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Impaired and enhanced attentional function in children with attention deficit/hyperactivity disorder

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ABSTRACT

Background. The symptom domain of inattention in attention deficit/hyperactivity disorder (ADHD) suggests that there are neuropsychological fields of attention in which subjects with ADHD express deficits. However, studies using differentiated neuropsychological attentional tests in ADHD are lacking.

Method. A consecutive series of 35 subjects with ADHD aged 9–12 years were assessed on a computer-driven neuropsychological test battery for attentional functions. Their performance was classified according to the data of a normative sample of 187 healthy subjects aged 9–12 years, and compared with the performance of 35 matched healthy control subjects.

Results. According to normative data, most ADHD subjects performed on all attentional measures within the normal range. Comparisons with the control group revealed that ADHD subjects reacted faster on all attentional tests, yielding statistical significance for the Go/No go test and the Divided Attention test. They also performed with significantly fewer errors on the Divided Attention test. On the Go/No go test, Visual Scanning test and Attentional Shift test ADHD subjects committed significantly more errors than control subjects.

Conclusions. Our results suggest a differential pattern rather than a deficit pattern of attentional functions in ADHD. It is suggested that the more rapid response style of ADHD subjects leads to a more erroneous performance in self-paced attentional tasks and to a better performance in externally paced attentional tasks. However, neuropsychological tests of attention do not contribute to the clinical diagnosis of ADHD.

INTRODUCTION

Attention deficit/hyperactivity disorder (ADHD) as defined by the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV) (American Psychiatric Association, 1994) represents a syndromic diagnosis including three symptom domains: inattention, impulsivity and hyperactivity. The symptom domain of inattention includes difficulties in sustaining attention, especially in tasks that require effortful mental processing, distractability, difficulties in organizing things and difficulties in focusing attention, resulting in careless mistakes and forgetfulness.

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The symptom domain of inattention as presented by the DSM-IV suggests that subjects with this disorder present with attentional abnormalities which are thought to become evident in psychological, especially neuropsychological tests (Denckla, 1996). Most studies focusing on the assessment of attention in ADHD used the continuous performance test as a measure of sustained attention. Many of these studies found a higher rate of commission errors of ADHD subjects on this test (Corkum & Siegel, 1993). However, apart from this finding no experimental design considered to tap attentional functions has consistently shown impairments of ADHD subjects (Van der Meere *et al.* 1991; Dinklage & Barkley, 1992; Schachar *et al.* 1993; Barkley, 1997).

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There is now a growing body of evidence suggesting that attention is achieved by the interaction of many attentional subcomponents and involves a complex and dynamical interplay of various neuroanatomical networks (Mirsky, 1987; Posner & Petersen, 1990; Mesulam, 1990, 1998). Basically, three attentional components have been defined: selective attention, sustained attention and shifting attention. A further component is represented by the capacity to divide attention. Divided attention relates to the concept of attention as a limited processing capacity (Kahnemann, 1973; Lane, 1982). So far, ADHD subjects have been investigated on paradigms of sustained (e.g. continuous performance test; Corkum & Siegel, 1993), selective (e.g. Go/No go test; Rubia *et al*. 2001) and shifting (Kempton *et al*. 1999; McDonald *et al*. 1999; Cepeda *et al*. 2000; Williams *et al*. 2000) attention, whereas studies on attentional capacity in ADHD are lacking.

In the present investigation, we studied various attentional functions in 35 ADHD subjects aged between 9 and 12 years using a neuropsychological test battery for attentional functions (Zimmermann & Fimm, 1993) being widely used in the clinical diagnosis of neurological or psychiatric disorders of adults and children. ADHD subjects were compared with 35 matched healthy control subjects, and were further classified according to the normative data of a sample of 187 healthy subjects aged 9–12 years. The goals of our study were: (1) to verify whether sustained attention is impaired in ADHD subjects; (2) to investigate whether selective attention, divided attention and the capacity to shift attention are also compromised in ADHD subjects; and (3) to analyse how attentional functions relate to each other and to clinical variables of ADHD.

METHOD

Subjects

The sample comprised 35 subjects with the clinical diagnosis of both ADHD (DSM-IV) (American Psychiatric Association, 1994) and hyperkinetic disorder (ICD-10) (World Health Organization, 1993). All subjects were regularly seen as out-patients at the Child and Adolescent Psychiatric Hospital of the University of Göttingen. Inclusion criteria consisted of: ages between 9 and 12 years; German as the first language; and an IQ of $\geqslant 80$. Subjects with a history of head injury, neurological diseases, tic disorders or substance abuse were excluded. Consensus diagnoses were obtained in all cases from two or more independent raters. Twenty subjects were treated with methylphenidate hydrochloride (10–25 mg/day; half-life: 2–4 h). In 11 of these subjects, the pharmacological treatment started before subjects participated in this study. These subjects were tested at weekends, i.e. 24–30 h after the last dose.

Subjects with ADHD were compared with 35 healthy control subjects. Only subjects without psychiatric or neurological disease were studied. Control subjects were recruited in public schools and perfectly matched ADHD subjects in terms of age and intelligence (Table 1). We did not control for gender as the results of a larger sample of healthy subjects aged 9–12 years ($N=187$, including the 35 control subjects of this study) did not reveal significant gender differences in intelligence or on any attentional measure used in this study (Kunert *et al*. 1996). Our ADHD sample comprised predominantly male subjects (see Table 1). The use of only male control

Table 1. *Demographic and clinical characteristics of all subjects*

	ADHD subjects ($N=35$)	Control subjects ($N=35$)
Age (years), mean (S.D.)*	11·0 (1·4)	10·9 (1·1)
Sex, female : male, *N*†	3 : 32	14 : 21
IQ, mean (S.D.)*, ‡	102 (11)	102 (10)
Hyperactivity rating, mean (S.D.)§		
Parents	1·8 (0·5)	
Teacher	1·8 (0·4)	
DSM-IV diagnoses, *N*		
ADHD, combined type¶	35	
Reading disorder	12	
Disorder of written expression	18	
Mathematics disorder	5	
Conduct disorder	1	
Anxiety disorder	1	
Enuresis	2	

* The groups did not differ significantly (*t* test; $P>0{\cdot}05$).

† The groups differed significantly (Fisher's exact test; $P<0{\cdot}01$).

‡ *Mannheimer Intelligenztest für Kinder und Jugendliche* (*MIT-KJ*) (Conrad *et al*. 1976).

§ According to Conners (1973). Twenty subjects scored above the cut-off point of 1·5, i.e. 2 S.D. above the mean of a normative sample (Sprague *et al*. 1974). Values were available for 29 subjects.

¶ Twenty-two ADHD subjects met the criteria for one or two learning disorders.

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subjects would have resulted in a less accurate intelligence matching (>5 points difference in a subject pair of the same age).

After complete description of the study to parents and subjects written informed consent was obtained. The Ethical Committee of the Medical Faculty of the University of Göttingen had approved of the study design.

Neuropsychological assessment

ADHD subjects were assessed at the Child and Adolescent Psychiatric Hospital of the University of Göttingen. Control subjects were tested in a room of their school. Testing took place in two sessions. In the first session, intelligence was assessed by use of the *Mannheimer Intelligenztest für Kinder und Jugendliche* (Conrad *et al*. 1976). In the second session, attentional performance was tested by use of a computer-driven test battery for the assessment of attentional functions (*Testbatterie zur Aufmerksamkeitsprüfung*) (Zimmermann & Fimm, 1993). This battery is a valid tool for the clinical assessment of attentional functions of adults and children (Földeny *et al*. 2000). The following tests were administered in a pseudorandom order.

Visual Scanning

This test is one of sustained and selective attention. A matrix of 25 squares spaced symmetrically on a computer screen is presented. All squares have each one interrupted line. The target stimulus is a square with an interrupted upper line. Some trails contain the target stimulus (critical trials) and some do not (non-critical trials). The position of the target stimulus varies across critical trials according to a pseudorandom order. Critical and non-critical trials also vary according to a pseudorandom order. Subjects have to press a left-hand button if they detect a target stimulus, or a right-hand button if they cannot detect a target stimulus. The inter-trial interval is 0·5 s. Reaction time as well as false negative (critical trials) and false positive (non-critical trials) responses were recorded. Twenty-five critical and 25 non-critical trials were administered.

Go/No go

Two versions of the task were administered. The first version is a test of impulsivity. An upright cross and a cross rotated about 45° are presented sequentially in a pseudorandom order. The upright cross serves as target stimulus. The second version of the task is a test of selective attention. Five squares with different filling patterns are used as stimuli. Two of these stimuli serve as target stimuli. Subjects have to press a button when a target stimulus appears on the screen, each trial lasts 2 s and the inter-trial interval is 0 s. Reaction time as well as false negative and false positive responses were recorded for both versions respectively. For each version 50 trials were administered.

Attentional Shift

This test measures shifting abilities. A (one-figure) number and a letter are presented simultaneously on the left and right of a computer screen, with the position (left or right) of these stimuli (number or letter) varying across trials according to a pseudorandom order. Subjects have to press a left- or right-hand button corresponding to the position of the target stimulus. The target stimulus (number or letter) alternates between trials. Each trial uses different numbers and letters. The inter-trial interval is 0·5 s. Reaction time and errors were recorded. Fifty trials were administered.

Divided Attention

This test is a dual-task paradigm that measures attentional capacity. Two tasks have to be mastered simultaneously. In the visual task, four asterisks appear in four of 16 positions spaced symmetrically on a computer screen and permanently marked by dots. In steps of 2 s, each one of the four asterisks switches to a different position. Subjects have to press a button when the four asterisks form a square. In the auditory task, two tones (one with a high and another with a low pitch) are presented sequentially in a pseudorandom order. Subjects have to press the same button when two tones of the same pitch follow each other. Each trial lasts 2 s and contains one visual and two auditory stimuli. Visual and auditory target stimuli never appear in the same trial and vary across trials according to a pseudorandom order. The inter-trial interval is 0 s. Reaction time as well as false negative and false positive responses were recorded. One hundred trials were administered.

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Table 2. *Classification of ADHD subjects according to normative data*

	Percentile				
	⩽5th	>5th⩽16th	>16th⩽84th	>84th<95th	⩾95th
IQ	0	8	77	9	6
Attentional measures					
Reaction time (ms)					
Attentional Shift	11	9	57	17	6
Divided Attention	5	6	57	23	9
Go/No go (2 targets)	3	6	60	26	5
Visual Scanning					
Critical trials	3	6	54	23	14
Non-critical trials	9	0	60	14	17

	Percentile		
	⩽16th	>16th⩽84th	>84th
False positive responses/errors			
Attentional Shift	42	49	9
Go/No go (2 targets)	34	34	32
False negative responses			
Divided Attention	17	54	29
Visual Scanning: critical trials	37	49	14

ADHD subjects were classified according to the normative data of a sample of 187 healthy subjects aged 9–12 years (Kunert *et al.* 1996). However, normative data are not available for all attentional measures (see Table 3) used in this study.

Percentages of ADHD subjects scoring below the 5th percentile, between the 5th and 16th percentile, between the 16th and 84th percentile, between the 84th and 95th percentile, or above the 95th percentile are given respectively. The variability of errors and false positive or negative responses is too small to differentiate the 5th and 95th percentiles.

Statistical analyses

Statistical computations were performed using the *Statistical Package for the Social Sciences* (*SPSS for Windows, Version 9.0.1*). All analyses were two-tailed and the alpha was defined as $P<0{\cdot}05$. Additionally to group comparisons and correlational analyses, a discriminant analysis was performed using a backward method (significance level for removing variables: $\alpha=0{\cdot}05$). Internal reclassification was done by using the leave-one-out method (Lachenbruch, 1967).

RESULTS

Classification of ADHD subjects according to normative data

ADHD subjects were classified according to the normative data of a sample of 187 healthy subjects aged between 9 and 12 years (Kunert *et al.* 1996).

Table 2 illustrates that most ADHD subjects performed on all attentional tests within the normal range. Twice as much ADHD subjects as would be expected performed on the test Divided Attention, Go/No go (two targets) and Visual Scanning (critical trials) with a reaction time between the 84th and 95th percentile. On the other hand, the number of ADHD subjects performing on the error scores of the test Attentional Shift, Go/No go (two targets) and Visual Scanning (critical trials) below the 16th percentile was two to three times as high as would be expected.

Group differences

ADHD subjects ($N=35$) were compared with 35 healthy control subjects matched for age and intelligence (Table 1).

Reaction time

ADHD subjects showed on all attentional tests faster reaction times than control subjects (Table 3). These differences yielded significance for the tests Divided Attention ($t=-2{\cdot}2$; $P<0{\cdot}04$), Go/No go (two targets) ($t=-2{\cdot}2$; $P<0{\cdot}04$), and Visual Scanning (critical trials) ($t=-2{\cdot}3$; $P<0{\cdot}02$).

Errors

ADHD subjects committed significantly more errors than control subjects on the Attentional Shift test ($t=2{\cdot}3$; $P<0{\cdot}03$), and more false

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Table 3. *Attentional measures*: *comparison of ADHD and control subjects*

	ADHD subjects ($N=35$)	Control subjects ($N=35$)	
	Mean (S.D.)	Mean (S.D.)	*P*
Attentional Shift			
Reaction time (ms)	1106 (314)	1122 (263)	NS
Errors	9·0 (5·0)	5·8 (3·9)	*
Divided Attention			
Reaction time (ms)	802 (118)	866 (126)	*
False positive responses	1·3 (1·3)	3·5 (3·0)	NS
False negative responses	5·1 (2·8)	6·9 (3·1)	*
Go/No go			
1 target			
Reaction time (ms)	467 (94)	492 (91)	NS
False positive responses	6·2 (5·2)	5·2 (5·0)	NS
False negative responses	1·7 (2·6)	0·6 (1·3)	*
2 targets			
Reaction time (ms)	630 (75)	672 (85)	*
False positive responses	1·3 (1·3)	1·0 (1·3)	NS
False negative responses	0·1 (0·3)	0·1 (0·3)	NS
Visual Scanning			
Critical Trials, reaction time (ms)	3677 (1174)	4213 (1105)	*
Non-critical Trials, reaction time (ms)	6775 (2729)	6917 (1948)	NS
False positive responses	1·0 (1·5)	0·7 (1·0)	NS
False negative responses	5·0 (4·1)	3·0 (2·4)	*

Statistical comparison by *t* test: $*P<0·05$; NS, not significant.

negative responses on the Go/No go test (one target) ($t=2·2$; $P<0·03$) and the Visual Scanning test ($t=-2·6$; $P<0·02$). However, ADHD subjects committed significantly fewer false negative responses than control subjects on the Divided Attention test ($t=-2·5$; $P<0·02$). The number of false positive responses did not differ between groups on any attentional test (Table 3).

Discriminant analysis

A stepwise discriminant analysis was performed with 15 attentional measures (as listed in Table 3). The procedure resulted in a discriminant function with 3 variables that was highly significant (Wilks' $\lambda=0·74$; $P<0·01$). The three variables were: Divided Attention, false negative responses (standardized canonical discriminant function coefficient $c=-0·73$; $P<0·01$), Visual Scanning, false negative responses ($c=0·57$; $P=0·05$) and Attentional Shift, errors ($c=-0·53$; $P<0·05$). Internal reclassification was done using the leave-one-out method (Lachenbruch, 1967). Twenty-six ADHD-subjects and 24 control subjects, that is a total of 50 subjects (71% of all subjects) were reclassified correctly.

Relationships between attentional measures

Correlational analysis of ADHD and control subjects ($N=70$) revealed that numbers of errors in the Go/No go test (one target) were negatively related to reaction time on this test (false negative responses, $r=-0·51$, $P<0·001$; false positive responses, $r=-0·58$, $P<0·001$), indicating worse performance of subjects with high reaction speed. Similar relationships were obtained when ADHD subjects ($N=35$) were considered alone (false negative responses, $r=-0·53$, $P<0·001$; false positive responses, $r=-0·61$, $P<0·001$).

However, numbers of false negative responses in the Divided Attention test were positively related to reaction time, indicating better performance of subjects with high reaction speed (ADHD subjects and control subjects, $r=0·29$, $P<0·02$; ADHD subjects alone, $r=0·34$, $P<0·05$).

Influence of the severity of ADHD symptoms

The severity of symptoms of ADHD subjects as rated according to Conners (1973) (teacher rating; see Table 1) was negatively related to reaction time ($r=-0·41$; $P<0·05$) and positively related to the amount of false positive responses

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($r = 0{\cdot}49$; $P < 0{\cdot}05$) on the Go/No go test (one target). Subjects with high symptom levels reacted faster and performed more false positive responses than subjects with low symptom levels.

Influence of learning disorders

A significant proportion of subjects met the criteria of a learning disorder according to DSM-IV (Table 1). Comparison of subjects with ADHD alone ($N = 13$) *versus* subjects with ADHD and learning disorders ($N = 22$) however revealed no significant differences in intelligence or any attentional measure (U tests, $P\text{s} > 0{\cdot}20$).

Effects of stimulant medication

Eleven ADHD subjects were receiving stimulant medication. These subjects were tested at weekends, i.e. 24–30 h after the last dose. Comparison of these subjects with 11 unmedicated ADHD subjects matched for age and IQ revealed significant differences (U tests) on the Go/No go test (one target). Medicated subjects reacted slower and performed with less false positive and negative responses than unmedicated subjects (reaction time, 529 ms *v.* 447 ms, $Z = -2{\cdot}27$; false positive responses, 2·1 *v.* 7·2, $Z = -2{\cdot}62$; false negative responses, 0·2 *v.* 1·5, $Z = -2{\cdot}48$; all $P\text{s} < 0{\cdot}05$). Medicated subjects were also rated as less hyperactive on Conners' scale (teacher rating) than unmedicated subjects (1·5 *v.* 2·0, $Z = -1{\cdot}9$; $P < 0{\cdot}05$).

DISCUSSION

Summary of findings

In the present investigation we assessed attentional functions by aid of an attentional test battery in a sample of 35 children (aged 9–12 years) with ADHD and 35 matched healthy control subjects. According to normative data, most ADHD subjects performed on all attentional measures within the normal ranges (see Table 2).

Compared with control subjects, ADHD subjects reacted significantly faster on the Divided Attention and Go/No go (two targets) tests (see Table 3). They also performed with significantly fewer false negative responses on the Divided Attention test. On the other hand, ADHD subjects performed with significantly more false negative responses on the Go/No go test (one target) and the Visual Scanning test, and significantly more errors on the Attentional Shift test.

A discriminant analysis yielded a significant function with the variables Divided Attention, false negative responses (on which ADHD subjects performed better than controls), and Visual Scanning, false negative responses and Attentional Shift, errors (both on which ADHD subjects performed worse than controls).

ADHD subjects with or without learning disorders did not differ on any attentional measure. However, ADHD subjects receiving stimulant medication performed better on the Go/No go (one target) test and were rated as less hyperactive than unmedicated ADHD subjects. Accordingly, the severity of hyperactivity symptoms was correlated with the Go/No go (one target) test, indicating better performance of ADHD subjects with lower symptom levels.

Pattern of attentional functions in ADHD

Our results suggest a differential pattern rather than a deficit pattern of attentional functions in ADHD. The ADHD subjects of our study were impaired on the Go/No go (one target) test. This test connotes a test of impulsivity as subjects are required to respond to or inhibit responding to very similar stimuli. Our ADHD subjects were also impaired on the Attentional Shift test and the Visual Scanning test. These tests require a self-paced responding of subjects. Self-paced tasks give the opportunity to choose one's own response speed, whereas externally paced tasks present a fixed number of stimuli in a given time. The Divided Attention test has an externally paced stimulus presentation. The ADHD subjects of this study were facilitated on this test. The rather subtle nature of the attentional deficits of our ADHD subjects (see Table 2) as well as their facilitated performance on the Divided Attention test raises the idea that the attentional deficits of ADHD subjects may be secondary to another deficit.

The performance pattern of our ADHD subjects may be explained by their faster response style (see Table 3). A faster response style leads to a more erroneous performance in self-paced tasks, where ADHD subjects were often described spending less time looking at the stimuli (Sonuga-Barke *et al.* 1992; Denckla, 1996; Barkley, 1997). However, fast reaction time

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seems to make it easier to respond to an externally paced dual-task paradigm (Divided Attention test): ADHD subjects responded faster and more accurately than controls, and faster reaction times on the Divided Attention test were significantly related to better performance on this test.

Magnetic resonance studies have demonstrated size reductions in frontal and striatal regions of ADHD subjects, and molecular genetic studies have shown that the diagnosis of ADHD is associated with polymorphisms in some dopamine genes (Swanson *et al.* 1998). It seems likely that abnormalities in fronto-striatal neural circuits are mainly responsible for the motor and hyperactivity symptoms of ADHD subjects. Fronto-striatal abnormalities may also be responsible for the deficits of intentional behaviour and motor and self-control, which are frequently described in ADHD subjects (Van der Meere *et al.* 1991; Denckla, 1996; Barkley, 1997; Kempton *et al.* 1999; Rubia *et al.* 1999, 2001; Williams *et al.* 2000; Sergeant *et al.* 2002). We suggest that the pattern of attentional performance found in our ADHD subjects may be best explained as secondary to these deficits.

Implications for the clinical diagnosis of ADHD

When classified according to normative data, most ADHD subjects of our study performed on all attentional tests within the normal range (see Table 2). The attentional test battery used in this study is a widely used and valid tool for the clinical assessment of neurological and psychiatric diseases of adults and children (Földeny *et al.* 2000), and has proven to be of high sensitivity especially to detect attentional deficits in subjects with frontal lobe damage. Most of our ADHD subjects scored on Conners' scale more than two standard deviations above the mean of a normative sample (see Table 1), and were clinically considered as moderately to strongly affected cases. Clinical diagnoses verified in each case the presence of persisting symptoms of inattention.

Our data suggest that neuropsychological tests of attention do not contribute to the clinical diagnosis of ADHD. Only the minority of our ADHD subjects scored on the attentional tests below the 16th percentile of a normative sample (see Table 2). Although significant impairments of ADHD subjects were found on a number of attentional measures, mean differences between ADHD and control subjects were on all attentional measures rather small (see Table 3). The discriminant analysis yielded three significant variables. However, one of these variables (false negative responses in the Divided Attention test) represents a performance being significantly better than that of control subjects and therefore may be not useful for the clinical diagnosis of a disorder. To summarize, neither group comparisons, normative classification of individual subjects, nor discriminant analysis proves to be valuable for the clinical diagnosis of ADHD.

The rather subtle differences which emerged between ADHD and control subjects of our study may be best explained as caused by the faster response style of our ADHD subjects, and by their poorer responding in self-paced situations. The impression of inattention in everyday school or home life may evolve because ADHD subjects are hyperactive and often fail to inhibit or delay responding, or to exhibit well paced responding (Denckla, 1996). However, besides this deficit, ADHD subjects seem to possess an advantage in situations, in which many stimuli have to be attended and responded to at the same time. In everyday life, these situations may be as frequent as situations demanding selective and sustained attention (Kahnemann, 1973; Lane, 1982).

Methodological limitations

The attentional test battery used in this study is a valid tool for the clinical assessment of attentional functions of adults and children. However, the attentional tests used in this study lack the complexity of multivariate experimental designs which are necessary to explore the attentional deficits of ADHD subjects in more detail.

Our ADHD sample comprised 32 male and 3 female subjects but was compared with a control group containing 21 male and 14 female subjects (see Method section). We could not find gender differences in our normative sample on any attentional measure used in this study (Kunert *et al.* 1996). However, we cannot rule out the possibility that gender differences exist in the attentional functions of ADHD children.

ADHD subjects with ($N=13$) or without learning disorders ($N=22$) did not differ in intelligence or on any attentional measure. Due to the small samples and non-parametric testing

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procedures the power of our tests might have been limited. However, according to diagnostic experience group differences of one-half of standard deviation units or more should be considered as clinically relevant. Aiming at group differences of this magnitude sample sizes of $\geqslant 12$ subjects account for a statistical power of 0·80 (effect size) and therefore are sufficient to detect clinically relevant differences.

ADHD subjects receiving stimulant medication ($N=11$) performed better on a test of impulsivity (Go/No go, one target) than matched unmedicated ADHD subjects ($N=11$), although medicated subjects were tested 24–30 h after the last dose. Medicated subjects were also rated as less hyperactive than unmedicated subjects. It might be concluded that stimulant medication has a long lasting positive effect on the attentional functions of ADHD children. However, a longitudinal study design is needed to clarify this issue.

Conclusion

Differentiated neuropsychological tests of attention do not contribute to the clinical diagnosis of ADHD.

Future studies comparing the predominantly inattentive and predominantly hyperactive-impulsive ADHD subtype should clarify which cognitive deficit underlies the clinically observed inattention, and whether this deficit can be sufficiently separated from deficits represented by the symptom domains of hyperactivity and impulsivity.

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