absence of significant group differences may to some extent be ascribed to an inevitable diversity within the patient groups that was still present. Phenotypic heterogeneity is common to both ADHD (see Nigg, 2005 for a review) and PDD-NOS and this may to some extent have distorted the results. Another explanation for the absence of significant differences between the groups may be that the measurement of ERD/ERS is sensitive to any kind of noise elicited during the task. This is especially an issue when testing children with developmental psychopathology and is difficult to correct for.

In sum, the above study on alpha and theta ERD/ERS did not provide additional information with respect to possible differences in processes related to working memory and selective attention between children with either ADHD and/or PDD-NOS. A power problem in the multiple group comparisons may have been an impeding factor in finding significant differences.