**The influence of environment, behavior, and attention deficits on
cognitive development in school-aged children**

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**The influence of environment, behavior, and attention deficits on
cognitive development in school-aged children**

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The gods did not reveal,
From the beginning,
All things to us;
But in the course of time,
Through seeking we may learn,
And know things better.

But as for certain truth,
No man has known it,
Nor will he know it;
Neither of the gods,
Nor yet of all the things of which I speak.
And even if by chance he were to utter
The final truth,
He would himself not know it;
For all is but a woven web of guesses.

Xenophanes, ±500 Before Christ

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An introduction to Attention-Deficit/Hyperactivity Disorder (ADHD)

Abstract

Over the past decades, it has become clear that ADHD is a prevalent and serious condition, which can influence the entire life span of the affected individual. Since Still's description in 1902 of a behavioral pattern similar to ADHD, a voluminous literature has been published about the subject, capturing the interest of researchers and clinicians from many disciplines (e.g., child neurology, neuropsychology, and psychiatry). Recent advances in structural and functional brain imaging techniques (such as PET and (f)MRI), permitting the study of the human brain in vivo, have shown, for instance, abnormalities in brain structure and brain function in children with ADHD when compared to healthy controls. Knowledge of the neuropsychological characteristics, which are believed to be the manifestation of an underlying brain abnormality or dysfunction, of children with ADHD is growing. Executive functions are especially thought to be important in this context. Although the explosion of media and scientific attention has served to increase our awareness and knowledge of ADHD, there is still misunderstanding about the condition and a continuing need for up-to-date, comprehensive, and scientifically based knowledge of and discussion on the subject. Therefore, the aim for this thesis was to increase our knowledge of ADHD, and more specifically of the relation between neuropsychological functioning and ADHD. In the first chapter of the thesis, an outline is given of current knowledge of ADHD in terms of history, prevalence rates, sex differences, etiology, and outcome. The limitations of existing data are also discussed. The link between these limitations and the research presented here is covered more extensively in subsequent chapters.

Introduction

History of ADHD

In 1902, during a series of published lectures to the Royal College of Physicians, Still presented a group of children who were overactive, unable to concentrate, often aggressive, defiant, resistant to discipline, and excessively emotional. He believed that these children displayed a major ‘lack in moral control of behavior’, and that the behavioral and learning deficiencies that arose later in development could be accounted for by early, mild and undetected damage to the brain. Additionally, Tredgold (1908) concluded a few years later that the moral deficiency of these children resulted more specifically from an organic abnormality of the higher levels of the brain.

The idea of an organic abnormality underlying the symptomatology described above persisted for several decades, as reflected by the many diagnostic terms used. Examples of these terms are ‘brain injured child’, which was introduced in 1947 by Strauss & Lethinen, ‘Minimal Brain Damage’ and ‘Minimal Brain Dysfunction (MBD)’. In the early 1970s these diagnostic terms were eventually abandoned, mainly because there was no evidence of brain pathology and, more specifically, no evidence of structural or functional brain abnormalities at the time. It was in 1972, after the publication of the DSM-II (American Psychiatric Association, 1968), that a trend was born by which emphasis was on the behavioral patterns (that is, symptoms) instead of on the hypothesized etiology.

Today, the condition that is characteristically most similar to Still’s ‘defect in moral control’ or Strauss’ ‘Brain Injured Child’ is called ‘Attention-Deficit/Hyperactivity Disorder (ADHD)’. According to the latest edition of the DSM (American Psychiatric Association, 1994), ADHD can best be defined by means of comprehensive terms such as attention deficits, impulsive behavior, and hyperactivity (see appendix A for a complete description). Because almost all children will show some of the predefined characteristics at some stage in their life, one can only speak of ADHD under strict conditions, including definitions related to the duration of symptomatology (e.g., the behavior has to be manifest over a period of at least 6 months), severity (e.g., the behavior has to be present in at least two domains, for instance at home and at school), and concordance between relatives of the child (e.g., both the teacher and the parent have to observe the abnormal behavior).

In sum, it can be concluded that, over the past centuries, the condition which is presently known as Attention-Deficit/Hyperactivity Disorder (ADHD) underwent many transformations in terminology and definition, and that significant adjustments in terms of the descriptive and etiological components of behavior have been made in this context.

Prevalence rates, sex differences, comorbidity, and outcome

ADHD is one of the most frequently monitored developmental syndromes worldwide and is known to occur in several cultures. Prevalence estimates fluctuate between 1% and 20%, with an average of 3 - 5% for the general population (Barkley, 1998; Kroes et al., 2001), depending on how strictly criteria are applied, cultural differences, and the degree of consensus between caregivers, teachers, and physicians (Lambert, Sandoval, & Sassone, 1978). Both in clinical and epidemiological samples, it has been found that ADHD is much more common in boys than in girls – 9 to 1 in clinical samples and 4 to 1 in epidemiological samples (Cantwell, 1996). Today, the accuracy of these estimates is being questioned (Baumgaertel, Wolraich, & Dietrich, 1995; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996). As shown recently, girls seem to have primarily inattentive and cognitive problems and less of the aggressive/impulsive conduct symptomatology that would probably lead to an earlier referral (Abikoff et al., 2002).

In addition, comorbidity has been revealed to be an important aspect to consider when dealing with a child suffering from ADHD. For example, in 50 - 80% of the cases, ADHD occurs simultaneously with other psychiatric or developmental problems (reviewed by Biederman, Newcorn, & Sprich [1991], and Jensen, Martin, & Cantwell [1997]), although the actual prevalence of comorbidity may vary across different types of samples depending on whether the sample is clinical (pediatric or psychiatric) or epidemiological (Busch et al., 2002). The most important comorbid syndromes and/or co-occurring disorders are (i) Oppositional Defiant Disorder and Conduct Disorder (at school age estimates range from 40 - 90%), (ii) Anxiety (approximately in 25% of the cases) and Mood Disorders (15 - 20%), (iii) Learning Disabilities (20%), (iv) minor forms of Pervasive Developmental Disorders, (v) Gilles de la Tourette syndrome, and (vi) the Developmental Coordination Disorder (as reviewed by Biederman et al. [1991], Bird, Gould, & Staghezza, [1993], Busch et al. [2002], Fergusson, Horwood, & Lynskey [1993], Hinshaw [1992], Jensen et al. [1997], Russo & Beidel [1994], Scahill et al. [1999], Szatmari, Offord, & Boyle [1989], and Tannock [1998]). Comorbidity often has consequences for the diagnostic process and can have an impact on the natural history of the disorder and on the success of treatment programs. For instance, several authors have stated that the neuropsychological deficits and the outcomes (e.g., drug use and driving-related accidents) of children with a concurrent ADHD and Conduct Disorder are worse than those of children with ADHD or those of children with Conduct Disorders alone (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993; Halperin et al., 1990; Herrero, Hechtman, & Weiss, 1994; Mannuzza, Gittelman-Klein, Bessler, Malloy, & Lapadula, 1993; Moffitt, 1990; Moffitt & Henry, 1989). Assessment and treatment of comorbid disorders is, therefore, often as important as assessment and treatment of ADHD (Prins & Ten Brink, 2000; Tannock, 1998).

Next, in contrast to earlier beliefs, follow-up studies have consistently documented ADHD symptoms to persist in adolescence and young adulthood (Hechtman, Weiss, Perlman, & Amsel, 1984; Weiss & Trokenberg Hechtman, 1993). Although relatively little is known about ADHD children as young adults, the information that does exist suggests that at least 60% of the children with ADHD will continue to have symptoms of ADHD as they grow up (Barkley, 1996). For instance, interpersonal problems continue to bother as many as 75% of the children/young adults, and depression and low self-esteem are also common. Therefore, the problems that adults have to face as a consequence of earlier ADHD symptoms in childhood range from residual ADHD symptoms that impair home or work adjustment to depression, substance abuse, low self-esteem, accident proneness, and anti-social personality (Weiss & Trokenberg Hechtman, 1993; Wender, Reimherr, & Wood, 1981).

In conclusion, ADHD is a prevalent, complex, and serious syndrome affecting the entire life span of an individual suffering from it. It is thus extremely important to learn more about its etiology, diagnostic trademarks, and treatment.

Etiology of ADHD

Over the years, many researchers have studied the etiology of ADHD. Although results are at times inconsistent, much has been learned in the past decades. Preliminary results lead to the conclusion that no single etiological factor can explain all cases of the clinical syndrome ‘ADHD’ and that more likely an interaction of both psychosocial and biological factors leads to a final common pathway of the syndrome. In contrast to the voluminous literature written about the subject, capturing the interest of researchers and clinicians from many disciplines (Tannock, 1998; Weiss, 1996), only the two leading models will be discussed here, namely (A) the influence of genetics and (B) the neurobiological models that have an emphasis on structural and biochemical impairments.

ADHD: Is the syndrome heritable?

The first model concerns the separate and interactive effects of genetics in childhood psychiatric syndromes. If there is a genetic component in ADHD, the syndrome should be more prevalent among biological relatives of a child with ADHD than among relatives of control subjects. Over the past decades, several studies have reported that ADHD is diagnosed at least 5 times more often among the relatives of ADHD children than among other families. In addition, high rates of disorders or syndromes, such as behavioral disorders (like conduct disorder and oppositional defiant disorder), anxiety disorders, and mood disorders, were found among first-degree relatives of individuals suffering from ADHD (e.g., Biederman et al. [1986]). Also, twin and adoption studies support the hypothesis that there is a genetic component in ADHD, even after controlling for environmental factors (e.g., Morrison & Stewart [1971] and Van der Oord, Boomsma, &

Verhulst [1994]).

However, caution in interpreting these results is warranted for several reasons. For one, as mentioned earlier, ADHD is found to occur simultaneously with other psychiatric or developmental problems in 50 - 80% of the cases. Comings et al. (2000) reported that some of these co-occurring disorders or syndromes also have a genetic component. Therefore, in children with both ADHD and other disabilities or syndromes, the genetic effects may be due to the presence of the co-occurring symptoms in the group and not so much due to ADHD. However, after controlling for comorbidity, consistent evidence still points toward an increased prevalence of both childhood and adulthood ADHD in first-degree and second-degree relatives of ADHD probands, a relation that applies to both males and females (reviewed by Faraone & Biederman [1994]).

ADHD: From a neurobiological perspective

Until the 1980s, a main cause of ADHD symptomatology was believed to be an organic lesion in the brain, resulting primarily from brain infection, trauma, or other injuries and complications that occurred during pregnancy or at the time of delivery. Support for this theory comes, for example, from the finding that brain damage, particularly hypoxic/ischemic types of insults, is associated with greater attention deficits and hyperactivity (Cruickshank, Eliason, & Merrifield, 1988; O'Dougherty, Neuchterlein, & Drew, 1984). In addition, similarities have been found between ADHD symptoms and the behavioral characteristics of humans with lesions or injuries to the frontal lobes in general and the prefrontal lobes in particular (Benton, 1991; Heilman, Voeller, & Nadeau, 1991; Levin, 1938; Mattes, 1980). Both ADHD and frontal lobe patient groups display deficits in inhibition, sustained attention, regulation of motivation and emotion, and the capacity to organize behavior as a function of time. In contrast, an actual history of significant brain injuries is reported in only 10% of ADHD children. Thus the occurrence of injuries is unlikely to account solely for ADHD in most affected children (Rutter, 1977).

In addition, recent advances in structural and functional brain imaging techniques (such as PET and (f)MRI) that permit the study of the human brain in vivo have led to a new understanding of developmental disorders. Also, these improvements have led to non-invasive techniques that allow the visualization of normal human brain development. Knowledge of the normal developmental changes and variability in terms of brain structure and brain function across childhood and adolescence will lead eventually to the identification of differences associated with psychopathology such as ADHD (Tannock, 1998).

Appendix A. Diagnostic Criteria for Attention-Deficit/Hyperactivity Disorder (ADHD).

	Criteria for ADHD
a.	Either (1) or (2):
1.	<i>Inattention</i> Six (or more) of the following symptoms of inattention have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:
a.	Often fails to give close attention to details or makes careless mistakes in schoolwork, work or other activities;
b.	Often has difficulty sustaining attention in tasks or play activities;
c.	Often does not seem to listen when spoken to directly;
d.	Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions);
e.	Often has difficulty organizing tasks and activities;
f.	Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework);
g.	Often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books or tools);
h.	Is often easily distracted by extraneous stimuli;
i.	Is often forgetful in daily activities;
2.	<i>Hyperactivity/Impulsivity</i> Six (or more) of the following symptoms of hyperactivity/impulsivity have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:
a.	Often fidgets with hands or feet or squirms in seat;
b.	Often leaves seat in classroom or in other situations in which remaining seated is expected;
c.	Often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings or restlessness);
d.	Often has difficulty playing or engaging in leisure activities quietly;
e.	Is often “on the go” or often acts as if “driven by a motor”;
f.	Often talks excessively;
g.	Often blurts out answers before questions have been completed;
h.	Often has difficulty awaiting turn;
i.	Often interrupts or intrudes on others (e.g., butts into conversations or games).
B.	Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before age 7 years.
C.	Some impairment from the symptoms is present in two or more settings (e.g., at school (Granholm, Chock, & Morris, 1998) and at home).
D.	There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.
E.	The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

In the case of ADHD, imaging studies point toward structural changes in brain regions. For example, several authors have reported a smaller right prefrontal

cortex in ADHD (Filipek et al., 1997; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopoulos, 1990), differences in the volume of the caudate nucleus with a corresponding loss or reversal of the asymmetry found in normal controls (Castellanos et al., 1994; Castellanos et al., 1996; Filipek et al., 1997; Hynd et al., 1993), a smaller globus pallidus (Aylward et al., 1996; Singer et al., 1993), and a decreased volume of the corpus callosum (including the posterior “splenium” region and the genu, rostrum, and rostral body in the anterior region) (Baumgardner et al., 1996; Castellanos et al., 1996; Hynd et al., 1991). Finally, a smaller total cerebral volume, reduced white matter in the basal ganglia structures, and a smaller cerebellum have been reported (Castellanos et al., 1996; Filipek, 1999). Results derived from functional neuroimaging experiments support the involvement of the above-mentioned areas as an etiological factor underlying ADHD symptomatology (Baving, Laught, & Schmidt, 1999; Ernst et al., 1994; Sieg, Gaffney, Preston, & Hellings, 1995; Zametkin, Liebenauer, Fitzgerald, & al., 1993; Zametkin, Nordahl, Gross, & al., 1990).

The finding, that Central Nervous System (CNS) stimulants (such as dextroamphetamine [Dexerine] and methylphenidate [Ritalin]) tend to promote normalization of behavior in children suffering from symptoms of inattentive, restless, and/or impulsive behavior, supports the hypothesis that there is an underlying brain abnormality in ADHD. The term ‘CNS stimulants’ refers to those medications that raise the level of activity, arousal, or alertness. A number of studies (including cerebral blood flow or positron emission tomography [PET]) have shown that CNS stimulants increase activity in the striatum, the bilateral orbital-frontal areas, and the left sensorimotor and parietal areas. Also the connections between the orbital-frontal and the limbic regions are found to be activated during treatment with stimulants (Lou, Henriksen, Bruhn, Borner, & Nielson, 1989; Lou, Henriksen, & Bruhn, 1984; Redman & Zametkin, 1991; Vles et al., 2003). The mechanisms underlying the positive effects of these drugs on behavior are still insufficiently understood. Gaultieri, Hicks, & Mayo (1983) hypothesized that the stimulants act to canalize or decrease fluctuation and variability in arousal, attention, and CNS reactivity, thereby enhancing the persistence of responding and increasing cortical inhibition. Still others (e.g., Haenlein & Caul [1987]) propose that stimulants decrease the threshold for reinforcement through enhancement of the arousal of the CNS behavioral activation system, thereby creating a persistence of responding to tasks or activities. Stated differently, activities in which the organism engages (particularly those that involve sustained effort) become more reinforcing, resulting in prolonged responding to them relative to responding under non-medication conditions. Caution is needed when interpreting these hypotheses and related data, because the studies investigating the effects of medication on ADHD symptomatology have their limitations.

In conclusion, the results are very encouraging because the above-mentioned localized cerebral structural abnormalities and dysfunctions found in ADHD are

consistent with theoretical models of an abnormal frontal-striatal function in ADHD and with attention network hypotheses. Also, the volumetric differences in both the cerebellum and the basal ganglia are of interest given the evidence that both brain regions have neuronal links with the prefrontal cortex (Middleton & Strick, 1994; Papa, Berger, Sagvolden, Sergeant, & Sadile, 1998; Papa, Sergeant, & Sadile, 1998), and that these connections are part of the anatomical substrate regulating higher-order cognitive processes, such as working memory, rule based learning, and planning (e.g., Middleton & Strick [1994]). However, caution in the interpretation of the neuroanatomical evidence is still warranted, because of sample bias (e.g., small sample sizes, sex differences, limited data on neuropsychological characteristics and handedness of the participants), inconsistencies in findings for both normal controls and children with ADHD, etc.

Information processing in ADHD: a neuropsychological perspective

The above-mentioned hypothesis of an underlying brain dysfunction is supported further by neuropsychological evidence reflecting a higher order neuropsychological dysfunction in ADHD (Vaijda et al., 1998). In school-aged children, cognitive deficits are hypothesized to be a core part of ADHD symptomatology and are thought to play a major role in the difficult adaptation of children suffering from this disorder (Seidman, Biederman, Faraone, Weber, & Ouellette, 1997). As a group, these children tend to exhibit sub-average or a relatively poor performance on various classical neuropsychological tests measuring both input-and output-related information processes. For example, a deficiency was found in sustained attention or vigilance, as observed by an increased variability in test performance and a decreased accuracy (Barkley, 1998). In addition, children with ADHD had a poorer performance on several aspects of executive functioning (such as organization and complex problem solving), non-verbal working memory, internalization of speech, self-monitoring and self-regulation (Barkley, 1998; Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). The results concerning the cognitive strengths and weaknesses in ADHD are unfortunately at times still confusing, and information processing models and/or theories to support the choice of which tests to use in experimental designs are often lacking. Future research in this area should therefore be based on theoretical models.

Examples of theories that relate neuropsychological functioning and ADHD and which should be studied more extensively, are (1) Barkley's disinhibition theory, (2) the theory of a time perception deficit in ADHD, and (3) the cognitive-energetic model. Barkley's disinhibition theory states that the construct of impulsiveness (i.e., poor behavioral inhibition) is a central deficit in ADHD. Children suffering from the disorder fail to inhibit or delay a behavioral response, which secondarily causes the observed deficits in executive functioning and motor output (Barkley, 1998; Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). Another theory concerning a cognitive deficit in ADHD is associated with time per-

ception. Several authors have stated that a deficit in time estimation or an altered sense of time may explain several problems related to ADHD, such as problems with waiting, delaying responses, and with delaying gratification (Barkley, Koplowitz, Anderson, & McMurray, 1997; Rubia, Taylor, Taylor, & Sergeant, 1999; Rubia et al., 2001; Smith, Taylor, Rogers, Newman, & Rubia, 2002; Sonuga-Barke, Saxton, & Hall, 1998; Stevens, Stover, & Backus, 1970). A third theory is the cognitive-energetic model of information processing. This model states that the fundamental problem in ADHD is not so much a structural cognitive limitation (as stated in, for instance, Barkley's model) but more an energetic limitation, and that the key symptoms of ADHD (i.e., poor attention capacity, restlessness, and a lack of impulse control) are mainly caused by state factors, such as presentation rate of stimuli, time-on-task, reward, and external control and by ability factors per se (e.g., August, 1987; Barber, Milich, & Welsh, 1996; Borchering et al., 1988; Borger & Van der Meere, 2000; Van der Meere, Vreeling, & Sergeant, 1992; Van der Meere, Stemerink, & Gunning, 1995). In conclusion, the outcome of empirical research on this issue has been less consistent than expected, and there are insufficient data to support any one theory.

Limitations of available research

Although an explosion of articles written over the last decades has increased our awareness and knowledge of ADHD, these articles still have several limitations. For instance, much of the research performed on the nature of ADHD is exploratory or descriptive and lacks a theoretical basis (Taylor, 1996). This is unfortunate, as only the acceptance or rejection of a hypothesis based on theory will lead to further insight and additional hypotheses regarding a disorder such as ADHD. Furthermore, only few studies involving childhood ADHD had a longitudinal prospective design, whereas this type of research is needed to provide information concerning the (cognitive) development of children disabled by a disorder of attention, hyperactivity, and impulsivity early in life. Because the behavioral expression of ADHD changes over time, and at least some symptoms are present before the age of 7 years (American Psychiatric Association, 1994), and because the period between the ages 5 and 7 years is believed to be critical for later cognitive development (Bernstein, 1989; Riva, Nichelli, & Devoti, 2000), cognitive development may well be influenced most by the early expression of ADHD. Research is still needed to confirm this hypothesis.

Next, there is a marked lack of information concerning the specificity of findings regarding ADHD. In most cases, ADHD co-occurs and possibly interacts with other syndromes or disorders, such as conduct disorder, learning disabilities, or anxiety. In the literature, both ADHD and these co-occurring syndromes have been associated with deviations from normal development (e.g., in cognitive performance). To ensure that having the syndrome 'ADHD' contributes to a specific pattern of deviations, one has to control for these co-morbid factors. There-

fore, future research should include pathological control groups and/or to define ADHD⁻ (minus comorbid disorder) and ADHD⁺ (plus comorbid disorder) groups to ascertain the specificity of findings in relation to ADHD. The lack of sufficient control for confounding or mediating factors (such as deviations in intelligence, reading skills, medication usage, and sex differences) has been emphasized earlier. Future studies concerning developmental disorders in general and ADHD in particular should take the above-mentioned points into consideration, thereby guaranteeing applied and suitable diagnostic and treatment strategies for children with these disorders.

Goals of the thesis

As mentioned above, ADHD seriously affects the entire life span of the affected individual and his/her environment. The development of children suffering from ADHD is believed to be significantly deviant from what is considered to be normal, that is, it deviates from the behavior patterns humans (and within a certain range) express in a certain period of their development. Currently available information about the syndrome has a number of limitations, and thus it is essential to increase our knowledge of ADHD. From this perspective, the main focus of the present thesis was two-fold, namely:

- (a) To increase knowledge about ADHD. Although the syndrome can be viewed from a number of perspectives (e.g., child neurology or neuropsychology), it was decided to examine the cognitive development of children with ADHD more closely in the studies described in this thesis. From the literature it is known that ADHD co-occurs frequently with other syndromes, such as learning disabilities and conduct disorder. In order to ensure that the syndrome 'ADHD' contributes to a specific pattern of deviations, one has to control for these co-morbid factors. Thus studies should include pathological control groups to ascertain the specificity of findings in relation to ADHD. In this context, the lack of sufficient control for confounding or mediating factors (such as deviations in intelligence, reading skills, medication usage, and sex differences) was emphasized earlier. In the present thesis, these confounding and/or mediating factors and comorbidity were taken into account in the studies of the cognitive development of children with ADHD.
- (b) The expression of behavior in children is believed to lie on a continuum with normal behavior on the one end and abnormal or clinical behavior on the other, with children who display minor or sub-clinical behavior problems being intermediate (see figure 1). To understand children with ADHD better, it is necessary to extend current knowledge of the influence of behavior (as measured on a continuum from normal to clinical)

on executive control functions in children. This was the second goal of the studies described in this thesis. Also, the influence of environment and biology as being additive to the behavioral characteristics of the child was also investigated.

Figure 1. The continuum of behavior expression.

Study of Attention Disorders Maastricht: The design

In order to achieve the goals set above, namely to extend knowledge concerning the cognitive development of healthy children and children suffering from ADHD, additional research is needed. The research presented in the chapters of this thesis is embedded in an extensive, longitudinal research program entitled 'Study of Attention Disorders Maastricht (SAM)'.

The SAM study consists of four separate phases (for an expanded description of the study, see Kalff et al. [2001] and Kroes et al. [2001]), as briefly described here (see table 1). *Stage 1: Selection of participants.* During this phase, all caregivers of children following the second grade of normal kindergarten in the Southern Netherlands were asked to give permission for participation in the SAM study. In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. Based on the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), three groups were selected, namely (A) a group of children scoring high either on the CBCL externalizing broad-band scale ($> 90^{\text{th}}$ percentile) or the CBCL Attention problems subscale ($> 95^{\text{th}}$ percentile); (B) a group of children scoring within a clinical range on the CBCL Internalizing scale ($> 90^{\text{th}}$ percentile), but without fulfilling the criteria for group A membership; (C) a control group with low CBCL total problem scores ($< 90^{\text{th}}$ percentile) and matched to group A and B in terms of age (± 2 months), sex and school (urban vs. rural). *Stage 2: First neuropsychological assessment.* After inclusion, cognitive assessment of the selected children was completed by a neuropsychologist and well-trained assistants (see for a detailed description: Kalff et al. [2002]).

Stage 3: Child Psychiatric Interview. The caregivers of the selected children were asked to participate in a screening interview in which the semi-structured, psychiatric interview, called the ADIKA was used (Dutch translation of the DICA: caregiver version; Herjanic & Reich, 1982; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). The ADIKA asks questions about several DSM-III-R-classifications for childhood psychopathology¹ (American Psychiatric Association, 1987), using a systematic, horizontal approach. Specifically for the classifications ‘ADHD’ and ‘Pervasive Developmental Disorder’, substantial adjustments were made to the interview according to the criteria set by the DSM-IV (American Psychiatric Association, 1994). Finally, *stage 4: Second neuropsychological assessment.* Three years after the initial inclusion, all selected children were again asked to participate in the SAM study. In this stage, all children were tested neuropsychologically, using several tests measuring functions such as verbal skills, attention, visuospatial performance, and scholarly performance.

Table 1. Timetable of the Study of Attention Disorders Maastricht (SAM).

	Stage 1: Selection of participants	Stage 2: Neuropsychological assessment (1 st)	Stage 3: ADIKa	Stage 4: Neuropsychological assessment (2 nd)
Cohort 1 (N=±2300)	Sept 96-June 97 N=452	Jan 97- Sept 97 N=400	Jan 98- Sept 98 N=403	Jan 00- Oct 00 N=301
Cohort 2 (N=±2100)	Sept 98-June 99 N=337	Jan 99 - Sept 99 N=337	Jan 00 – Sept 00 N=304	-

The objective of the SAM study was to conduct the entire sequence of steps for two birth cohorts (start 1st cohort: 1996 - 1997; start 2nd cohort: 1998 - 1999). Because of the extensiveness of the SAM study, several articles and theses have already been published (Kalff, 2002; Kroes, 2002) and a number of new articles will be submitted in the near future.

The outline of the thesis

In line with the goals mentioned earlier, the thesis consists of two parts. In part I (chapters 2 - 4), the influence of behavior, as measured on a continuum from normal to clinical, on executive control functions in children was investigated. In addition, the influence of environment and biology as additive to the behavioral characteristics of children was also investigated. In part II (chapters 5 - 9), re-

¹ Such as mood disorders (e.g., major depression, dysthemia, bipolar syndrome), anxiety disorders (e.g., separation anxiety, phobia, overanxious disorder, avoidant disorder), conduct disorders (e.g., oppositional disorder), disorders of elimination (e.g., functional encopresis and functional enuresis), obsessive compulsive disorder, post traumatic stress disorder, pervasive developmental disorders.

search questions related to the (cognitive) functioning of children with ADHD were investigated in depth. In chapter 10, the results described in the various chapters of the thesis are combined and subsequently discussed within the scope of existing literature. A short overview of the chapters of this thesis is given below.

Part I

Chapter 2:   **Predicting school career based on the behavioral, biological, and contextual characteristics of a preschool-aged child.**

Good academic performance is a major protective factor in a child's life. In this context, it is important to increase the chance that a child will be successful at school. Therefore, the goal of the study presented in chapter 2 was to elucidate factors to identify, in an earlier stage, children at risk for a poor academic performance. The main research question of chapter 2 was whether a profile of biological, behavioral, and contextual variables at preschool age can predict a child's school career (e.g., successful, staying down in any class, or transfer to special education) 3 years later.

Chapter 3:   **A longitudinal study on the both quantity and quality of sleep in children and the influence of behavioral and contextual factors.**

Although sleep problems are commonly observed in children, there is relatively little research on this subject. For this reason, two issues related to childhood sleep were examined more extensively in chapter 3, namely (a) the influence of behavioral, biological, and contextual factors on sleep, and (b) the stability of sleep over a 2-year-period.

Chapter 4:   **Semantic category fluency versus initial letter fluency over time as a measure of automatic and controlled processing in healthy school-aged children.**

Verbal fluency tasks are frequently used both in clinical and in research settings. In general, verbal fluency tasks are operationalized as the number of words produced, usually within a restricted category, over a limited period of time (usually 60 seconds). It is believed that this type of task is suitable for determining the strategies used for retrieving data from the lexicon and the semantic memory system. Successful performance on these tasks is thought to depend on efficient executive functioning and normal attention capacity. A new method for analyzing performance on

the fluency task is to investigate the compilation of words over time and its relation to automatic and controlled information processing. Based on this information, fluency tasks were evaluated more thoroughly in a sample of healthy, 9-year-old children (Chapter 4). The impact of environment, age, and sex on the fluency of speech was also studied in this chapter.

Part II

Chapter 5: **Verbal Fluency over time as a measure of automatic and controlled processing in children with ADHD.**

A cognitive function highly correlated with executive functioning and attention capacity, and often used to evaluate cognitive functioning in ADHD, both clinically and experimentally, is fluency of speech (Barkley, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). This function is usually defined as the number of words produced, usually within a restricted category, over a limited period of time (usually 60 seconds). Inconclusive evidence exists concerning the ability of verbal fluency to differentiate ADHD children from controls. In the majority of cases, only the production of words in 60-90 seconds is used as the main outcome variable, whereas the inclusion of the variable 'time' (as studied in healthy children in chapter 4) could provide new insight into automatic and controlled processes and fluency performance in ADHD (as described in chapter 5).

Chapter 6: **Controlled visuomotor preparation deficits in ADHD.**

Several aspects of information processing (e.g., encoding, motor execution) have been thoroughly assessed in ADHD. A relatively unexplored subject is visuomotor preparation. This is unfortunate, because earlier findings of an inefficient motor execution in ADHD may well be explained by a sub-optimal preparation of the motor response. With this thought in mind, children with ADHD were tested for their automatic and controlled visuomotor preparation abilities and compared to pathological controls and normal children, using a relatively new instrument, called the Finger Precuing Test. Results of this study are described in chapter 6.

Chapter 7:   **Executive functioning and behavioral problems (ADHD, CD/ODD) in school-aged children.**

Increasingly, evidence is pointing toward the involvement of the frontal lobes in ADHD, which has led to ADHD being referred to as a disorder of executive functioning. To test this model in terms of outcome and specificity of possible findings, the performance of children with ADHD on tasks measuring executive functioning was compared with that of children with other pathology (e.g., Conduct Disorders) and healthy controls. Several aspects of executive functioning were included in the analyses, such as task switching, verbal inhibition, and working memory. Results are described in chapter 7.

Chapter 8:   **Information processing in ADHD children with or without Learning Disabilities.**

Currently available data concerning the weaknesses in the cognitive profile of children with ADHD are not always consistent. Theories to support the choice of tests in experimental and clinical settings are often lacking. Therefore, the objective of the study presented in chapter 8 was to test the value of cognitive tests and to map the cognitive performance of children with ADHD more extensively.

Chapter 9:   **Longitudinal follow-up on the cognitive performance of children with ADHD.**

There are no data on the longitudinal development of children with ADHD compared with that of healthy children and children classified with psychopathology in general (but other than ADHD). In order to increase knowledge of the cognitive development of children suffering from ADHD, two aims were defined in chapter 9. The first aim was to answer the question whether cognitive performance on specific tests improves in children with ADHD over a 3-year follow-up. The second aim was to test whether the average cognitive profile of children with ADHD as a function of time differs from that of pathological controls and/or healthy controls or whether these cognitive profiles are identical for all groups. Tasks measuring either working memory or visuomotor integration capabilities are discussed in this chapter more extensively.

Chapter 10: Concluding remarks

In chapter 10, the results presented in the various chapters of the thesis are combined and discussed within the scope of existing knowledge of ADHD.

References

- Abikoff, H. B., Jensen, P. S., Arnold, L. L. E., Hoza, B., Hechtman, L., Pollack, S., Martin, D., Alvir, J., March, J. S., Hinshaw, S., Vitiello, B., Newcorn, J., Greiner, A., Cantwell, D. P., Conners, C. K., Elliott, G., Greenhill, L. L., Kraemer, H., W.E., P. J., Severe, J. B., Swanson, J. M., Wells, K., & Wigal, T. (2002). Observed classroom behavior of children with ADHD: Relationship to gender and comorbidity. *Journal of Abnormal Child Psychology*, 30, 349-359.
- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- American Psychiatric Association. (1968). *Diagnostic and statistical manual of mental disorders* (2nd ed.). Washington, DC: American Psychiatric Association.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3th ed.). Washington DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- August, G. J. (1987). Production deficiencies in free recall: A comparison of hyperactive, learning-disabled, and normal children. *Journal of abnormal Child Psychology*, 15, 429-440.
- Aylward, E. H., Reiss, A. L., Reader, M. J., Singer, H. S., Brown, J. E., & Denckla, M. B. (1996). Basal ganglia volumes in children with Attention-Deficit Hyperactivity Disorder. *Journal of Child Neurology*, 11, 112-115.
- Barber, M. A., Milich, R., & Welsh, R. (1996). Effects of reinforcement schedule and task difficulty on the performance of Attention Deficit Hyperactivity Disorder and control boys. *Journal of Clinical Child Psychology*, 25, 66-76.
- Barkley, R. A. (1996). Attention Deficit-Hyperactivity Disorder. In E. J. Mash & R. A. Barkley (Eds.), *Child psychopathology* (pp. 63-112). New York: The Guilford press.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (ODD). *Journal of abnormal Child Psychology*, 29(6), 541-556.
- Barkley, R. A., Guevremont, D. C., Anastopoulos, A. D., DuPaul, G. J., & Shelton, T. L. (1993). Driving-related risks and outcomes of attention deficit hyperactivity disorder in adolescents and young adults: A 3- to 5-year follow-up survey. *Pediatrics*, 92, 212-218.
- Barkley, R. A., Koplowitz, S., Anderson, T., & McMurray, M. B. (1997). Sense of time in children with ADHD: Effects of duration, distraction, and stimulant medication. *Journal of International Neuropsychological Society*, 3, 359-369.

- Baumgaertel, A., Wolraich, M. L., & Dietrich, M. (1995). Comparison of diagnostic criteria for attention deficit disorders in a German elementary school sample. *Journal of the American Academy Child and Adolescent Psychiatry*, 34, 629-638.
- Baumgardner, T. L., Singer, H. S., Denckla, M. B., Rubin, M. A., Abrams, M. T., Colli, M. J., & Reiss, A. L. (1996). Corpus callosum morphology in children with Tourette syndrome and attention deficit hyperactivity disorder. *Neurology*, 4, 477-482.
- Baving, L., Laught, M., & Schmidt, M. H. (1999). Atypical frontal brain activation in ADHD: Preschool and elementary school boys and girls. *Journal of the American Academy Child and Adolescent Psychiatry*, 38(11), 1363-1371.
- Benton, A. (1991). Prefrontal injury and behavior in children. *Developmental Neuropsychology*, 7(275-282).
- Bernstein, D. (1989). Language development: the school age years. In D. Bernstein & E. Tiegermen (Eds.), *Language and communication disorders in children*. Columbus, OH: Merrill/MacMillan.
- Biederman, J., Munir, K., Knee, D., Habelow, W., Armentano, M., Autor, S., Hoge, S. K., & Waternaux, C. (1986). A family study of patients with attention deficit disorder and normal controls. *Journal of Psychiatric Research*, 20, 263-274.
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety and other disorders. *American Journal of Psychiatry*, 148, 564-577.
- Bird, H. R., Gould, M. S., & Staghezza, B. M. (1993). Patterns of diagnostic comorbidity in a community sample of children aged 9 through 16 years. *Journal of the American Academy Child and Adolescent Psychiatry*, 32, 361-368.
- Borcherding, B., Thompson, K., Kruesi, M., Bartko, J., Rapoport, J. L., & Weingartner, H. (1988). Automatic and effortful processing in Attention Deficit/Hyperactivity Disorder. *Journal of Abnormal Child Psychology*, 16(3), 333-345.
- Borger, N., & Van der Meere, J. (2000). Motor control and state regulation in children with ADHD: A cardiac response study. *Biological Psychology*, 51, 247-267.
- Busch, B., Biederman, J., Glassner Cohen, L., Sayer, J. M., Monuteaux, M. C., Mick, E., Zallen, B., & Faraone, S. V. (2002). Correlates of ADHD among children in pediatric and psychiatric clinics. *Psychiatric Services*, 53, 1103-1111.
- Cantwell, D. P. (1996). Attention Deficit Disorder: A review of the past 10 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35, 978-987.
- Castellanos, F. X., Giedd, J. N., Eckburg, P., Marsh, W. L., Vaituzis, A. C., Kaysen, D., Hamburger, S. D., & Rapoport, J. L. (1994). Quantitative morphology of the caudate nucleus in Attention Deficit Hyperactivity Disorder. *American Journal of Psychiatry*, 151, 1791-1796.
- Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D., Vaituzis, A. C., Dickstein, D. P., Sarfatti, S. E., Vauss, Y. C., Snell, J. W., Lange, N., Kaysen, D., Krain, A. L., Ritchie, G. F., Rajapakse, J. C., & Rapoport, J. L. (1996). Quantitative brain Magnetic Resonance Imaging in Attention-Deficit Hyperactivity Disorder. *Archives of General Psychiatry*, 53, 607-616.
- Comings, D. E., Gade-Andavolu, R., Gonzalez, N., Wu, S., Muhleman, D., Blake, H., Dietz, G., Saucier, G., & MacMurray, J. P. (2000). Comparison of the role of dopamine, serotonin, and noradrenaline genes in ADHD, ODD, and conduct disorder.

- der: Multivariate regression analysis of 20 genes. *Clinical Genetics*, 57, 178-196.
- Cruickshank, B. M., Eliason, M., & Merrifield, B. (1988). Long-term sequelae of water near-drowning. *Journal of Pediatric Psychology*, 13, 379-388.
- Ernst, M., Liebenauer, L. L., King, C., Fitzgerald, G. A., Cohen, R. M., & Zametkin, A. J. (1994). Reduced brain metabolism in hyperactive girls. *Journal of the American Academy Child and Adolescent Psychiatry*, 33, 858-868.
- Faraone, S. V., & Biederman, J. (1994). Genetics of Attention Deficit Hyperactivity Disorder. In L. L. Greenhill (Ed.), *Child and adolescent psychiatric clinics of North America: Disruptive disorders* (Vol. 3, pp. 285-301).
- Fergusson, D., Horwood, L., & Lynskey, M. (1993). Prevalence and comorbidity of DSM-III-R diagnoses in a birth cohort of 15-year-olds. *Journal of the American Academy Child and Adolescent Psychiatry*, 32, 1127-1135.
- Filipek, P. A. (1999). Neuroimaging in the developmental disorders: The state of the science. *Journal of Child Psychology and Psychiatry*, 40, 113-128.
- Filipek, P. A., Semrud-Clikeman, M., Steingard, R. J., Renshaw, P. F., Kennedy, D. N., & Biederman, J. (1997). Volumetric MRI analysis comparing subjects having attention-deficit hyperactivity disorder with controls. *Neurology*, 48, 589-601.
- Gaultieri, C. T., Hicks, R. E., & Mayo, J. P. (1983). Hyperactivity and homeostasis. *Journal of the American Academy Child and Adolescent Psychiatry*, 22, 382-384.
- Granholm, E., Chock, D., & Morris, S. (1998). Pupillary responses evoked during verbal fluency tasks indicated semantic network dysfunction in Schizophrenia. *Journal of Clinical and Experimental Neuropsychology*, 20(6), 856-872.
- Haenlein, M., & Caul, W. F. (1987). Attention deficit disorder with hyperactivity: A specific hypothesis of reward dysfunction. *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 356-362.
- Halperin, J. M., O'Brien, J. D., Newcorn, J. H., Healey, J. M., Pascualva, D. M., Wolf, L. E., & Young, J. G. (1990). Validation of hyperactive, aggressive, and mixed hyperactive/aggressive disorders in children: A research note. *Journal of Child Psychology and Psychiatry*, 31, 455-459.
- Hechtman, L., Weiss, G., Perlman, T., & Amsel, R. (1984). Hyperactives as young adults: Initial predictors of adult outcome. *Journal of the American Academy of Child Psychiatry*, 23, 250-260.
- Heilman, K. M., Voeller, K. K. S., & Nadeau, S. E. (1991). A possible pathophysiological substrate of attention deficit hyperactivity disorder. *Journal of Child Neurology*, 6, 74-79.
- Herjanic, B., & Reich, W. (1982). Development of a structured psychiatric interview for children: Agreement between child and parent on individual symptoms. *Journal of Abnormal Child Psychology*, 10, 307-324.
- Herrero, M. E., Hechtman, L., & Weiss, G. (1994). Antisocial disorders in hyperactive subjects from childhood to adulthood: Predictive factors and characterization of subgroups. *American Journal of Orthopsychiatry*, 64, 510-521.
- Hinshaw, S. P. (1992). Externalizing behavior problems and academic underachievement in childhood and adolescence: Causal relationships and underlying mechanisms. *Psychological Bulletin*, 111, 127-155.
- Hynd, G. W., Hern, K. L., Novey, E. S., Eliopoulos, D., Marshall, R., Gonzalez, J. J., & Voeller, K. K. (1993). Attention Deficit-Hyperactivity Disorder and asymmetry of

- the caudate nucleus. *Journal of Child Neurology*, 8(339-347).
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., & Eliopoulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder with hyperactivity. *Archives of Neurology*, 919-926.
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., Eliopoulos, D., & Lyytinen, H. (1991). Corpus callosum morphology in Attention Deficit-Hyperactivity Disorder: Morphometric analysis of MRI. *Journal of Learning Disabilities*, 24, 141-146.
- Jensen, P. S., Martin, B. A., & Cantwell, D. P. (1997). Comorbidity in ADHD: Implications for research, practice, and DSM-IV. *Journal of the American Academy Child and Adolescent Psychiatry*, 36, 1065-1079.
- Kalff, A. C. (2002). *Neurocognitive performance and demographic variables in children at risk of Attention-Deficit/Hyperactivity Disorder*. Maastricht University, Maastricht.
- Kalff, A. C., Hendriksen, J. G. M., Kroes, M., Vles, J. S. H., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., & Jolles, J. (2002). Neurocognitive performance of 5- and 6-year-old children who met criteria for Attention Deficit/Hyperactivity Disorder at 18 months follow-up: Results from a prospective population study. *Journal of Abnormal Child Psychology*, 30(6), 589-598.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKa). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Kroes, M. (2002). *Early motor, psychosocial and behavioural characteristics of Attention-Deficit/Hyperactivity Disorder*. University Hospital Maastricht, Maastricht.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Lambert, N. M., Sandoval, J., & Sassone, D. (1978). Prevalence of hyperactivity in elementary school children as a function of social system definers. *American Journal of Orthopsychiatry*, 48, 446-463.
- Levin, P. M. (1938). Restlessness in children. *Archives of Neurology and Psychiatry*, 39, 764-770.
- Lou, H., Henriksen, L., Bruhn, P., Borner, H., & Nielson, J. B. (1989). Striatal dysfunction in attention deficit and hyperkinetic disorder. *Archives of Neurology*, 46, 48-52.
- Lou, H. C., Henriksen, L., & Bruhn, P. (1984). Focal cerebral hypoperfusion in children with dysphasia and/or attention deficit disorder. *Archives of Neurology*, 46, 48-52.
- Mannuzza, S., Gittelman-Klein, R., Bessler, A., Malloy, P., & Lapadula, M. (1993). Adult outcome of hyperactive boys: Educational achievement, occupational rank,

- and psychiatric status. *Archives of General Psychiatry*, 50, 565-576.
- Mattes, J. A. (1980). The role of frontal lobe dysfunction in childhood hyperkinesis. *Comprehensive Psychiatry*, 21, 358-369.
- Middleton, F. A., & Strick, P. L. (1994). Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive functioning. *Science*(266), 458-461.
- Moffitt, T. E. (1990). Juvenile delinquency and attention deficit disorder: Boys' developmental trajectories from age 3 to 15. *Child Development*, 61, 893-910.
- Moffitt, T. E., & Henry, B. (1989). Neuropsychological assessment of executive functions in self-reported delinquents. *Developmental Psychopathology*, 1, 105-118.
- Monsch, A. U., Bondi, M. W., Butters, N., Paulsen, J. S., Salmon, D. P., Brugger, P., & Swenson, M. R. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology*, 8, 25-30.
- Morrison, J. R., & Stewart, M. A. (1971). A family study of the hyperactive child syndrome. *Biological Psychiatry*, 3, 189-195.
- O'Dougherty, M., Neuchterlein, K. H., & Drew, D. (1984). Hyperactive and hypoxic children: Signal detection, sustained attention, and behavior. *Journal of Abnormal Psychology*, 93, 178-191.
- Papa, M., Berger, D. F., Sagvolden, T., Sergeant, J. A., & Sadile, A. G. (1998). A quantitative cytochrome oxidase mapping study, cross-regional and neurobehavioural correlations in the anterior forebrain of an animal model of attention deficit hyperactivity disorder. *Behavioural Brain Research*, 94(197-212).
- Papa, M., Sergeant, J. A., & Sadile, A. G. (1998). Reduced transduction mechanisms in the anterior accumbal interface of an animal model of the attention-deficit hyperactivity disorder. *Behavioural Brain Research*, 94, 187-196.
- Perugini, E. M., Harvey, E. A., Lovejoy, D. W., Sandstrom, K., & Webb, A. H. (2000). The predictive power of combined neuropsychological measures for Attention-Deficit/Hyperactivity Disorder in children. *Child Neuropsychology*, 6(2), 101-114.
- Prins, P., & Ten Brink, E. (2000). Richtlijnen voor een multimodale behandeling van ADHD. In P. Prins & N. Pameijer (Eds.), *Protocolen in de jeugdzorg: Richtlijnen voor diagnostiek, indicatiestelling en interventie*. Lisse: Swets & Zeitlinger.
- Redman, C. A., & Zametkin, A. J. (1991). Ritalin and brain metabolism. In L. L. Greenhill & B. B. Osmon (Eds.), *Ritalin: Theory and patient management* (pp. 289-300). New York: Mary Ann Liebert.
- Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, 71, 267-284.
- Rosser, A., & Hodges, J. (1994). Initial letter and semantic category fluency in Alzheimer's disease, Huntington's disease, and Progressive Supranuclear Palsy. *Journal of Neurology, Neurosurgery and Psychiatry*, 57, 1389-1394.
- Rubia, K., Taylor, A., Taylor, E., & Sergeant, J. A. (1999). Synchronization, anticipation, and consistency in motor timing of children with dimensionally defined attention deficit hyperactivity behaviour. *Perceptual and Motor Skills*, 89, 1237-1358.
- Rubia, K., Taylor, E., Smith, A., Oksannen, H., Overmeyer, S., Bullmore, E., & Newman, S. (2001). Neurophysiological analyses of impulsiveness in childhood hyperactivity. *British Journal of Psychiatry*, 179, 138-143.
- Russo, M. F., & Beidel, D. C. (1994). Comorbidity of childhood anxiety and externalizing disorder: Prevalence, associated characteristics, and validation issues. *Clinical*

- Psychology Review*, 14, 199-221.
- Rutter, M. (1977). Brain damage syndromes in childhood: Concepts and findings. *Journal of Child Psychology and Psychiatry*, 18, 1-21.
- Scahill, L., Schwab-Stone, M., Merikangas, K. R., Leckman, J. F., Zhang, H., & Kasl, S. (1999). Psychosocial and clinical correlates of ADHD in a community sample of school-age children. *Journal of the American Academy Child and Adolescent Psychiatry*, 38(7), 976-984.
- Seidman, L. J., Biederman, J., Faraone, S. v., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of Attention Deficit-Hyperactivity Disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical psychology*, 65(1), 150-160.
- Sieg, K. G., Gaffney, G. R., Preston, D. F., & Hellings, J. A. (1995). Spect brain imaging anomalies in attention deficit hyperactivity disorder. *Clinical Nuclear Medicine*, 20, 55-60.
- Singer, H. S., Reiss, A. L., Brown, J. E., Aylward, E. H., Shih, B., Chee, E., Harris, E. L., Reader, M. J., Chase, G. A., Bryan, R. N., & Denckla, M. B. (1993). Volumetric MRI changes in basal ganglia of children with Tourette's syndrome. *Neurology*, 43, 950-956.
- Smith, A., Taylor, E., Rogers, J. W., Newman, S., & Rubia, K. (2002). Evidence for a pure time perception deficit in children with ADHD. *Journal of Child Psychology and Psychiatry*, 43(4), 529-542.
- Sonuga-Barke, E. J., Saxton, T., & Hall, M. (1998). The role of interval underestimation in hyperactive children's failure to suppress responses over time. *Behavioural Brain Research*, 94, 45-50.
- Stevens, D. A., Stover, C. E., & Backus, J. T. (1970). The hyperkinetic child: Effects of incentives on the speed of rapid tapping. *Journal of Consulting and Clinical Psychology*, 34, 56-59.
- Still, G. F. (1902). Some abnormal psychical conditions in children. *The Lancet*, 1, 1008-1012, 1077-1082, 1163-1168.
- Strauss, A. A., & Lethinen, L. E. (1947). *Psychopathology and education of the brain-injured child*. New York: Grune & Stratton.
- Szatmari, P., Offord, D. R., & Boyle, M. H. (1989). Correlates, associated impairments, and patterns of service utilization of children with attention deficit disorder: Findings from the Ontario Child Health Study. *Journal of Child Psychology and Psychiatry*, 30, 205-217.
- Tannock, R. (1998). Attention Deficit Hyperactivity Disorder: Advances in cognitive, neurobiological and genetic research. *Journal of Child Psychology and Psychiatry*, 39, 65-99.
- Taylor, E. (1996, January). *Discussions of current theories of ADHD*. Paper presented at the International Society for Research in Child and Adolescent Psychopathology, Los Angeles, CA.
- Tredgold, C. H. (1908). *Mental deficiency*. New York: Wood.
- Van der Meere, J., Vreeling, H. J., & Sergeant, J. (1992). A motor presetting study in hyperactive, learning disabled and control children. *Journal of Child Psychology and Psychiatry*, 33(8), 1347-1354.
- Van der Meere, J. J., Stemerink, N., & Gunning, W. B. (1995). Effects of presentation

- rate of stimuli on response inhibition in ADHD children with and without tics [comment]. *Perceptual Motor Skills*, 81(1), 259-262.
- Van der Oord, E. J. C. G., Boomsma, D. I., & Verhulst, F. C. (1994). A study of problem behaviors in 10- to 15-year old biologically related and unrelated international adoptees. *Behavior Genetics*, 24, 193-205.
- Vaidya, C. J., Austin, G., Kirkorian, G., Ridlehuber, H. W., Desmond, J. E., Glover, G. H., & Ganrieli, J. D. E. (1998). Selective effects of methylphenidate in attention deficit hyperactivity disorder: A functional magnetic resonance study. *Proceedings of the National Academy of Sciences of the United States of America*, 95, 14994-14999.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Vles, J. S. H., Feron, F. J. M., Hendriksen, J. G. M., Jolles, J., van Kroonenburgh, M. J. P. G., Weber, W. E. J. (2003). Methylphenidate down-regulates the dopamine receptor and transporter system in children with attention deficit hyperkinetic disorder (ADHD). *Neuropediatrics*, 34(2), 77-80.
- Weiss, G. (1996). Attention deficit hyperactivity disorder. In M. Lewis (Ed.), *Child and adolescent psychiatry: A comprehensive textbook* (pp. 544-563). Baltimore, MD: Williams & Wilkins.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children, adolescents and adults*. (2 ed.). New York: The Guilford Press.
- Wender, P. H., Reimherr, F. W., & Wood, D. R. (1981). Attention deficit disorder ('minimal brain dysfunction') in adults. A replication study of diagnosis and drug treatment. *Archives of General Psychiatry*, 38(4), 449-456.
- Wolraich, M. L., Hannah, J. N., Pinnock, T. Y., Baumgaertel, A., & Brown, J. (1996). Comparison of diagnostic criteria for attention-deficit hyperactivity disorder in a county-wide sample. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35, 319-324.
- Zametkin, A. J., Liebenauer, L. L., Fitzgerald, G. A., & al., e. (1993). Brain metabolism in teenagers with Attention-Deficit Hyperactivity Disorder. *Archives of General Psychiatry*, 50, 333-340.
- Zametkin, A. J., Nordahl, T. E., Gross, M., & al., e. (1990). Cerebral glucose metabolism in adults with hyperactivity of childhood onset. *New England Journal of Medicine*, 323, 1361-1366.

Predicting school career based on the behavioral, biological, and contextual characteristics of a preschool-aged child¹

Abstract

The goal of the present study was to elucidate risk factors relevant for identifying children at risk of failure at school (academic delay or transfer to special education) in a general population. Data related to the biological and contextual characteristics and the behavior of the child were collected for 1317 preschool-aged children living in the Limburg area in the Netherlands. After deletion of missing data on the continuous and non-continuous predictors, data from 1235 children were available for analysis. Subsequently, 3 years later, the school career of these children was mapped. Based on these data, three mutually exclusive categories were created: (I) Children who had passed through school successfully ($n = 924$); (II) Children who had stayed down at least one class (before or after inclusion in the study at kindergarten) but who were still learning within the normal school environment ($n = 277$); (III) Children who were transferred, after inclusion in the study at preschool age, from a normal school to a school for children with special needs ($n = 34$). The approach used in this study was new with regard to (a) the longitudinal component of the study, (b) the earlier mentioned benefit of the inclusion of a general population sample, and (c) that the children were assessed in early childhood, at the time when they had just entered the first classes of a normal school. Data analysis revealed that a model predictive for school outcome consisted of biological, contextual, and behavioral factors. Behavioral variables registered at kindergarten that appeared to be predictive for later school career were scores on the Child Behavior Checklist (CBCL) attention problems scale and the CBCL delinquency scale. In addition, the level of occupational achievement, sex of the child, age of mother at birth, number of children in the family, living area, and family status appeared to be a predictor of school career.

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Introduction

A successful learning experience in school is an important protective factor in a child's life, in a sense that children who do well in school seem to graduate with cognitive skills that prepare them for later life challenges, whereas poor scholastic performance is believed to be a relevant risk factor for many behavioral and social problems at a later stage (Durlak, 2001). For example, children who fail at school are characterized by a diminished amount of peer relations, more drug use and delinquency, and lowered psychological well-being (including self-esteem, self-efficacy, and life satisfaction). In this context, it seems highly relevant to enhance the chance of a successful experience of children in school, for instance, by early identifying those children at-risk for poor academic performance and to develop adapted interventions for them (Barnett, 1995; Cadieux & Boudreault, 2002; Durlak, 2001; Fletcher & Foorman, 1994).

To accomplish the first objective of early identification of children at risk for poor academic performance, the terms 'at-risk' and 'risk factors' have to be defined properly. In the scientific literature, the term 'at-risk' is applied to those children who possess certain physical, behavioral, or social characteristics which are statistically associated with having problems in normal adaptation or development (Cadieux & Boudreault, 2002; Frymier & Gansneder, 1989; Tjossum, 1976). The development of an individual occurs within the multiple contexts of home, school, and the neighborhood. All these aspects may contribute singularly or co-occurring to the development of adjustment problems, and may therefore include risk-factors for academic failure (Greenberg, Lengua, Coie, & Pinderhughes, 1999; Sameroff & Seifer, 1990). For these reasons, the study of elements, which are predictive of academic achievement, should be embedded in the analyses of the biological, behavioral, and contextual elements to which children can be exposed and which may cause a heightened risk.

Over the last decades, several professionals have shown interest in the early identification of kindergarten pupils at-risk of poor academic performance (e.g., Cadieux & Boudreault [2002], Cadieux & Leduc [1992], and Shapiro, Accardo, & Capute [1998]). The primary aim of these studies was to reveal so-called risk factors on educational disabilities within a population of infants exposed to an increased medical risk at birth. For instance, many researchers have studied the relationship between birth weight and academic achievement, in which low birth weight or the factor 'small for gestational age' was predictive of poorer cognitive skills and educational outcomes through childhood compared with children with normal weight (Jefferis, Power, & Hertzman, 2002; Matte, Bresnahan, Begg, & Susser, 2001; Richards, Hardy, Kuh, & Wadsworth, 2001; Shenkin et al., 2001; Siedman et al., 1992; Sorensen et al., 1997).

Only few studies have actually understated the additional importance of assessing the contributions of risk factors (such as perinatal and socio-demographic factors) to educational disabilities within a representative general population rather than

within samples which are pre-selected by clinical referral (Resnick et al., 1999; Stanger, Achenbach, & McConaughy, 1993). Relatively few potential predictors of school outcome have been considered in this context (including SES, externalizing and internalizing behavior), whereas the effects of multiple risk factors within a theoretical model and studied within a general population would provide new insight in this complex matter (Greenberg et al., 1999).

A major obstacle related to these general population studies is unfortunately that these studies often involve a long, complex, and rigorous process for which educators do not always have sufficient human, material, or financial resources. Because of the relative rarity of retention at school and transferal to special education within a general population, mostly case-control studies and designs with healthy newborns have been used in literature. This has the obvious limitation of small sample sizes and restricts the generalizability to the population. In contrast, the availability of information on children and school records in a geographically defined area would allow the consideration of nearly all children in that region and permits utilization of school placement as an outcome (Jefferis et al., 2002). Identifying predictors of poor outcomes in a nationally representative general population sample avoids the earlier mentioned biasing factors inherent in clinically referred or school-based samples (Stanger et al., 1993).

Therefore, the objective of this study was to assess the relative effects and the influence of certain characteristics (e.g., the attention capacity of a child as measured on a continuum with normal attention on the one end and abnormal attention on the other, with children who display minor or sub-clinical attention problems being intermediate) on educational outcome, as measured in a geographically defined, general population sample of children. The study design was as follows: children who originally were in the second grade of normal kindergarten were monitored on their school career over a period of three years. Educational outcome was defined as whether or not these children had passed school successfully over this period of three years (that is, 'was there any educational delay or transfer to special education?'). Components of this study which are new in comparison to earlier research are (a) the longitudinal component of the study, (b) the earlier mentioned benefit of the inclusion of a general population sample, and (c) the fact that the children were assessed in early childhood, at the time that they had just entered the first classes of a normal school. With regard to the last point, it has been suggested that school entrance and the first years of school are critical developmental periods, at which time children may be at greater risk for developing difficulties in social adjustment or scholastic performance (Clancy & Pianta, 1993; Greenberg et al., 1999; Kellam et al., 1991). It is relevant to evaluate whether we can distinguish the factors that predict deviations in school career in children, who have started at a normal level.

Methods

Selection of participants

This report is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)' (Kalff et al., 2001; Kroes et al., 2001) and is embedded in a longitudinal, population-based design. The entire SAM program enclosed four successive stages. For the present study, the data of only two stages were used. These two stages will be summarized below. An overview of the data collection for answering the research questions included in the present chapter was presented in figure 1.

Figure 1. A schematic representation of the data collection as part of SAM.

Stage 1 (during the months 1-9): A sample of 2256 Dutch children attending second grade of normal kindergarten and living in the region South Limburg of the Netherlands was approached to participate in the present study. In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. It is during this grade that the Youth Health Care invites the children for a Periodic Health Examination, which is usually attended by the vast majority (around 98%) of children. The initial approach of the families for participation in the SAM-study took place in conjunction with this Periodic Health Examination for it was a perfect opportunity to reach a large sample of healthy young children. During the visit to the Youth Health Care for the periodic health examination, the caregivers of these children were asked to participate in the SAM study and, in case of approval, to fill in an informed consent and a questionnaire as part of a large longitudinal cohort study. Caregivers could return the papers by mail. Response rate of the written informed consent was 57.5% ($n_{\text{responders}} = 1317$). For this group of responders, information was gathered on the child, on the family, and on environmental variables with help of the care-

giver and the school doctor of the Youth Health Care. In addition, various aspects of the behavior of the children were systematically questioned with the caregiver-version of the Child Behavior Checklist (CBCL).

Stage 2 (months 39-49): Approximately three years after the initial inclusion in stage 1, the school career (nominal, retention, or placement in special education) for the entire population as defined in the first stage was registered.

A description of the study sample is provided in Table 1. While comparing the distribution of scores over the groups, no differences were found between the entire population of 2256 children and the sample of 1317 responders.

Table 1. School career for both the entire population (N = 2256) and the sample of responders (n = 1317).

School career	Entire popula- tion		Sample	
	N	%	N	%
Nominal academic career	1533	68	934	71
Retention of classes at normal school	541	24	290	22
- Retention before inclusion	197	9	97	7
- Retention after inclusion	326	14	187	14
- Retention before and after inclusion	18	1	6	0.5
Transfer to special education after inclusion	62	3	37	3
- ZMOK	8	0.4	5	0.4
- SBO	51	2.3	31	2.4
- ZMLK	2	0.1	1	0.1
- Handicapped children	1	0	0	0
Missing data	120	5	56	4

Variables

Outcome Variables

The outcome variable was educational placement three years after initial inclusion. Three mutually exclusive categories were created: (I) Children who had passed school successfully at least until stage 2 of the study; (II) Children who retained at least one class (before or after inclusion in the study at kindergarten) but were still learning within the normal school environment; (III) Children who were transferred, after the initial inclusion in the SAM-study, from a normal school to a school for special education.

In the Netherlands, placement in a school for special education is only conducted after a multidisciplinary evaluation procedure by qualified professionals using widely accepted assessment tools and methods. Reasons for a placement can be related to conditions resulting in persistent and maladaptive behaviors, such as disturbed behavior, educable mental handicaps (including learning disabilities), psychological problems marked by difficulties in the acquisition and use of lan-

guage, reading, or writing or math, and emotional handicaps. Based on these conditions, different types of special education can be distinguished in the Netherlands. For instance, there are special schools for children with moderate to severe learning disabilities (in the Netherlands the term ‘SBO/MLK’ is used to refer to a school for moderate learning disabilities and ZMLK for a school for severe learning disabilities), schools for children with severe behavioral problems (ZMOK), and schools for handicapped children.

Biological and contextual predictor variables

The biological and contextual risk factors considered in the present article are summarized in Table 2. The mean and standard deviation (SD) of the continuous predictor variable was provided in this table for each group. In addition, frequencies (both the percentages and the sums of raw data) were given for the categorical predictors. Included variables were related to familial, environmental and behavioral aspects of the child. Predictor Variables: Biologically related. Both (a) age at the time of inclusion (in years) and (b) sex of the child were included in the data collection. Predictor Variables: Contextual related. Several family-related risk factors were included in the present study, namely (c) The Level of Occupational Achievement of the caregiver (LOA) is based on the full description of the parental occupation and was originally scored on a 8-points-scale, ranging from unskilled to scientific skilled labor (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded as a separate category. When the LOA differed between mother and father or if data was missing for one caregiver, the highest available score was chosen. For the present study, the LOA-scores were transformed from a 8-points-scale to a 3-points-scale, ranging from low (LOA-codes 0, 1, 2, 3), middle (4 & 5), to high (6 & 7); (d) The country of birth of the parents was defined as Dutch vs. Foreign born; (e) The family status was scored as to whether the child was living with two parents or with one parent; (f) Professional support given to the mother for mental health or psychiatric problems; (g) The maternal age at birth; (h) Number of children in the family. Predictor Variables: Social environment related. In addition, one aspects related to social environment was included here, namely (i) the living area of the child (urban vs. rural).

Behavioral Predictor Variables

The behavioral predictor factors considered in the present article were also summarized in Table 2. Frequencies (both the percentages and the sums of raw data) were given for the categorical behavioral related predictors. Predictor Variables: Behavioral. Behavior of children at preschool age was measured by use of the caregiver-version of the *Child Behavior Checklist (CBCL)*. Originally, the CBCL was developed by Achenbach & Edelbrock (1983) and revised and translated into Dutch by Verhulst, Koot, & Van der Ende (1996). Primarily, it is used as a

screening instrument but it has been demonstrated that the CBCL is useful in detecting children with and without behavior problems according to their parents (Steingard, Biederman, Doyle, & Sprich-Buckminster, 1992). Based on the 113 ordinal-scaled items, a total problem-scale, two broadband scales (that is, *Externalizing* and *Internalizing behavior problems*) and subsequently nine narrowband scales (that is, *Withdrawn*, *Physical complaints*, *Anxiety/Depression*, *Social problems*, *Thought problems*, *Attention problems*, *Delinquent behavior*, *Aggressive behavior*, and *Sexual problems*) can be derived with the help of a pre-set algorithm. T-scores were calculated ranging from 50-100, on basis of norms corrected for sex and age (Verhulst et al., 1996). In addition, Verhulst, Koot, & Van der Ende (1996) defined borderline and clinical cut-off scores for the narrowband scales (borderline :T-scores have to be between 67 and 70 (that is, between the 95th – 98th percentile; clinical: T-scores have to be larger than 70 (that is, above 98th percentile).

Results

As a first step, the missing data were analyzed. Of the 1317 cases included in the data selection, 82 cases included missing data on the ordinal or nominal predictors, namely nationality ($n = 29$), family status ($n = 17$), mental support mother ($n = 26$), number of children in the family ($n = 17$), LOA ($n = 12$), maternal age at birth ($n = 20$), and the dependent, outcome variable ($n = 56$). Secondly, correlations between the predictor variables were calculated and are displayed in table 3. Because extremely high correlations were not found between the predictors, multicollinearity was believed to be ruled out.

After deletion of missing data on the continuous and non-continuous predictors, data from 1235 children were available for the analyses: 924 children with a nominal school career, 277 children who retained classes at normal schools, and 34 children who were transferred to special education after inclusion in the study. Because the sample of children in special education is relatively small, it was decided to combine groups II and III, and thus to evaluate variables that are predictive of a normal school career vs. a deviant school career.

By use of a stepwise logistic regression analysis, the predictive power of contextual, biological, and behavioral factors on school career was tested in three steps. The biological variables (age and sex) were included in the model as a first step, contextual variables as a second step, and the behavioral variables as a third step. Comparison of log-likelihood ratios revealed a reliable improvement of the model with each succeeding step (model 0 vs. 1: chi square = 33.6, $p < .001$; model 1 vs. 2: chi square = 118.4, $p < .001$; model 2 vs. 3: chi square = 151.9, $p < .001$). It was thereby permitted to include the biological and contextual, as well as the behavioral related predictors in the final analyses. After addition of the all predictor variables, Nagelkerke R^2 was found to be .171.

Table 2. Descriptive statistics for child, family, and environmental characteristics of the responders sample (n = 1317) as a function of group membership.

Variables	Group I Nominal		Group II Retention		Group III Special school		Missing school data	
	N	%	N	%	N	%	N	%
Sex								
Boys	468	67.0	169	24.2	23	3.3	39	5.6
Girls	466	75.4	121	19.6	14	2.3	17	2.8
Nationality parents								
Dutch	844	73.6	244	21.3	30	2.6	29	2.5
Foreign born	84	59.6	42	29.8	5	3.5	10	7.1
Missing	6	20.7	4	13.8	2	6.9	17	58.6
Family status								
Two parents	860	74.2	245	21.1	21	1.8	33	2.8
One parent	72	51.1	45	31.9	14	9.9	10	7.1
Missing	2	11.8	0	0	2	11.8	13	76.5
Living area								
Urban	520	67.1	194	25.0	31	4.0	30	3.9
Non urban	414	76.4	96	17.7	6	1.1	26	4.8
Number of children in family								
1 child	131	66.8	46	23.5	9	4.6	10	5.1
2 children	547	74.2	158	21.4	13	1.8	19	2.6
> 2 children	253	68.9	86	23.4	12	3.3	16	4.4
Missing	3	17.6	0	0	3	17.6	11	64.7
Mental support mother								
No	895	72.1	276	22.2	33	2.7	37	3.0
Yes	33	66.0	10	20.0	2	4.0	5	10.0
Missing	6	23.1	4	15.4	2	7.7	14	53.8
Maternal age at birth								
≤ 26 years	173	58.1	91	30.5	19	6.4	15	5.0
27-33 years	555	74.6	157	21.1	12	1.6	20	2.7
>33 years	203	79.6	40	15.7	4	1.6	8	3.1
missing	3	15.0	2	10.0	2	10.0	13	65.0
LOA								
low	282	59.7	137	29.0	33	7.0	20	4.2
middle	285	73.6	84	21.7	3	0.8	15	3.9
high	365	81.8	62	13.9	1	0.2	18	4.0
missing	2	16.7	7	58.3	0	0	3	25.0

Variables	Group I Nominal		Group II Retention		Group III Special school		Missing school data	
Withdrawn								
Control	897	71.9	268	21.5	32	2.6	51	4.1
Borderline	17	50.0	12	35.3	2	5.9	3	8.8
Clinical	20	57.1	10	28.6	3	8.6	2	5.7
Physical complaints								
Control	868	72.0	255	21.2	34	2.8	48	4.0
Borderline	39	61.9	18	28.6	2	3.2	4	6.3
Clinical	27	55.1	17	34.7	1	2.0	4	8.2
Anxiety/Depression								
Control	902	71.8	270	21.5	35	2.8	50	4.0
Borderline	24	63.2	9	23.7	0	0.0	5	13.2
Clinical	8	36.4	11	50.0	2	9.1	1	4.5
Social problems								
Control	916	72.4	270	21.3	29	2.3	51	4.0
Borderline	14	51.9	7	25.9	3	11.1	3	11.1
Clinical	4	16.7	13	54.2	5	20.8	2	8.3
Thought problems								
Control	915	71.9	272	21.4	35	2.7	51	4.0
Borderline	8	44.4	5	27.8	2	11.1	3	16.7
Clinical	11	42.3	13	50.0	0	0	2	7.7
Attention problems								
Control	913	72.9	262	20.9	27	2.2	51	4.1
Borderline	17	45.9	14	37.8	5	13.5	1	2.7
Clinical	4	14.8	14	51.9	5	18.5	4	14.8
Delinquent behavior								
Control	899	73.3	251	20.5	28	2.3	49	4.0
Borderline	21	41.2	22	43.1	3	5.9	5	9.8
Clinical	14	35.9	17	43.6	6	15.4	2	5.1
Aggressive behavior								
Control	881	72.3	254	20.8	32	2.6	52	4.3
Borderline	27	57.4	16	34.0	1	2.1	3	6.4
Clinical	26	51.0	20	39.2	4	7.8	1	2.0
Sexual problems								
Control	910	71.7	274	21.6	32	2.5	54	4.3
Borderline	17	58.6	7	24.1	4	13.8	1	3.4
Clinical	7	38.9	9	50.0	1	5.6	1	5.6
	M	SD	M	SD	M	SD	M	SD
Age								
Child at inclusion (in yrs)	5.8	0.3	6.0	0.5	6.0	0.6	5.9	0.4

Table 3. Inter-correlations among predictor variables (n = 1235).

Predictor variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Sex	-																	
2. Age	-.053	-																
3. LOA	.001	.080 ^b	-															
4. Nation	.055	-.003	.127 ^c	-														
5. Family status	-.007	.009	.231 ^c	.020	-													
6. Living area	-.014	.002	-.156 ^c	-.063 ^a	-.132 ^c	-												
7. Nr. of children	-.031	-.008	-.194 ^c	.099 ^b	-.085 ^b	.067 ^a	-											
8. Mental support	.010	.028	.043	.022	.095 ^b	-.053	-.061 ^a	-										
9. Maternal age	.020	.085 ^b	.373 ^c	.038	.055	-.115 ^c	-.190 ^c	-.007	-									
10. Withdrawn	.007	.026	.059 ^a	.000	.064 ^a	-.008	-.006	.122 ^c	.068 ^a	-								
11. Physical complaints	.052	.004	.051	.062 ^a	.022	-.010	-.061 ^a	.107 ^c	.067 ^a	.105 ^c	-							
12. Anxiety/Depression	-.006	.040	.069 ^a	.066 ^a	.027	.005	-.029	.115 ^c	.081 ^b	.407 ^c	.174 ^c	-						
13. Social problems	.036	.063 ^a	.072 ^a	.040	.129 ^c	-.039	-.021	.160 ^c	.070 ^a	.362 ^c	.114 ^c	.326 ^c	-					
14. Thought problems	.004	.028	.078 ^b	.023	.072 ^a	-.033	-.019	.099 ^b	.038	.193 ^c	.134 ^c	.288 ^c	.156 ^c	-				
15. Attention problems	-.021	.112 ^c	.133 ^c	.020	.085 ^b	-.025	-.028	.108 ^c	.096 ^b	.308 ^c	.130 ^c	.241 ^c	.382 ^c	.275 ^c	-			
16. Delinquency	-.078 ^b	.036	.106 ^c	.054	.089 ^b	-.061 ^a	.015	.120 ^c	.071 ^a	.190 ^c	.150 ^c	.250 ^c	.415 ^c	.144 ^c	.371 ^c	-		
17. Aggression	-.018	.023	.108 ^c	.086 ^b	.139 ^c	-.072 ^a	-.024	.169 ^c	.079 ^b	.255 ^c	.148 ^c	.254 ^c	.338 ^c	.320 ^c	.379 ^c	.480 ^c	-	
18. Sexual problems	-.036	.001	.055	.069 ^a	.085 ^b	-.047	.006	.085 ^b	.069 ^a	.108 ^c	.131 ^c	.190 ^c	.263 ^c	.077 ^b	.115 ^c	.258 ^c	.144 ^c	-

^a Correlation is significant at the .05 level (2-tailed).

^b Correlation is significant at the .01 level (2-tailed).

^c Correlation is significant at the .001 level (2-tailed).

Table 4 and 5 show the influence of included predictive factors on school career. B-values, standard errors (S. E.), and confidence intervals (C. I.) were given in case of significant effects. Several socio-demographic, biological variables and variables belonging to the behavioral set reliably enhanced prediction of a normal school career vs. deviant school career; that is the p-values of these predictors were below .05. Biological age and sex were significantly predictive of school career. Contextual predictors of school career were: family status, living area, number of children in a family, maternal age at birth, and LOA. Finally, aspects of behavior measured at preschool age that were predictive of school career were: CBCL attention problems and CBCL delinquent behavior.

Discussion

The objective of the present study was to assess the relative effects and the influence of biologically, environmentally, or behaviorally determined characteristics as measured on preschool age on school outcome in a geographically defined, general population sample of children. As mentioned in the introduction, components of the study presented in this chapter and new in comparison to earlier research are (a) the longitudinal component of the study, (b) the benefit of the inclusion of a general population sample, and (c) the fact that the children were assessed in early childhood, at the time that they had just entered the first classes of a normal school, and followed from that point over a period of three years. With regard to the point of early assessment, it has been suggested that school entrance and the first years of school are critical developmental periods, at which time children may be at greater risk for development of problems in adjustment or scholastic performance (Clancy & Pianta, 1993; Greenberg et al., 1999; Kellam et al., 1991). The majority of studies which have assessed the role of social environment on school functioning included older children, who were in their middle childhood and/or adolescence (e.g., Greenberg et al. [1999]), whereas the positive aspect of the study presented in this chapter is that it enables the evaluation of the long-term influence of early biological, contextual, and behavioral influences on school career.

Finally, as mentioned in the introduction of this chapter, the development of an individual occurs within the multiple contexts of home, school, and the neighborhood. Several factors related to its family-environment (e.g., the child is living with one parent or two parents) or the cognitive characteristics of the individual child (e.g., attention problems) may contribute singularly or simultaneously to the development of adjustment problems, and may therefore include risk-factors for a compromised scholastic performance (Greenberg et al., 1999; Sameroff & Seifer, 1990). For these reasons, the study of elements, which predict scholastic outcome, was embedded here in the analyses of the biological, behavioral, and contextual elements to which children can be exposed and which may cause a heightened risk. The rationale of including biological, contextual, as well

as behavioral predictors was supported by the data. As presented in this chapter, the fit of the statistical model which was used on the data increased significantly (when comparing the log-likelihood ratios) when adding a combination of a number of components (biological, contextual, and behavioral) versus only adding one single component (for instance a model including only context-related predictors). The influence of the individual biological and contextual elements included in this chapter will be discussed here first, and will be succeeded by a discussion of the behavioral elements. However, the reader should keep in mind that all types of predictors (biological, contextual, and behavioral) were entered in three steps (first biological factors, second contextual factors and third behavioral factors) in the analyses and that the predictors included in the present study are not the only biological, contextual and behavioral factors imaginable.

The influence of biological and contextual elements

With regard to the biological and contextual elements measured at preschool age, the data presented in this chapter suggest that certain elements, measured at an early phase in development, are predictive for the school career of a child at a later stage. Factors that contributed to the prediction of school career later in life are for instance (a) the level of occupational achievement of the caregiver of the child, (b) maternal age at birth, (c) number of children in the family, (d) family status, (e) living area, (f) sex, and (g) age of the child at inclusion.

More specifically, a highly relevant contextual element is believed to be the socio-economic status (SES) of the family in which the child is living. In relatively many studies, a SES index is calculated based on data concerning the parental education and/or parental occupation. In the present study, of the parameter 'occupational achievement of the caregiver' (LOA) was included. Because LOA was found to be predictive of school career in the present study, it can be concluded that SES, as estimated from the level of occupational achievement of the caregiver collected in the study, is a main predictor of a longitudinal school career in a model including several biological, contextual, and behavioral components. These results are comparable to studies of Childs & McKay (2001) and Walker, Greenwood, Hart, & Carta (1994). Greenberg et al. (1999) suggested in this context that SES was a possible marker for more specific demographic factors, such as a single-parent family structure, family size, and mother's age at birth, which have been found to relate to children's adjustment. It would, therefore, give additional information if the so-called macro-demographic variables (e.g., ethnicity, and SES, LOA) were filtered out of the analysis to consider the role of the more specific demographic factors. In the present study, the role of these so-called macro-demographic variables (e.g., race and SES) was considered in the analyses simultaneously with the more specific demographic variables. As mentioned earlier, in this type of analysis SES was found to be the main predictor. However, post-hoc the effect of SES was filtered out from the analyses (as

suggested by Greenberg et al. [1999]). As a result of this, it was found that although the effects of the other predictors remained comparable, the predictor variable 'number of children within the family' was not a significant predictor of school career. After correction for SES, a significant relation was found in the present study between the number of children in a family and academic performance, while including other biological, contextual, or behavioral predictors. As found in the present study after inclusion of LOA in the model, smaller families have been related to an increased chance for a successful school career, whereas in larger families (more than 2 children) child rearing is believed to become more rule ridden, less individual parental attention for each child, and less investment of resources. Thereby, the children from larger families have an increased risk for a deviant school career. Furthermore, with or without correction for SES, family status as measured at preschool age was predictive for school career. In the group with a deviant school career, a relatively high percentage of children were living with only one parent.

In addition, maternal age at birth was found to be associated with later school performance, while correcting for other predictors. Children with relatively young (age < 27 years) mothers displayed an increased risk for a deviant school career, compared to children with average aged (27 - 33 years) and older (> 33 years) mothers. This finding is believed to be an addition to the results of earlier conducted studies, for in these studies it was found that this variable was predictive for psychological problems in children; the influence of maternal age on school career as was done in the present study, has to our knowledge not been studied earlier (Brooks-Gunn & Furstenberg, 1986).

Also, maternal depression has been related to psychopathology in children (Canino, Bird, Rubio-Stipec, Bravo, & Alegria, 1990; Myers, Taylor, Alvy, Arrington, & Richardson, 1992; Shaw, Keenan, & Vondra, 1994), however, no research is presently available in which maternal depression is related to scholastic performance. In the present study, no additional significant predictive values were found for the mental support given to the mother on the longitudinal school career of the child, while correcting for other predictive factors (such as family status, LOA, and behavioral characteristics of the child). However, we included in this perspective only those mothers who received professional help for their mental problems. Sub-clinical psychopathology of the caregiver was not taken into consideration.

In our study, the physical environment in which the child develops was found to be a minor predictor of school career. It thereby makes a difference whether the children are living in the urban or rural areas when predicting school career. Of the nominal group a relatively large percentage was living in the non-urban area, whereas for the other group this percentage is relatively small. From literature, it is additionally known that the physical environment of the home and subsequently the school may also play a significant role in children's well-being. The

provision of learning stimulation, an adequate play environment, and physical safety have been related to behavioral problems and to academic functioning (Cohen & Brook, 1987; Dubow & Ippolito, 1994; Duncan, Brooks-Gunn, & Klebanov, 1994; Elardo & Bradley, 1981; Greenberg et al., 1999).

Finally, sex tended to be predictive of academic achievement later in life over and above other predictive factors (such as biological, contextual, and behavioral related variables). Boys had more chance, compared to girls, to develop a deviant school career.

Scores on the Child Behavior Checklist as predictors

Next to the biological and contextual predictors, two behavioral characteristics of the child measured at preschool age contributed to the prediction of school career. Attention problems and delinquent behavior measured at preschool age were predictive for school career. Relatively high percentages of clinical and borderline scores on the CBCL attention problems-subscale and of borderline scores on the CBCL delinquent behavior-subscale were found in the group of children who had a deviant school career. The finding that especially a diminished attention capacity is predictive for deviant scholar performance later includes relevant implications regarding early intervention-strategies and also states the importance of earlier detection of children with for instance Attention-Deficit/Hyperactivity Disorder (ADHD). Earlier conducted studies in this context, e.g., Cadieux & Boudreault (2002), Mantzicopoulos (1997), Simner (1983), Verhulst, Koot, & Van der Ende (1994), were only of limited applicability because there were only small samples of subjects tested within the design and because children who repeated a grade in the follow-up were not considered in the analyses. Therefore, it can be concluded that the results presented in this chapter are a new and significant addition to the existing literature.

Points of consideration

This study has limitations. For instance, only a limited number of biological, contextual, and behavioral variables were included in the present study. To increase our knowledge concerning predictive factors at preschool age for academic outcome later, it is necessary to search for other elements (e.g., neighborhood risks, family stress (such as negative life events), and specified cognitive tasks or measures of emotional development).

In addition, the cohort study included a relatively high percentage of non-responders (that is, ca. 42.5%). However, for the periodic health examination, all children (both responders and non-responders) were already examined as part of the routine health examination carried out by the school doctor. By law, school doctors are allowed to use medical information anonymously for epidemiological

Table 4. Logistic regression analysis of school career as a function of psychosocial and behavioral variables.

	B	S. E.	p-value	C. I. lower bound	C. I. upper bound
Sex					
Boys	.360	.143	.012	1.083	1.897
Girls					
Nationality					
Dutch					
Foreign born					
Family status					
Two parents	-.522	.218	.017	.387	.909
One parent					
Living area					
Urban	.326	.153	.033	1.026	1.870
Non urban					
Number of children in family					
1 child	-.404	.227	.075	.427	1.042
2 children	-.418	.166	.012	.476	.911
> 2 children					
Position of the child in sibship					
1 st child					
2 nd child					
> 2 nd child					
Mental support mother					
No					
Yes					
Age Child at inclu- sion	.628	.173	.000	1.334	2.633
Maternal age at birth					
≤ 26 years					
27-33 years	-.339	.174	.052	.506	1.003
>33 years	-.579	.240	.016	.350	.896
LOA					
low					
middle	-.351	.178	.048	.497	.998
high	-.915	.195	.000	.273	.588

purposes. Therefore, it was possible to compare two random samples of 200 non-responders with 200 responders with regard to child characteristics (sex, age), family variables (parental occupation, nationality, family structure), and environmental variables (living area) collected from the medical status of the

Table 5. Logistic regression analysis of school career as a function of psychosocial and behavioral variables.

	B	S. E.	p-value	C.I. lower bound	C.I. upper bound
Withdrawn					
Control					
Borderline					
Clinical					
Physical complaints					
Control					
Borderline					
Clinical					
Anxiety/Depression					
Control					
Borderline					
Clinical					
Social problems					
Control					
Borderline					
Clinical					
Thought problems					
Control					
Borderline					
Clinical					
Attention problems					
Control					
Borderline	.742	.393	.059	.973	4.531
Clinical	2.043	.662	.002	2.108	28.254
Delinquent behavior					
Control					
Borderline	.890	.349	.011	1.228	4.827
Clinical	.676	.449	.133	.815	4.739
Aggressive behavior					
Control					
Borderline					
Clinical					
Sexual problems					
Control					
Borderline					
Clinical					

Youth Health Care. This comparison was necessary to generalize the finding to the entire population. However, no significant differences between the responders and non-responders groups were found on the variables the groups were compared (for a full description, see Kroes et al. [2001]). The data presented in table

1, in which the school career of responders and non-responders were described, supported this thought. With some caution, the results described in the present chapter can thereby be generalized to the entire population. Next, the group of children who performed normal at school may include some children who were, in comparison to their classmates, relatively young at inclusion. However, based on an article of Morrison, Griffith, & Alberts (1997), it may be concluded that the outcome of children who are young when entering kindergarten are not at risk for academic underachievement, lowered self-esteem, or later adaptation problems. We thereby concluded that our results would not differ when comparing the children who were very young when entering the study and children who were at a nominal age. Finally, cross-informant reports, like Teacher Reports, were not included here. However, Barkley (1998) reported evidence of a 90% overlap between parent reports and teacher reports. In addition, the inclusion of teacher reports² at preschool age can increase the predictive value of academic achievement but this type of measure is beatific. As stated by several authors, there are limitations in the reliability and validity of teachers' ratings of for instance attention and distractibility issues. It may well be that a score on a rating reflects the implicit expectations of the teacher about gender, age of the child and the context. In addition, it may be that teachers include a long time interval during which they have known the child to evaluate the present situation, and finally scoring may depend on the idiosyncratic interaction between the child and the teacher (Childs & McKay, 2001; Childs, 1997; Rutter et al., 1997). Research in the field of the additive value of teacher informants at preschool age is, therefore, recommended for the future.

Concluding remarks

Based on the data presented in this chapter, it can be concluded that a number of factors, e.g. the attention capacity of the child measured at preschool age, are predictive of school career later in life, even in a general population. For the future, it would be interesting, first, to include additional data concerning the cognition and emotional status of children at preschool age as predictors, secondly, to measure interactions of these predictive variables, and, thirdly, to follow the children over an even longer period of time and to test this general population with respect to their performance on more specified academic tests, such as tests measuring reading skills, mathematics, and spelling, and also in terms of the development of addictions and social competence. The main objectives for the future should therefore be 'can we, based on these newly acquired data, predict with more certainty at an early age, which children deviate in their development from normality? And in addition, if it is eventually possible to select those chil-

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² Concerning the behavior of the child, but also the academic performance as judged by the teacher.

dren at risk with a high amount of certainty, this information should be used to develop specified and more effective preventive intervention strategies’.

References

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barnett, W. S. (1995). Long-term effects of early childhood programs on cognitive and school outcome. *The future of children*, 5(3), 25-50.
- Brooks-Gunn, J., & Furstenberg, F. (1986). The children of adolescent mothers: Physical, academic and psychological outcomes. *Developmental Review*, 6, 224-251.
- Cadieux, A., & Boudreault, P. (2002). Psychometric properties of a kindergarten behavior rating scale to predict later academic achievement. *Psychological Reports*, 90, 687-698.
- Cadieux, A., & Leduc, A. (1992). L'identification des élèves à risque. *Apprentissage et socialisation*, 15, 11-108.
- Canino, G. J., Bird, H. R., Rubio-Stipec, M., Bravo, M., & Alegria, M. (1990). Children of parents with psychiatric disorder in the community. *Journal of the American Academy Child and Adolescent Psychiatry*, 29, 398-406.
- Childs, G., & McKay, M. (2001). Boys starting school disadvantaged: Implications from teachers' ratings of behaviour and achievement in the first two years. *British Journal of Educational Psychology*, 71, 303-314.
- Childs, G. H. (1997). A concurrent validity study of teachers' ratings for nominated 'problem' children. *British Journal of Educational Psychology*, 67, 457-474.
- Clancy, C. H., & Pianta, R. C. (1993). The Metropolitan Readiness Test as a descriptor and predictor of children's competence in kindergarten through grade two. *Journal of Psychoeducational Assessment*, 11, 144-157.
- Cohen, P., & Brook, J. (1987). Family factors related to the persistence of psychopathology in childhood and adolescence. *Psychiatry*, 50, 332-345.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functie-analyse*. Den Haag: SDU uitgeverij.
- Dubow, E. F., & Ippolito, M. R. (1994). Effects of poverty and quality of the home environment on changes in the academic and behavioral adjustment of elementary school age children. *Journal of Clinical Child Psychology*, 23, 401-412.
- Duncan, G. J., Brooks-Gunn, J., & Klebanov, P. K. (1994). Economic deprivation and early childhood development. *Child Development*, 65, 296-318.
- Durlak, J. (2001). School problems in children. In M. C. Roberts (Ed.), *Handbook of clinical child psychology* (3th ed.). New York: John Wiley & Sons, Inc.
- Elardo, R., & Bradley, R. H. (1981). The Home Observation for Measurement of the Environment (HOME) Scale: A review of research. *Developmental Review*, 1, 113-145.
- Fletcher, J. M., & Foorman, B. R. (1994). Issues in definition and measurement of learning disabilities: The need for early intervention. In G. R. Lyon (Ed.), *Frames of reference for the assessment of learning disabilities* (pp. 185-200). Baltimore,

MD: Brookes.

- Frymier, J., & Gansneder, B. (1989). The Phi Delta Kappa study of students at risk. *Phi Delta Kappa*, 71, 142-146.
- Greenberg, M. T., Lengua, L. J., Coie, J. D., & Pinderhughes, E. E. (1999). Predicting developmental outcomes at school entry using a multiple-risk model: Four American communities. *Developmental Psychology*, 35(2), 403-417.
- Jefferis, B. J. M. H., Power, C., & Hertzman, C. (2002). Birth weight, childhood socio-economic environment, and cognitive development in the 1958 British birth cohort study. *BMJ*, 325(7359), 305.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kellam, S. G., Werthamer-Larsson, L., Dolan, L. J., Brown, C. H., Mayer, L. S., Rebok, G. W., Anthony, J. C., Laudolff, J., Edelsohn, G., & Wheeler, L. (1991). Developmental epidemiologically based preventive trials: Baseline modeling of early target behaviors and depressive symptoms. *American Journal of Community Psychology*, 19, 563-584.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Mantzicopoulos, P. Y. (1997). Do certain groups of children profit from early retention? A follow-up study of kindergartners with attention problems. *Psychology in the Schools*, 34, 115-128.
- Matte, T. D., Bresnahan, M., Begg, M. D., & Susser, E. (2001). Influence of variation in birth weight within normal range and within sibships on IQ at 7 years: Cohort study. *BMJ*, 323, 310-314.
- Morrison, F. J., Griffith, E. M., & Alberts, D. M. (1997). Nature-Nurture in the classroom: Entrance age, school readiness, and learning in children. *Developmental Psychology*, 33(2), 254-262.
- Myers, H. F., Taylor, S., Alvy, K. B., Arrington, A., & Richardson, M. A. (1992). Parental and family predictors of behavior problems in inner-city Black children. *American Journal of Community Psychology*, 20, 557-576.
- Resnick, M. B., Gueorguieva, R. V., Carter, R. L., Ariet, M., Sun, Y., Roth, J., Bucciarelli, R. L., Curran, J. S., & Mahan, C. S. (1999). The impact of low birth weight, perinatal conditions, and sociodemographic factors on educational outcome in kindergarten. *Pediatrics*, 104(6), e74.
- Richards, M., Hardy, R., Kuh, D., & Wadsworth, M. E. (2001). Birth weight and cognitive function in the British 1946 birth cohort: Longitudinal population based study. *BMJ*, 322, 199-203.
- Rutter, M., Dunn, J., Plomin, R., Simonoff, E., Pickles, A., Maughan, B., Ormel, J., Meyer, J., & Eaves, L. (1997). Integrating nature and nurture: Implications of

- person-environment correlations and interactions for developmental psychopathology. *Development and Psychopathology*, 9(2), 335-264.
- Sameroff, A. J., & Seifer, R. (1990). Early contributors to developmental risk. In S. Weintraub (Ed.), *Risk and protective factors in the development of psychopathology* (pp. 52-66). New York: Cambridge University Press.
- Shapiro, B. K., Accardo, P. J., & Capute, A. J. (1998). *Specific reading disabilities: A view of the spectrum*. Timonium, MD: York.
- Shaw, D. S., Keenan, K., & Vondra, J. (1994). Developmental precursors of externalizing behavior: Ages 1 to 3. *Developmental Psychology*, 30, 355-364.
- Shenkin, S. D., Starr, J. M., Pattie, A., Rush, M. A., Whalley, L. J., & Deary, I. J. (2001). Birth weight and cognitive function at age 11 years: the Scottish Mental Survey 1932. *Archives of Disease in Childhood*, 85, 189-196.
- Siedman, D. S., Laor, A., Gale, R., Stevenson, D. K., Mashlach, S., & Danon, Y. L. (1992). Birth weight and intellectual performance in late adolescence. *Obstetrics and Gynecology*, 79(4), 543-546.
- Simner, M. L. (1983). The warning signs of school failure: An updated profile of the at-risk kindergarten child. *Topics in Early Childhood Special Education*, 3, 17-27.
- Sorensen, H. T., Sabroe, S., Olsen, J., Rothman, K. J., Gillman, M. W., & Fischer, P. (1997). Birth weight and cognitive function in young adult life: Historical cohort study. *BMJ*, 315, 401-403.
- Stanger, C., Achenbach, T. M., & McConaughy, S. H. (1993). Three-year course of behavioral/emotional problems in a national sample of 4- to 16-year-olds: 3. Predictors of signs of disturbance. *Journal of Consulting and Clinical Psychology*, 61(5), 839-848.
- Steingard, R. J., Biederman, J., Doyle, A., & Sprich-Buckminster, S. (1992). Psychiatric comorbidity in attention deficit disorder: Impact on the interpretation of Child Behavior Checklist results. *Journal of the American Academy Child and Adolescent Psychiatry*, 31, 449-454.
- Tjossum, T. D. (1976). *Interventions-strategies for high risk children and young children*. Baltimore, MD: University Park Press.
- Verhulst, F. C., Koot, H. M., & Van der Ende, J. (1994). Differential predictive value of parents' en teachers' reports of children's problem behavior: A longitudinal study. *Journal of Abnormal Child Psychology*, 22(5), 531-546.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Walker, D., Greenwood, C., Hart, B., & Carta, J. (1994). Prediction of school outcomes based on early language production and socioeconomic factors. *Child Development*, 65, 606-621.

A longitudinal study on the both quantity and quality of sleep in children and the influence of behavioral and contextual factors¹

Abstract

The first aim of the study presented in this chapter was to study the association between contextual, biological, and behavioral characteristics of a child on the one hand and sleep on the other. For this purpose, several aspects related to sleep (e.g., presence of nightmares, amount of sleep, sleep problems in general) were examined in a non-clinical population of 5- to 6-year-old Dutch preschool-aged children ($n = 1258$). The results of this first experiment showed that sleep problems were commonly observed in preschool-aged children. Rates of parental reports of sleep problems, as observed in their child at least sometimes, ranged from 3.9% for an increased amount of sleep to 17.9% for nightmares, with general sleep problems (11.8%), sleep walking/talking (14.9%), and a decreased amount of sleep (11.4%) being intermediate. In addition, it was found that certain behavioral (e.g., physical complaints, thought problems, aggressive behavior, and anxiety/depression) and contextual (e.g., the level of occupational achievement of the caregiver, the number of children in the family, family status, and the age of the mother at birth) characteristics of preschool-aged children were correlated highly with specific parent-reported sleep problems. The second research question addressed the stability of sleep as a function of time. A sample of the children screened at preschool age (286 of the 1258 children) was screened again 3 years later by means of the Child Behavior Checklist (CBCL). Data obtained were compatible with the notion that problematic sleep and specific behavioral aspects (such as having attention problems) measured at preschool age were predictive of sleep problems 3 years later. This finding emphasizes the relevance of teaching parents about good sleep hygiene for their child in the hope of preventing more serious or chronic sleep-related problems.

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Introduction

Sleep problems are commonly observed in children. Prevalence estimates vary from 25% for preschool children (Mindell, 1993) to 43% in 8 - 10-year-olds (Kahn et al., 1989; Stores & Wiggs, 1998). Sleep problems are believed to be diverse in type, etiology, and treatment requirements, and to have serious effects on various aspects of development. Unfortunately, many questions related to this subject are still unanswered. Examples of those questions are concerned with the influence of contextual, biological, and behavioral factors on sleep (and consequently sleep problems) and the stability of sleep over time.

The development of an individual child occurs within the multiple contexts of home, school, and the neighborhood. All of these aspects may contribute singularly or in combination to the effectiveness of sleep (Greenberg, Lengua, Coie, & Pinderhughes, 1999; Sameroff & Seifer, 1990). For instance, the number of children in the family and the age and educational background of the mother were associated with night waking (Rona, Leah, Gulliford, & Chinn, 1998; Smedje, Broman, & Hetta, 1999). In addition, behavioral aspects of the child (including thoughts, attention, but also externalizing behavior) tended to be associated with the quality and quantity of sleep. For instance, clinical studies have reported high rates of sleep problems of various types in groups of children suffering from Attention-Deficit/Hyperactivity Disorder (Chervin, Dillon, Bassetti, Ganoczy, & Pituch, 1997; Corkum, Tannock, & Moldofsky, 1998; Dahl & et al., 1990), depression (Emslie, Rush, Weinberg, Rintelmann, & Roffwarg, 1990), Posttraumatic Stress Disorder (Glod, Teicher, Hartman, & Harakal, 1997; Ross, Ball, Sullivan, & Caroff, 1989), and learning disabilities (Mercier, Pivik, & Busby, 1993).

Recently, Aronen, Paavonen, Fjallberg, Soininen, & Torronen (2000) found in a relatively small, non-clinical sample of 7-12 yr olds ($n = 49$) a significant association between low true sleep time and teacher-reported attention problems, social problem behavior, and externalizing symptoms, such as aggressive and delinquent behavior. In addition, Stein, Mendelsohn, Obermeyer, Amromin, & Benca (2001) reported for a sample of 4 - 12-year-old children ($n = 472$) high correlations of sleep problems with parent reported internalizing and externalizing behavior and with the majority of CBCL factor scores.

Limitations of the above-mentioned studies were the small sample sizes, a bias towards the inclusion of children with high SES, and the cross-sectional nature of the study. In addition, a relatively high percentage of studies involving sleep pattern in children included only children referred to the clinical setting for some developmental problem. Referral bias as well as the presence of multiple and severe disorders may limit the generalizability of the clinical sample studies (Ferdinant & Verhulst, 1995). Identifying sleep patterns in a nationally representative general population sample should avoid these earlier mentioned biasing factors inherent in clinically referred or school-based samples (Aronen et al.,

2000; Stanger, Achenbach, & McConaughy, 1993). However, only few have actually studied sleep within a representative general population rather than within samples pre-selected by clinical referral (Resnick et al., 1999; Stanger et al., 1993).

Additional studies on the associations of contextual, biological, and behavioral characteristics in children and sleep are, therefore, still required, including well-defined, extensive population studies within a prospective, longitudinal design (Aronen et al., 2000). For this reason, the first research question addressed in this article relates to the association between contextual, biological, and behavioral characteristics of a child and the amount and quality of sleep. For this purpose we examined more extensively several aspects related to sleep (e.g., presence of nightmares, amount of sleep, and sleep problems in general) in a non-clinical sample of 5 - 6-year-old Dutch pre-school children ($n = \pm 2300$). Here, it was hypothesized that several aspects of social environment and behavior of the child at pre-school age may in part be associated with inadequate sleep.

Cross-sectional studies repeatedly found that sleep problems are prevalent in all stages of development (Blader, Koplewicz, Abikoff, & Foley, 1997; Simonds & Parraga, 1982; Stein et al., 2001). However, to our knowledge only few prospective, longitudinal studies have been published that examine the stability of sleep patterns as a function of time. This is unfortunate for information concerning the longitudinal development of sleep patterns (especially deviant patterns) may include implications for future treatment protocols. Therefore, the second aim of the study presented in this chapter was to explore how sleep patterns in school-aged children change over a period of three years, within a longitudinal, prospective study design. With respect to the stability of sleep problems, it is additionally interesting to study the influence of other aspects of behavior, which were measured at preschool age on sleep measured three years later. Therefore, the third aim of the study was to examine the influence of behavioral factors on sleep within a longitudinal design.

For all aims, the data concerning specific sleep parameters, behavior, and environment were collected by use of questionnaires. Investigating children's sleep by using parents' reports derived from a questionnaire has the limitation of being reliant on parental subjectivity and recollection. However, there are at least three reasons to justify the use of questionnaires, namely (a) the method provides the opportunity to collect information from a large sample of children, (b) knowledge about parents' perceptions is important, since it is usually the parent who considers the child as sleep or behaviorally disturbed and in need of remedy, and (c) parents are believed to be good informants on specific types of problems observable and concrete, such as difficulties in initiating sleep, bedtime resistance, night terrors and bedwetting. Other types of problems, like night waking, may escape the parents' notice (Aronen et al., 2000; Stein et al., 2001; Stores, 1996).

Methods

Sample and survey method

This report is part of a large prospective population study entitled 'The Study of Attention Disorders Maastricht (SAM)', which was approved by the Medical Ethics' Committee of the Academic Hospital in Maastricht, The Netherlands. The SAM study consists of 4 separate phases (for an expanded description of the study, see Kalff et al. [2001] and Kroes et al. [2001]). For the present chapter, only three stages are relevant and will be discussed here. An overview of the data collection for answering the research questions included in the present chapter is presented in figure 1.

Figure 1. A schematic representation of the data collection as part of SAM.

In the first phase (months 1 - 9), a sample of ± 2300 Dutch children attending second grade of normal kindergarten and living in the region South Limburg of the Netherlands was approached to participate in the present study. In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write, and it is during this grade that the children were invited by the Youth Health Care for a Periodic Health Examinations. The vast majority (around 98%) of children usually attend these health examinations. The initial approach of participants for the SAM-study took place in conjunction with this Periodic Health Examination for it was a perfect opportunity to reach a large sample of healthy young children. During the visit to the Youth Health Care for the periodic health examination, the caregivers of these children were asked to participate in the SAM-study and, in case of approval, to fill in an informed consent and a questionnaire as part of a large longitudinal cohort study. Caregivers could return the papers by mail. Response rate of the written informed consent and filled in questionnaires was 57.5% ($n = 1317$). By law, Dutch school doctors, conducting the earlier-mentioned health examina-

tions, are allowed to use medical information anonymously for epidemiological purposes. Therefore, it was possible to compare two random samples of 200 non-responders with 200 responders for child characteristics (such as age, sex), family variables (parental occupation, family structure, nationality of the parents), and environmental variables (living area) collected from the medical status of the Youth Health Care. This comparison was necessary because of the relatively large percentage of non-responders, however, no significant differences between the groups were found (for a full description, see Kroes et al. [2001]).

In *phase 2 (months 1 - 9)*, a subgroup ($n = 452$) of the responders who were initially included was defined on the basis of the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), and selected for further research (for an extended description of the selection criteria, see Kalff et al. [2001] and Kroes et al. [2001]). Based on the Dutch version of the Child Behavior Checklist (CBCL), three subgroups were selected, namely (A) a group of children ($n = 173$) scoring high either on the CBCL externalizing broad-band scale ($> 90^{\text{th}}$ percentile) or the CBCL Attention problems subscale ($> 95^{\text{th}}$ percentile); (B) a group of children ($n = 59$) scoring within a clinical range on the CBCL Internalizing scale ($> 90^{\text{th}}$ percentile), but without fulfilling the criteria for group A membership; (C) a control group ($n = 220$) with low CBCL total problem scores ($< 90^{\text{th}}$ percentile) and matched to group A and B in terms of age (± 2 months), sex and school (urban vs. rural). This selected subgroup of 452 children was approached again three years after the original inclusion (*phase 3: months 39 - 49 follow-up*) for participation in a follow-up of the study. This follow-up consisted of filling in the CBCL by the caregivers of the child. In total, 286 caregivers filled in the CBCL.

Instruments

Biological and contextual variables measured at preschool age

The biological and contextual risk factors considered in the present article are summarized in Table 2. The mean and standard deviation (S. D.) of the continuous predictor variable was provided in this table. In addition, frequencies (both the percentages and the sums of raw data) were given for the categorical predictors. Included variables were related to familial, environmental and behavioral aspects of the child. Predictor Variables: Biologically related. Both (a) age at the time of inclusion (in years) and (b) sex of the child were included in the data collection. Predictor Variables: Contextual related. Several family-related risk factors were included in the present study, namely (c) The Level of Occupational Achievement of the caregiver (LOA) which is based on the full description of the parental occupation and originally scored on a 8-points-scale, ranging from unskilled to scientific skilled labor (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded as a separate category.

When the LOA differed between mother and father or if data was missing for one caregiver, the highest available score was chosen. For the present study, the LOA-scores were transformed from a 8-points-scale to a 3-points-scale, ranging from low (LOA-codes 0, 1, 2, 3), middle (4 & 5) to high (6 & 7); (d) The country of birth of the parents was defined as Dutch vs. foreign born; (e) The family status was scored as to whether the child was living with two parents or with one parent; (f) The maternal age at birth, as defined on a three-points-scale ranging from relatively young (age < 27 years) to average aged (27 - 33 years) and older (> 33 years); (g) Number of children in the family. Predictor Variables: Social environment related. In addition, one aspects related to social environment was included here, namely (h) the living area of the child (urban vs. rural).

Behavioral and sleep characteristics - at preschool age and follow-up

Behavior of the children was measured by use of the caregiver-version of the Child Behavior Checklist (CBCL). Originally, the CBCL was developed by Achenbach & Edelbrock (1983) and revised and translated into Dutch by Verhulst et al. (1996). It was designed to be a screening instrument and previous published studies have demonstrated its usefulness for detecting children with and without behavior problems according to parental reports (Steingard et al., 1992). Of the 113 ordinal-scaled items, T-scores for a total problem scale, two broad-band scales (Externalizing and Internalizing behavior problems) and subsequently nine narrow-band scales (Withdrawn, Physical Complaints, Anxious/Depressed, Social Problems, Thought Problems, Attention Problems, Delinquent Behavior, Sexual Problems and Aggressive Behavior) were derived by use of a pre-set algorithm (Achenbach & Edelbrock, 1983). T-scores were calculated ranging from 50-100, on basis of norms correcting for sex and age (Verhulst et al., 1996). In addition, Verhulst et al. (1996) defined borderline and clinical cut-off scores for the narrowband scales (borderline :T-scores have to be between 67 and 70 (that is, between the 95th – 98th percentile; clinical: T-scores have to be larger than 70 (that is, above 98th percentile).

Finally, the CBCL included five items questioning the amount and quality of the child's sleep. Items related to the amount of sleep were (a) the child is sleeping less than other children (item 76), and (b) the child is sleeping more than other children (item 77). Quality of sleep was measured by (c) the child has in general trouble sleeping (item 100), (d) the child has nightmares (47), and (e) the child is sleep talking/walking (92). Caregivers were asked to estimate the frequency of occurrence of these sleep-related events on a 3-point-scale (0 = not true; 1 = somewhat or sometimes true; 2 = very true or often true). All of the sleep related items were not included in the above-mentioned behavior-related subscales of the CBCL.

Table 1. Descriptive statistics for child, family, and environmental characteristics of the responders' sample measured at preschool age (n = 1317).

Variables	N	%	Variables	N	%
Sex			Withdrawn		
Boys	699	53.1	Control	1248	94.8
Girls	618	46.9	Borderline	34	2.6
Nationality parents			Clinical	35	2.7
Dutch	1147	87.1	Physical complaints		
Foreign born	141	10.7	Control	1205	91.5
Missing	29	2.2	Borderline	63	4.8
Family status			Clinical	49	3.7
Two parents	1159	88.0	Anxiety/Depression		
One parent	141	10.7	Control	1257	95.4
Missing	17	1.3	Borderline	38	2.9
Living area			Clinical	22	1.7
Urban	775	58.8	Social problems		
Non urban	542	41.2	Control	1266	96.1
Number of children in family			Borderline	27	2.1
1 Child	196	14.9	Clinical	24	1.8
2 Children	737	56.0	Thought problems		
> 2 Children	367	27.9	Control	1273	96.7
Missing	17	1.3	Borderline	18	1.4
Maternal age at birth			Clinical	26	2.0
≤ 26 Years	298	22.6	Attention problems		
27-33 Years	744	56.5	Control	1253	95.1
>33 Years	255	19.4	Borderline	37	2.8
Missing	20	1.5	Clinical	27	2.1
LOA			Delinquent behavior		
Low	472	35.8	Control	1227	93.2
Middle	387	29.4	Borderline	51	3.9
High	446	33.9	Clinical	39	3.0
Missing	12	0.9	Aggressive behavior		
			Control	1219	92.6
	M	SD	Borderline	47	3.6
Age			Clinical	51	3.9
Child at inclusion (in yrs)	5.9	0.4	Sexual problems		
			Control	1270	96.4
			Borderline	29	2.2
			Clinical	18	1.4

Results

Results of data measured at preschool age

As a first step in analyzing the data measured at preschool age, the missing data were analyzed. Of the 1317 cases included in the data selection, 59 cases were

eventually deleted because they had missing values on at least one of the ordinal or nominal predictors, namely nationality (n = 29), family status (n = 17), number of children in the family (n = 17), LOA (n = 12), maternal age (n = 20), and the dependent, outcome variables (nightmares: n = 2, decreased sleep: n = 5, increased sleep: n = 7, sleepwalking/talking: n = 2, general sleep problems: n = 5). Secondly, after deletion of missing data, correlations between the predictor variables were calculated. CBCL broad-band scales (internalizing behavior and externalizing behavior) and the total problems scale were not included in the table because these scales were derived from the 9 narrow-band scales of the CBCL and are, therefore, presumed to correlate high. The correlations between the predictor variables included in the present study ranged from -.194 to .480. Because no extremely high correlations were found between the predictor variables, multicollinearity was believed to be ruled out.

Thirdly, the distribution of the scores on the 5 items of the CBCL related to sleep as measured at preschool age over 1258 children is displayed in figure 2. The results displayed here are highly comparable with the results described by Verhulst et al. (1996), except for the scores on CBCL item 77 (that is, the child sleeps more than other children). In the present study, a relatively low percentage of the parents (3.9%) reported at least sometimes an increased amount of sleep in their children. This percentage is higher in a comparable age group studied by Verhulst et al (1996), who estimated the percentage of the occurrence of an increased amount of sleep in children at preschool age around 10%.

Figure 2. A 100% stacked column table including the scores on the 6 items of the CBCL related to sleep as measured at preschool age (n = 1258).

Furthermore, in the present study, Spearman correlations were calculated to study

the association between different types of sleep problems in preschool-aged children. Results of these analyses are reported in table 2. At preschool age, the correlations between different aspects of sleep were found to be moderate.

Table 2. Correlation of the scores on the 6 items of the CBCL related to sleep as measured at preschool age (n = 1258).

	1	2	3	4	5
Nightmares	-				
Decreased sleep	.140*	-			
Increased sleep	.046	-.010	-		
Sleep walking/talking	.366*	.121*	.055	-	
General sleep problems	.236*	.455*	-.012	.265*	-

* Correlation is significant at the .001 level (2-tailed).

Next, because the sample of children, who often had sleep problems, is relatively small, it was decided for each sleep-related variable to combine the group of children who sometimes had sleep problems and the group of children who often had sleep problems, while studying variables that are predictive of a normal sleep vs. a deviant sleep. By use of separate stepwise logistic regression analyses, the predictive power of contextual and behavioral factors on each CBCL sleep item was tested, while including age and sex as covariates. Comparison of the log-likelihood ratios within each individual logistic regression revealed a reliable improvement of the model while including the biological and contextual, as well as the behavioral related predictors. After addition of all predictor variables, Nagelkerke R^2 was found to be .108 for the item related to nightmares, .083 for a decreased amount of sleep, .136 for an increased amount of sleep, .120 for sleep walking/talking, and .078 for general sleep problems.

Table 4 and 5 show the influence of the included predictive factors on each CBCL sleep-related scale. Exp(B) and confidence intervals (C. I.) were given in case of significant effects. A number of socio-demographic variables and variables belonging to the behavioral set reliably enhanced prediction on the diverse aspects of sleep, that is the p-values of these variables were below .05. Contextual variables predictive of sleep were: the level of occupational achievement of the caregiver, the number of children in the family, family status, and the age of the mother at birth. Finally, aspects of behavior measured at preschool age that were predictive of sleep were: physical complaints, thought problems, aggressive behavior, and anxiety/depression, withdrawn, social problems, and delinquent behavior.

Table 4. Logistic regression analysis of school career as a function of psychoso-
cial and behavioral variables.

	Nightmares		Decreased amount of sleep		Increased amount of sleep		Walk- ing/talking		General sleep prob- lems	
	exp (B)	C.I.	exp (B)	C.I.	exp (B)	C.I.	exp (B)	C.I.	exp (B)	C.I.
Nationality										
Dutch										
Foreign born										
Family status										
Two parents	0.5 ^b	0.3-0.8								
One parent										
Living area										
Urban									1.5 ^a	1.0-2.2
Non urban										
Number of chil- dren										
1 child			2.0 ^b	1.2-3.2					1.6	1.0-2.7
2 children			0.8	0,5-1.3					0.9	0.6-1.4
> 2 children										
Position in sib- ship										
1 st child										
2 nd child										
> 2 nd child										
Mental support mother										
No										
Yes										
Age Child at inclusion										
Maternal age at birth										
≤ 26 years										
27-33 years	1.0	0.7-1.4			1.4	0.7-2.9				
>33 years	1.6 ^a	1.0-2.5			0.3	0.1-1.3				
LOA										
low										
middle							0.7 ^a	0.5-1.0		
high							0.3 ^c	0.2-0.5		

^a Correlation is significant at the .05 level (2-tailed);

^b Correlation is significant at the .01 level (2-tailed);

^c Correlation is significant at the .001 level (2-tailed).

Table 5. Logistic regression analysis of school career as a function of psychosocial and behavioral variables.

	Nightmares		Decreased amount of sleep		Increased amount of sleep		Walk-ing/talking		General sleep problems	
	exp (B)	C. I.	exp (B)	C. I.	exp (B)	C. I.	exp (B)	C. I.	exp (B)	C. I.
Withdrawn										
Control										
Borderline					6.1 ^c	2.3-16.7				
Clinical					1.3	0.3-5.7				
Physical complaints										
Control										
Borderline	3.1 ^c	1.7-5.6	1.1	0.5-2.5	3.6 ^c	1.5-8.7	3.1 ^c	1.7-5.7		
Clinical	2.9 ^b	1.4-5.7	3.7 ^c	1.8-7.7	2.6	0.9-7.7	3.8 ^c	1.9-7.4		
Anxiety/Depression										
Control										
Borderline	1.8	0.8-4.0	3.3 ^b	1.4-7.4						
Clinical	4.1 ^b	1.4-12.3	1.2	0.3-4.0						
Social problems										
Control										
Borderline							2.8 ^a	1.1-6.8		
Clinical							0.6	0.2-2.0		
Thought problems										
Control										
Borderline	1.9	0.6-6.0							2.1	0,6-6,8
Clinical	3.6 ^a	1.3-10.1							8.2 ^c	3,1-21,8
Attention problems										
Control										
Borderline										
Clinical										
Delinquent behavior										
Control										
Borderline			3.2 ^b	1.5-6.5						
Clinical			1.1	0.4-3.1						

	Nightmares		Decreased amount of sleep		Increased amount of sleep		Walk-ing/talking		General sleep prob- lems	
	exp (B)	C. I.	exp (B)	C. I.	exp (B)		exp (B)	C. I.	exp (B)	C. I.
Aggressive behavior										
Control										
Borderline	1.4	0.6-3.0					2.1 ^a	1.0-4.4	1.1	0,4-2,7
Clinical	2.5 ^a	1.2-4.9					2.4 ^a	1.2-4.9	2.7 ^b	1,3-5,6
Sexual problems										
Control										
Borderline					7.2 ^c	2.5-20.3				
Clinical					4.8 ^a	1.1-19.7				

^a Correlation is significant at the .05 level (2-tailed);

^b Correlation is significant at the .01 level (2-tailed);

^c Correlation is significant at the .001 level (2-tailed).

Results of data measured at the 3-years-follow-up

Scores on the 5 sleep-related items of the CBCL as measured both at preschool age and at follow-up are displayed in figure 3^{a,b,c,d,e}. To analyze the follow-up data and to relate them with the data gathered at preschool age, two types of analyses were conducted for each sleep parameter separately. First, a chi-square analysis was conducted in which a Kappa score was calculated to measure the relation between sleep at preschool age and sleep measured at follow-up (Kappa scores ranged from .163 - .393; see figure 3) on the one hand and the relation between CBCL behavior scores measured at preschool age and behavior measured at follow-up (Kappa scores ranged from .104 for sex problems to .486 for aggressive behavior) on the other. Both behavior and sleep tended to be relatively stable over time.

Secondly, CART analyses were conducted including behavioral, biological, contextual, and sleep characteristics measured at preschool age to examine their influence on sleep at follow-up. CART is an acronym for Classification and Regression Trees, and is a decision-tree procedure introduced in 1984 by Breiman, Friedman, Olshen, and Stone. Based on these analyses, a decision tree is drawn for each sleep item measured at follow-up. In short, a decision tree is a flow chart or diagram representing a classification system or predictive model. By use of strictly, binary, or two-way, splits, by posing questions with yes/no answers at each decision node, relationships between variables can be exposed. The advantages of CART are that (1) it includes a reliable pruning strategy, for it includes no problematic stopping rule; (2) a created decision tree is tested for new data, thereby avoiding overfitting or finding patterns that only apply to the training

data; (3) CART handles missing values in the database by substituting “surrogate splitters”, that is back-up rules that closely mimic the action of primary splitting rules. The surrogate splitter contains information that typically is similar to what would be found in the primary splitter. Other products treat all records with missing values as if the records all had the same unknown value; with that approach all such “missings” are assigned to the same bin. In CART, each record is processed using data specific to that record, allowing records with different data patterns to be handled differently, which results in a better characterization of the data. The main variables measured at preschool age that are predictive of sleep problems at a later stage were summarized for each separate item. In contrast to the analyses earlier conducted, CBCL total problems scale and the broad-bent scales were also included in the CART-analyses, for this type of analyses has no restrictions with regard to multicollinearity.

With respect to the characteristics of the child predictive for scores on the *CBCL Nightmares-item* measured at follow-up as measured by CART there were also clear findings. The decision tree and the calculated variable importance revealed that CBCL attention problems, CBCL total problems scale, and the age of the child at inclusion in the study measured at preschool age correlated highly with the appearance of nightmares at follow-up. On the learning set, children, who never had nightmares, were correctly predicted by the model in 69% of the cases; children who sometimes had nightmares were predicted in 72% correctly; and children who often had nightmares were predicted correctly in 100% of the cases. These percentages decreased when the model was applied to an independent data set (the percentage of correct classifications for children without nightmares was 63%, for children who sometimes had nightmares was 55%, and for children who often had nightmares was 43%).

Decreased amount of sleep measured at follow-up: The decision tree and the calculated variable importance revealed that ‘decreased amount of sleep measured at preschool age’ was the main predictor of a decreased amount of sleep at follow-up. On the learning set children, who slept normally, were correctly predicted by the model in 91% of the cases; children who sometimes slept less than their controls were predicted in 0% correctly; and children who often slept less were predicted correctly in 62% of the cases. These percentages stayed the same when the model was applied to an independent data set.

Increased amount of sleep measured at follow-up: The decision tree and the calculated variable importance revealed that CBCL social problems measured at preschool age and the age of the child at inclusion correlated highly with an increased amount of sleep at follow-up. On the learning set children, who slept normally, were correctly predicted by the model in 30% of the cases; children who sometimes slept more than their controls were predicted in 60% correctly; and children who often slept more were predicted correctly in 100% of the cases. These percentages decreased when the model is applied to an independent data

set (%correct classifications is for children with a normal amount of sleep 56%, for children with sometimes nightmares 0%, and for children with often nightmares 50%).

Sleep walking/talking measured at follow-up: The decision tree and the calculated variable importance revealed that CBCL Total problems measured at preschool age correlated highly with the appearance of sleepwalking/talking at follow-up. On the learning set children who never walked or talked in their sleep were correctly predicted by the model in 83% of the cases; children who sometimes showed sleep walking/talking were predicted in 47% correctly; and children who often had walked or talked during their sleep were predicted correctly in 71% of the cases. These percentages decreased when the model is applied to an independent data set (% correct classifications is for children without sleep talking/walking 78%, for children with sometimes sleep walking/talking 34%, and for children with often sleep walking/talking 29%).

General sleep problems measured at follow-up: The decision tree and the calculated variable importance revealed that CBCL attention scale, CBCL social problems, and general sleep problems measured at preschool age, and the age of the child at follow-up correlated highly with general sleep problem scores at follow-up. On the learning set children, who slept normally, were correctly predicted by the model in 73% of the cases; children who sometimes showed general sleep problems were predicted in 93% correctly; and children who often showed general sleep problems were predicted correctly in 100% of the cases. These percentages decreased when the model is applied to an independent data set (the percentage of correct classifications for children with a normal sleep was 68%, for children who sometimes showed general sleep problems 46%, and for children who often had general sleep problems 37%).

Discussion

The present study adds to the current knowledge on a number of points that will be discussed in the last paragraphs of this chapter. The first research question addressed in this article relates to the association between contextual, biological, and behavioral characteristics of a child and the amount and quality of sleep. For this purpose, several aspects related to sleep (e.g., presence of nightmares, amount of sleep, sleep problems in general) were examined in a healthy population of 5 - 6-year-old Dutch preschool-aged children. Additionally, only few prospective, longitudinal studies have, to our knowledge, been published that examine the stability of sleep as a function of time. This is unfortunate, because information concerning the longitudinal development of sleep patterns (especially deviant patterns) may include implications for future treatment protocols. Therefore, the second aim of the study presented in this chapter was to explore how sleep patterns in school-aged children change over a period of three years. With respect to the stability of sleep problems, it is additionally interesting to study the

influence of certain aspects of behavior (apart from sleep) measured at preschool age on sleep measured three years later. Therefore, the third aim of the study was to examine the influence of behavior on sleep within a longitudinal design.

The results of the study presented in this chapter will be discussed here. However, the reader should keep in mind that all types of predictors (biological, contextual, and behavioral) were entered simultaneously in the analyses and that the predictors included in the present study are not the only biological, contextual and behavioral factors imaginable.

Prevalence rates

Based on the present study, it can be concluded that, within a non-clinical population of children attending normal elementary schools, sleep problems are commonly observed. Rates of parental reports on sleep problems, as observed in their child at least sometimes, ranged from 3.9% for an increased amount of sleep to 17.9% for nightmares, with general sleep problems (11.8%), sleep walking/talking (14.9%), and a decreased amount of sleep (11.4%) being intermediate. Because of the diverse sleep measures (e.g., questionnaires, polysomnography) and different criteria (e.g., with regard to frequency of occurrence and age of inclusion) used to define 'sleep problems' in the literature, it is difficult to relate the prevalence scores of sleep problems calculated in the present study to those in other studies. For example, at pre-school age, Smedje et al. (1999) have established prevalence rates of certain types of sleep problems with the inclusion of parents' reports of 1844 children (aged 5 - 7 years old) from the general Swedish population. Within this population, 3.0% of the children had at least once a week a nightmare, 4.1% showed at least once a week sleep walking/talking, and 5.3% wetted their beds at least once a week. By use of a parent-completed Sleep behavior questionnaire, Stein et al. (2001) found additionally within a population of 4 - 12 year-old children that 8.5% displayed nightmares more than once a week, 2.4% sleepwalks more than once a week, 19.7% talks in their sleep more than once a week, and 10% suffered from enuresis.

Based on the data available from the present study and previous cross-sectional studies, it can, therefore, be concluded that sleep problems in children occur frequently, ranging from 2 - 25%, with several types of expression (e.g., decreased amount of sleep, nightmares) (Smedje et al., 1999; Stein et al., 2001). Unfortunately, the functional impairment of these sleep difficulties is believed to be grand. As Kahn et al. (1989) reported that more than 28% of the parents of children with sleep difficulties had expressed a desire with regard to counseling on the subject, and a part of the subjects (4%) were using sedatives on a regular basis.

Figure 3. A 100% stacked column table of scores on the CBCL sleep-related items as measured at preschool age and follow-up.

Contextual, and behavioral factors in relation to sleep measured at pre-school age

As mentioned already, significant associations have been found in earlier studies between sleep and socio-demographic and environmental variables, such as chaotic settings, inconsistent parenting, and maternal age at child's birth, West Indian and African origin, and mother's smoking behavior at home (Pollock, 1994; Rona et al., 1998; Stein et al., 2001). These last-mentioned studies have several disadvantages, notably small sample sizes, bias towards the inclusion of children with high SES, and the cross-sectional nature of the study. In addition, a relatively high percentage of studies involving sleep pattern in children included only children referred to the clinical setting for some developmental problem. Therefore, in the present study, a number of biological and contextual factors were associated with sleep as measured within a Dutch preschool-aged population. In this study, it was found that certain behavioral (e.g., physical complaints, thought problems, aggressive behavior, and anxiety/depression) and contextual (e.g., the level of occupational achievement of the caregiver, the number of children in the family, family status, and the age of the mother at birth) characteristics of preschool aged children were correlated highly with specified parent-reported sleep problems. Some of these findings will be discussed here in more detail.

More specifically, in the present study, physical complaints measured at preschool age were associated with almost all types of sleep problems, except for general sleep problems. That is, the scores on the sleep parameters increased when the number of physical complaints increased, which adds support to findings in smaller studies conducted earlier (Smedje et al., 1999; Stein et al., 2001). These studies reported, for a clinical referred population, sleep problems to correlate positively with allergy, ear infections, hearing problems, colic during infancy, and frequent falls. However, these earlier studies did not include more than one type of sleep problems.

Furthermore, nightmares and a decreased amount of sleep were correlated with borderline and clinical scores on the CBCL Anxiety / Depression-scale. Similar findings were done in the study of Johnson, Chilcoat, & Breslau (2000). They found that parental reports of anxiety and/or depression on the CBCL correlated significantly with general sleep problems, even after controlling for total problem behavior as scored on the CBCL. The additive value of the present study in comparison to the study of Johnson et al. lies in the inclusion of collecting information about other sleep parameters than general sleep alone (e.g., sleep walking/talking and nightmares).

In addition, it was found for increased sleep time to correlate positively with withdrawn and sexual problems as observed by the caregiver of the child, whereas a decreased sleep time was correlated significantly with borderline levels of anxiety, depression, and delinquent behavior as registered at preschool age. This last result is an addition to the study of Aronen et al. (2000), that showed

that a decreased amount of sleep was associated with aggressive and delinquent behavior, attention, social, and physical problems. The results of the study of Aronen et al. were gathered within a relatively small group ($n = 49$) of older children aged 7 - 12 years, whereas the present study included a much larger sample of children aged 5-6 years.

Finally, a significant correlation was found between general sleep problems and the area children live in. More general sleep problems were found in children living in urban areas compared to children living in rural areas. The data presented in this chapter revealed that living area was not significantly correlated with the aspects of sleep studied other than general sleep problems. This last finding may indicate that a general reporting bias exists in responding on the general sleep-item. It may be that in scoring this general sleep item, parents take into consideration additional aspects (for instance bedtime resistance, but also behavior through the day) than when scoring the more specified sleep parameters.

All of the above-mentioned findings add support to the notion that sleep problems can be environmentally or biologically induced or influenced, especially because the data presented in the current chapter were gathered within a well-defined sample from the general population.

Longitudinal aspect of sleep over a period of three years

As mentioned earlier in the introduction, cross-sectional studies repeatedly found that sleep problems are prevalent in all stages of development (Blader et al., 1997; Simonds & Parraga, 1982; Stein et al., 2001). However, to our knowledge only one prospective, longitudinal study (Johnson et al., 2000) has been published that examined the stability of general sleep as a function of time. In the study presented in this chapter, several aspects related to the amount and quality of sleep were registered over a three-year-period of time. From these data, it can be concluded that children classified as having some sort of sleep problem (either bound to quality or amount of sleep) at preschool age are more at risk of displaying sleep problems at a three year follow-up. Several aspects of sleep measured at preschool age tend to be relevant variables in predicting sleep patterns three years later (e.g., having sometimes or frequently a decreased amount of sleep at preschool age is predictive for having a decreased amount of sleep at follow-up).

However, the CART- and Kappa-analyses showed that sleep patterns measured at preschool-age are not the only significant predictors of sleep patterns later in life. A number of biological and behavior- related characteristics of the child registered at preschool age also helped to predict the outcome of a child having sleep problems or not. For instance, higher scores on the CBCL attention problems, CBCL social problems, and CBCL total problems scales as measured at preschool age were predictive for sleep problems later in life. Also the age at inclusion was an important variable to predict sleep patterns at follow-up (e.g.,

children above 5.9 years old at inclusion had an increased chance of having nightmares or an increased amount of sleep three years later).

Based on these data, it can be concluded that problematic sleep and behavioral aspects measured at preschool age still have their spin-off three years later. This finding emphasizes the relevance of the conclusions stated by (Stein et al., 2001): “discussing sleep patterns provides an opportunity to learn more about the child and family, to evaluate environmental and family interaction, and to educate the parents about good sleep hygiene with the hope of preventing more serious or chronic sleep-related problems”.

Points of consideration

Unfortunately, there are a number of limitations that should be considered while interpreting the results discussed above. Firstly, the non-responders rate of 44.5% in the present study may limit the generalizability of the results to the population of pre-school children aged 5 - 6 years. However, as mentioned in the method section, comparison of a random sample of 200 non-responders to a selection of responders revealed no significant differences between groups for individual, family related and environmental factors. The results presented in the manuscript are, therefore, believed to hold for the entire cohort of preschool children attending normal schools. Secondly, as mentioned earlier, sleep behavior in children was tested in the present study by means of a parent-completed questionnaire. As mentioned in the introduction, this type of data collection has its limitations. For instance, this screening-method is based on the subjectivity and recollection of the caregiver and the possibility of under-reporting must be taken into account, since the caregiver and the child usually sleep in separate rooms. Nevertheless, several studies have stated that parental questionnaires about children’s sleep are valid sources of information, and make it possible to gather information about large samples of children (Smedje et al., 1999; Stein et al., 2001). Positive, and in agreement with methods used by other investigators, is also the fact that the caregiver is urged in this study to report about sleep behavior of their children over a period of 6 months. The information gathered on the basis of such an extended period of time reduces the bias of transient sleep disturbances, and it also enables parents to report about sleep behavior with a low frequency of occurrence. Research including more objective sleep measures, such as EEG and polysomnography, may provide additional information concerning specific sleep parameters, like awakenings throughout the night, which are believed to be unreliably detected by parents. In addition, sensitive and objective measures can further assist in linking inadequate sleep to behavioral symptoms. As suggested by Stein et al. (2001) additional cross-cultural and epidemiological studies are needed to determine whether differences among studies are the result of different measures of sleep problems, sampling techniques, cohort effects, or societal trends reflecting an increase in sleep problems and poor sleeping habits in today’s youth.

Concluding remarks

Sleep disturbances of children in pre-schools are fairly common as seen for instance in the present study. Earlier conducted studies revealed that parents only seldom express or seek help for their child's sleep problems at preschool age (Rona et al., 1998; Smedje et al., 1999). However, based on the additional data presented in this chapter, it can be concluded that problematic sleep and behavioral aspects (such as attention problems) measured at preschool age still have their spin-off three years later. This finding emphasizes the relevance of early education to parents about for instance good sleep hygiene for their child with the hope of preventing more serious or chronic sleep-related problems. Additional research concerning clinical implications is still required.

References:

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Aronen, E. T., Paavonen, E. J., Fjallberg, M., Soininen, M., & Torronen, J. (2000). Sleep and psychiatric symptoms in school-age children. *Journal of the American Academy Child and Adolescent Psychiatry*, 39(4), 502-508.
- Blader, J. C., Koplewicz, H. S., Abikoff, H., & Foley, C. (1997). Sleep problems of elementary school children. *Archives of Pediatrics and Adolescent Medicine*, 151(5), 473-480.
- Chervin, R. D., Dillon, J. E., Basseti, C., Ganoczy, D. A., & Pituch, K. J. (1997). Pediatrics and Sleep: Symptoms of sleep disorders, Inattention, and Hyperactivity in children. *Sleep*, 20, 1185-1192.
- Corkum, P., Tannock, R., & Moldofsky, H. (1998). Sleep disturbances in children with Attention-deficit/Hyperactivity disorder. *Journal of the American Academy Child and Adolescent Psychiatry*, 37(6), 637-646.
- Dahl, R. E., & et al. (1990). The role of sleep disturbances in Attention deficit disorder symptoms: A case study. *Journal of Pediatric Psychology*, 16, 229-239.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functie-analyse*. Den Haag: SDU uitgeverij.
- Emslie, G. J., Rush, A. J., Weinberg, W. A., Rintelmann, J. W., & Roffwarg, H. P. (1990). Children with major depression show reduced rapid eye movement latencies. *Archives of Genetic Psychiatry*, 47, 119-124.
- Ferdinant, R. F., & Verhulst, F. C. (1995). Psychopathology from adolescence into young adulthood: an 8-year follow-up study. *American Journal of Psychiatry*, 152, 1586-1594.
- Glod, C. A., Teicher, M. H., Hartman, C. R., & Harakal, T. (1997). Increased nocturnal activity and impaired sleep maintenance in abused children. *Journal of the American Academy Child and Adolescent Psychiatry*, 36, 1236-1243.
- Greenberg, M. T., Lengua, L. J., Coie, J. D., & Pinderhughes, E. E. (1999). Predicting developmental outcomes at school entry using a multiple-risk model: Four American communities. *Developmental Psychology*, 35(2), 403-417.
- Johnson, E. O., Chilcoat, H. D., & Breslau, N. (2000). Trouble sleeping and anxi-

- ety/depression in childhood. *Psychiatry Research*, 94, 93-102.
- Kahn, A., Van der Merckt, C., Rebuffat, E., Mozin, M. J., Sottiaux, M., Blum, D., & Hennart, P. (1989). Sleep problems in healthy preadolescents. *Pediatrics*, 84, 542-546.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Mercier, L., Pivik, R. T., & Busby, K. (1993). Pediatric research: Sleep patterns in reading disabled children. *Sleep*, 16(3), 207-215.
- Mindell, J. A. (1993). Sleep disorders in children. *Health Psychology*, 12, 151-162.
- Pollock, J. I. (1994). Night-waking at five years of age: Predictors and prognosis. *Journal of Child Psychology and Psychiatry*, 34, 699-708.
- Resnick, M. B., Gueorguieva, R. V., Carter, R. L., Ariet, M., Sun, Y., Roth, J., Bucciarelli, R. L., Curran, J. S., & Mahan, C. S. (1999). The impact of low birth weight, perinatal conditions, and sociodemographic factors on educational outcome in kindergarten. *Pediatrics*, 104(6), e74.
- Rona, R. J., Leah, L. I., Gulliford, M. C., & Chinn, S. (1998). Disturbed sleep: Effects of sociocultural factors and illness. *Archives of Disease in Childhood*, 78, 20-25.
- Ross, R. J., Ball, W. A., Sullivan, K. A., & Caroff, S. N. (1989). Sleep disturbance as the hallmark of posttraumatic stress disorder. *American Journal of Psychiatry*, 146, 697-706.
- Sameroff, A. J., & Seifer, R. (1990). Early contributors to developmental risk. In S. Weintraub (Ed.), *Risk and protective factors in the development of psychopathology* (pp. 52-66). New York: Cambridge University Press.
- Shaffer, D. (1985). Enuresis. In L. Hersov (Ed.), *Child and adolescent psychiatry: Modern approaches* (pp. 465-481). London, United Kingdom: Blackwell Scientific Publications.
- Simonds, J., & Parraga, H. (1982). Prevalence of sleep disorders and sleep behaviors in children and adolescents. *Journal of the American Academy Child and Adolescent Psychiatry*, 21, 383-388.
- Smedje, H., Broman, J. E., & Hetta, J. (1999). Parents' report of disturbed sleep in 5-7-year-old Swedish children. *Acta Paediatrica Oslo*, 88, 858-865.
- Stanger, C., Achenbach, T. M., & McConaughy, S. H. (1993). Three-year course of behavioral/emotional problems in a national sample of 4- to 16-year-olds: 3. Predictors of signs of disturbance. *Journal of Consulting and Clinical Psychology*, 61(5), 839-848.
- Stein, M. A., Mendelsohn, J., Obermeyer, W. H., Amromin, J., & Benca, R. (2001). Sleep and behavior problems in school-aged children. *Pediatrics*, 107(4), E60.

- Stores, G. (1996). Practitioner Review: Assessment and treatment of sleep disorders in children and adolescents. *Journal of Child Psychology and Psychiatry*, 37(8), 907-925.
- Stores, G., & Wiggs, L. (1998). Clinical services for sleep disorders. *Archives of Disease in Childhood*, 79, 495-497.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.

Semantic category fluency versus initial letter fluency over time as a measure of automatic and controlled processing in healthy school-aged children¹

Abstract

The study presented in this chapter evaluated the performance on Semantic Category Fluency (SCF) versus Initial Letter Fluency (ILF) tasks of 91 healthy children aged 8.4 - 9.7 years. Verbal fluency was operationalized as the number of words produced in a restricted category in 60 seconds. In addition, word production in the first 15 seconds of either type of fluency task was taken as a measure of automatic information processing, whereas production from 15 seconds through 1 minute was taken as a measure of controlled information processing. Data revealed that in 60 seconds children produced significantly more words on the SCF tasks than on the ILF tasks, a pattern that differed from that known for adults. Furthermore, word production decreased significantly as a function of time on both SCF and ILF tasks. Data for performance over time suggested that children tended (equally for both types of fluency) to produce more correct answers over the first 15 seconds of a specific test compared to later time intervals (with equal duration). Also, word production on both types of fluency tasks was not identical across time intervals, suggesting that production is a function of both type of task and time samples. Finally, no sex or age differences were found for all measures of performance on either type of fluency tasks. In contrast, the level of occupational achievement of the caregiver (LOA) appeared to be a significant determinant of the child's performance on either type of fluency, indicating that LOA affected higher-order processes, such as the automation of newly learned verbal skills and effortful processing.

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Introduction

Verbal fluency tasks are frequently used both in clinical settings and in research. In general, these tasks have been operationalized as the quantity of words produced, usually within a restricted category, over a limited period of time (usually 60 seconds) (Lezak, 1995). It is furthermore believed that these fluency tasks are suitable for determining the strategies used for retrieving data from the lexicon and the semantic memory system (Martin, Wiggs, Lalonde, & Mack, 1994). Also, successful performance on these tasks is thought to be dependent on efficient executive functioning and normal attention capacity (Barkley, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). A substantial amount of experimental studies with verbal fluency tasks has been performed in adults. However, there is only limited information with regard to the performance of children on this type of tasks. This is unfortunate, as an efficient retrieval from the lexicon and the semantic memory system is expected to be of major importance for cognitive development (Bernstein, 1989), and fluency tasks could be of importance in the measurement of subtle maturational differences in these processes. This is especially the case in view of recent findings on individual patterns in cognitive development (Lupien, King, Meaney, & McEwen, 2001; McCulloch & Joshi, 2001). Subtle lags in maturation of an efficient semantic retrieval could lead to substantial inter-individual differences in the use of language and also in using higher cognitive processes (Riva, Nichelli, & Devoti, 2000). It therefore appears to be of high relevance to investigate semantic retrieval processes in children and to evaluate the influence of factors (e.g., environment and sex) that influence performance on this cognitive process. This is the purpose of the present study.

With respect to the research conducted earlier with verbal fluency tasks, two additional aspects should be noted, namely (1) the fact that there are different categories of fluency tasks and (2) the notion that different cognitive functions are underlying (successful) performance on these verbal fluency tasks. With regard to the first mentioned aspect, two major categories of verbal fluency tasks can be distinguished, namely (A) *semantic category fluency* (SCF; that is, recitation of examples of a given category) and (B) *initial letter fluency* (ILF; that is, generating words beginning with a given initial letter) (Monsch et al., 1994). Although the instruction is identical for both types, SCF is easier than ILF for children (Monsch et al., 1992; Ober, Dronkers, Koss, Delis, & Friedland, 1986). Furthermore, organization and retrieval of words phonemically seems to develop more slowly in children than the productivity of words from semantic categories (Riva et al., 2000). Because of these differences in complexity and development, it seems of high relevance to include both types of fluency in a study of the development of semantic retrieval in children. Unfortunately, in many studies only one type of fluency (in most cases the SCF) has been included.

With regard to the second aspect (that is, the cognitive functions underlying performance on the verbal fluency tasks), it is found that the outcome variable de-

fined in most experimental designs is solely the total number of words generated over 60 seconds on a fluency task. However, Troyer (2000) stated that evaluation of performance over 60 seconds does not provide information about the mechanisms underlying (reduced) test performance. She suggested that inspection of fluency performance as a function of time might provide additional insight in cognitive processing. For instance, a specific pattern in the production of words from the lexicon is found over the period of one minute in healthy adults, both in SCF and in ILF. It appears that in the first time slice (1 - 15 seconds) on either type of task, a ready pool of frequently used words is available and is automatically activated for production. As time passes, the pool is exhausted and the search for new words becomes both more effortful and less productive and thereby more dependent on executive functioning (Crowe, 1998). Successful performance on a verbal fluency task seems thereby dependent upon the effectiveness of automatic and controlled processing. In general, these automatic and controlled processes are believed to represent different stages of information processing, in which automatic processing is generally fast and relatively unconscious. Controlled processing on the other hand is in general slow, effortful, and attention-demanding (Fodor, 1983; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Because of the earlier mentioned task-related differences, the amount of effortful or controlled processing necessary for successful completion is believed to be higher in initial letter fluency compared to semantic category fluency. To our knowledge, the above-mentioned link between information processing and fluency tasks has only been applied limited in adults. No studies are, to our knowledge, presently available including children to examine automatic and controlled processes in relation to fluency performance. The first aim of the present study was, therefore, to evaluate semantic retrieval in healthy children on both types of verbal fluency task (SCF & ILF) in relation to the above-mentioned variations in time duration. It was hypothesized that performance on ILF would be compromised when compared to SCF and that this would apply especially for automatic retrieval. The second aim was to evaluate the possible influence of the factors 'age', 'sex' and 'socio-economic status' (SES; defined here as the level of occupational achievement of the caregiver of the child) on test performance. For these purposes, a group of healthy children aged 8.4 through 9.7 years was drawn from the Study of Attentional Disorders Maastricht (SAM; for an expanded description of the study, see Kalff et al. [2001] and Kroes et al. [2001]). The sampling procedure of this study enabled the exclusion of children who showed at kindergarten age (5 - 7 years) (even mild) forms of psychopathology or learning problems. This is of importance because of findings suggesting that the period between the ages of 5 and 7 years is critical for later cognitive development. It is during this period that teaching at school awakens a knowledge of the components of language at all levels of analysis: phonological, grammatical, semantic and pragmatic (Bernstein, 1989; Riva et al., 2000).

Methods

Participants and Procedure

The study was performed as an experiment in the course of the Study of Attentional Disorders Maastricht (SAM; Kalff et al. [2001] and Kroes et al. [2001]). Briefly, this is a large cross-sectional, longitudinal research program into the determinants of healthy cognitive development and incidence of learning problems and psychopathology. The study is performed in the southern parts of the Netherlands. The sampling frame consisted of approximately 2300 children (age 5 - 6 years) who visited the second grade of normal kindergarten. On the basis of a behavior questionnaire (the Child Behavior Checklist: Achenbach & Edelbrock [1983] and Verhulst, Koot, & Van der Ende [1996]), 452 children were selected for further research. In a second phase, 15 months after inclusion, the caregivers of 403 of the originally selected children were screened by use of a semi-structured psychiatric interview, called the ADIKA (Dutch translation of the DICA (caregiver version); Herjanic & Reich, 1982; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). With the ADIKA, several DSM-III-R/-IV classifications for childhood psychopathology were questioned by use of a systematic, horizontal approach. Finally, in a third phase (39 - 49 months after inclusion), all selected children were again asked to participate in the SAM-study. In total, 284 of the 403 children of whom we received ADIKA results in phase 2 agreed to participate in the follow-up (70.5%). During this third phase, all children were tested neuropsychologically by use of several tests, such as the verbal fluency test (NEPSY), Vocabulary-test (WISC-RN) and the Dutch Klepel reading test, which is a test for reading nonsense words. A neuropsychologist or one of three well-trained assistants administered the test battery.

For the experiment described in the present paper, only a part of the originally included sample was selected. Children attending special schools and/or children who had retained any class in school earlier in life were excluded for the current study. Children, who had scored high on the child psychiatric interview assessed in phase 2 on any of the above-mentioned DSM-III-R/-IV classifications and/or were known to use Ritalin or Dipiperon, were also excluded. Based on these criteria, data from 91 children were available for the analyses conducted within this study. Variables influential on research outcome were collected and summarized in Table 1, including age (as measured at the third phase), sex, the level of occupational achievement of the caregiver (LOA), an estimate of verbal intelligence, and performance on the Dutch Klepel reading test.

Table 1. Group characteristics of the selected sample (n = 91).

Variable		
Sex	41 boys: 50 girls	
	Mean	SD
Age	9.0	0.3
Vocabulary scores	9.6	2.5
Klepel scores	11.1	2.5
Occupation Parents	4.7	1.8

Instrumentation

Verbal fluency test (Korkman, Kirk, & Kemp, 1998): This test is a subtest of the NEPSY battery and is believed to be a measure of retrieval from semantic memory. It includes two independent types of verbal fluency, namely semantic category fluency (SCF) and initial letter fluency (ILF). SCF involves recitation of examples of a given category, whereas ILF involves the generation of words beginning with a given initial letter. The verbal fluency test consisted of (A) two trials of a SCF type task (to name as (1) many animals and (2) things you can eat or drink) and (B) two trials of an ILF type task (including the letters 'M' and 'S' (subtasks 3 & 4)). Consistent with standard instructions, participants were asked to generate over 60 seconds as many words as possible within the above-mentioned categories, excluding the names of humans and cities. For each subtask, total number of correct responses, incorrect responses, and perservations (that is, repetitions of correct words) were recorded over (A) 1 - 15 seconds, (B) 16 - 30 seconds, (C) 31 - 45 seconds, and (D) 46 - 60 seconds. To reduce error variances, data gained over subtasks 1, 2, 3, 4 were averaged over time samples for each type of fluency. Furthermore, in purpose of measuring the influence of environmental en biological factors on cognitive outcome, low controlled processing was defined as performance on the first 15 seconds of either type of fluency task and high controlled processing as performance over the succeeding 45 seconds of the test.

The Amsterdam Diagnostic Interview for Children and Adolescents (ADIKA; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997): This is the Dutch translation of the Diagnostic Interview for Children and Adolescent (Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenbout van der Sluijs et al., 1997). The ADIKA is a semi-structured psychiatric interview that yields scores for several child psychiatric syndromes according to DSM-III-R guidelines and was adapted by using the criteria of DSM-IV for diagnosing ADHD (American Psychiatric Association, 1987, 1994). Although the Dutch version of the DICA-III-R interview has not

been separately validated, DICA and DICA-III-R have been demonstrated to have high test-retest reliability and moderate correlations with clinician based diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Vocabulary: A subtest of the Wechsler Intelligence Scales (WISC-Revised Dutch Version: De Bruyn et al., 1986) was used to provide an estimate of general verbal ability (Lezak, 1995). The examiner asked the child to explain the meaning of certain words. The complexity of words increased with each item. Range of standard scores is 1 - 19 (mean score = 10, SD = 3). Reliability and validity are believed to be average to good (De Bruyn et al., 1986).

Klepel reading test (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994): This test provides a measure of the technical reading skills of a child. For 2 minutes, the child had to spell as many words possible from a list of non-existing words. With each item the complexity of words increased. Standard scores range from 1 - 19 (mean score = 10, SD = 3). This task was included as a covariate because of the assumed relation between the development of the ability to organize and retrieve words phonemically and spelling skills (Riva et al., 2000).

Level of Occupational Achievement of the caregiver (LOA): This variable was based on the full description of the parental occupation and was originally scored on a 7-point-scale, ranging from unskilled (code 1) to scientific skilled labor (code 7) (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Finally, for the purpose of the present article, this 7-point-scale was recoded into a group 'lower level occupation' (including scores 1, 2, 3, 4) and a group 'higher level occupation' (scores 5, 6, 7). Housewives and househusbands were coded (0) separately and entered in the low-level occupation category. When the LOA differed between mother and father or if data was missing for one caregiver, the highest score was chosen. In total, the caregivers of 35 children had a 'lower level occupation' and the caregivers of 56 children had a 'higher level occupation'.

Statistical Methods

Cognitive performance on either type of verbal fluency (semantic category and initial letter) was tested statistically for (A) the entire group and (B) differences in terms of (i) sex, (ii) age, and (iii) the level of occupational achievement of the caregiver (LOA). Total scores on both ILF and SCF tasks were normally distributed in our sample and so parametric techniques were selected as appropriate for the analyses. To achieve the first goal, a 2 x 4 (Fluency type x Time interval) Repeated Measures GLM was conducted while including age, sex, LOA, Vo-

cabulary scores, and Klepel scores as covariates in the model. In addition, the percentage of perseverations and incorrect responses were compared for differences among fluency tests by use of paired-samples t-tests. Finally, Pearson's correlation coefficients were calculated relating total scores on both types of fluency to the Vocabulary-test (WISC-Dutch Version) and performance on the Klepel reading test. Next, to determine the individual contribution of demographic and biological characteristics to test performance on either type of fluency (the second goal), the influence of sex, age, and the level of occupational achievement of the caregiver (LOA) on test performance were tested. For all between-subjects variables (sex, age, and LOA), a GLM Repeated Measures for unequal sample sizes within a non-experimental design was performed with type of fluency (semantic category fluency vs. initial letter fluency) and time samples (1 - 15 seconds as a measure of automatic processing of verbal skills, vs. 16 - 60 seconds as a measure of controlled processing) as within-subjects variables. Because of the relatively low number of subjects in some clusters, it was decided not to include all child factors simultaneously as independent variables in one model, but to test each factor separately, while correcting for scores on the other factors by including these as covariates in the analyses.

Standard, all analyses were corrected for verbal skills of the child by including the Vocabulary scores and Klepel reading scores as covariates in the model. The statistical package *SPSS for windows* version 11.0 was used to conduct the above-mentioned analyses. The critical value for rejecting the null hypotheses was defined at $p < 0.05$, post-hoc corrections for Bonferroni were made if necessary.

Results

Overall performance on different types of fluency tasks

A 2 x 4 (Fluency type x Time interval) Repeated Measures GLM revealed that, combined over the four time intervals, ILF and SCF differed significantly in the number of words produced ($F(1,85) = 7.66$; $p = .007$). Children generated more words over 60-sec from a semantic category ($\text{mean}_{\text{SCL}} = 15.03$ [$\text{SD} = 3.13$]) compared to words beginning with a certain letter ($\text{mean}_{\text{ILF}} = 7.55$ [2.71]). In addition, a significant difference was found in the number of words produced over the successive time intervals ($F(3,83) = 7.13$; $p < .001$). Production decreased significantly as a function of time on both SCF and ILF ($p < .001$ for all equations) and a tendency (equally for both types of fluency) was found for children to produce more correct answers over the 1 - 15 seconds of a specific test compared to the remaining time samples ($\text{mean}_{1-15\text{sec}} = 4.93$ [$\text{SD} = 0.88$]; $\text{mean}_{16-30\text{sec}} = 2.66$ [0.96]; $\text{mean}_{31-45\text{sec}} = 2.06$ [0.72]; $\text{mean}_{46-60\text{sec}} = 1.65$ [0.75]). Finally, a significant interaction was found between type of fluency and time on task ($F(3,83) = 4.21$; $p = .008$). The interaction indicated that the pattern of words produced over dif-

ferent time samples is not identical for SCF and ILF, suggesting that production is a function of both time and type of task (as shown in figure 1).

In addition, it was found in the present study that, compared to the SCF, children produced over 60-sec more incorrect responses while completing the ILF task ($t(1,90) = -3.35$; $p = .001$; incorrect responses_{SCF} = 0.05 [SD = 0.23] vs. incorrect responses_{ILF} = 0.48 [1.22]). No significant differences were found in terms of perseverations made ($t(1,90) = 0.18$; $p = .860$; perservations_{SCF} = 0.44 [0.79] vs. perseverations_{ILF} = 0.41 [1.66]).

Because of the earlier mentioned assumed relationship between the development of the ability to organize and retrieve words phonemically and spelling skills, correlation analyses were executed relating total scores on both types of fluency to the Vocabulary-test (WISC-Dutch Version) and performance on the Klepel reading test. For both the Vocabulary test and the Klepel reading test, no significant correlations were found with either type of fluency (Vocabulary tests: correlations of $\rho = .16$ [$p = .136$] for SCF and $\rho = .16$ [$p = .138$] for ILF test; the Klepel reading test: correlated $\rho = .03$ with the SCF [$p = .750$] and $\rho = .13$ with the ILF [$p = .219$]). In sum, no relationship was found in the present study between the performances on the fluency tasks on the one hand and the reading and vocabulary scores on the other. This result implicated that verbal fluency is not so much a language related function, but more related to the executive functions.

Figure 1. Level of production on the semantic category (SCF) and initial letter (ILF) forms of the verbal fluency test as a function of time.

Effects of biological and socio-demographic factors on test performance

In relation to the effects of biological and socio-demographic factors on test performance, it can first be concluded that no differences were found between girls and boys. In short, a GLM repeated measures analyses for unequal sample sizes

within an experimental design revealed no significant main effect of sex ($F(1,85) = 1.38$, $p = .243$) or interaction effects in terms of Sex x Type of fluency test ($F(1,85) = 0.34$, $p = .560$), Sex x Time ($F(1,85) = 0.16$, $p = .686$), and Sex x Type of fluency test x Time ($F(1,85) = 0.00$, $p = .947$) were found. When studying the way children retrieve words as a function of time, it can be concluded that girls and boys aged 9 years do not differ in word retrieval over time on either type of fluency.

Also, no significant effects were found for age differences. For the purpose of measuring age effects within a GLM model, the continuous variable 'age' was recoded into two variables namely younger children (< 9 years old) vs. older children (≥ 9 years old). No main effects nor significant interaction effects were found on the GLM repeated measures analyses (main effect for age ($F(1,85) = 2.65$, $p = .107$), Age x Fluency test ($F(1,85) = 0.44$, $p = .509$), Age x Time ($F(1,85) = 0.34$, $p = .561$), and Age x Fluency test x Time ($F(1,85) = 0.21$, $p = .651$). The pattern of fluency performance was identical for children below and above 9 years old, when studying the age intervals as defined within the present study.

In contrast, differential effects on the performance on fluency task were found in terms of the level occupational achievement of the caregiver (higher vs. lower). First, a trend was found for a main effect of LOA ($F(1,85) = 3.66$; $p = .059$). Overall, children whose parents had higher scaled occupations produced over time samples and type of fluency in average more words than the children whose parents had lower LOA scores. Secondly, although the $2 \times 2 \times 2$ (LOA x Fluency type x Time samples) GLM repeated measures analysis revealed no significant interaction effects in terms of LOA x Time samples ($F(1,85) = 0.01$, $p = .928$) and LOA x Type of fluency test ($F(1,85) = 2.81$, $p = .097$), a significant interaction was found for LOA x Type of fluency x Time samples ($F(1,85) = 4.69$, $p = .033$; see figure 2). Post-hoc analyses revealed that, at the age of 9 years, the differences between children from the lower and the higher LOA-category were most profound during the 16 - 60 seconds (controlled processing) of the well-known semantic category tasks and during the first 15 seconds (automated processing) of the newly acquired initial letter fluency tasks.

Discussion

The aim of the study was to enlarge the present knowledge concerning childhood performance while retrieving data from the lexicon, controlling for biological and environmental aspects of development. Inspection of data revealed, that over 60 seconds children produced significantly more words on the SCF tasks compared to the ILF, which is in line with our expectation. In addition, a significant difference was found in the number of words produced between the time intervals. Data of performance over time pointed towards a tendency (equally for both types of fluency) for children to produce more correct answers over the 1 - 15

seconds of a specific test compared to the time samples (with equal duration) that followed. A possible explanation for this decrease is purposed in the model of lexical organization (Crowe, 1996; Smith & Claxton, 1972). This model states that there are two types of stores, namely (1) a long-term store ('topicon') which is readily accessible and containing common words and (2) a more extensive lexicon which is searched after the topicon is exhausted. Based on this idea and supportive evidence, it can be hypothesised that, during the first time slice (1 - 15 seconds) of either type of fluency task, a ready pool of frequent words is available and automatically activated for production. As time passes the pool is exhausted and production becomes more effortful, less productive, and thereby more dependent on the executive functions (Crowe, 1998). Finally, a significant, relevant interaction was found between type of fluency and time on task. The interaction indicated that word production for the two tasks is not the same across the time interval suggesting that production is a function of both task and time.

Figure 2. Performance on either type of fluency task as a function of LOA (lower vs. higher). Note: *: $p < 0.050$; t: $p = .077$; SCF: Semantic category fluency; ILF: Initial letter fluency.

In addition, significant deviations were found when test results were measured against the performance of adult participants on identical assessment tools. Butters, Granholm, Salmon, Grant, and Wolfe (1987) found, for example, that, adult controls produced more correct words over 1 - 15 seconds of the semantic fluency tasks (compared to performance on the initial fluency tasks over the same period). Over a total of 60 seconds, adults appeared to be more successful in producing words on the initial letter fluency task compared to the semantic category fluency task. A reasonable explanation here might be that chronological development changes the systematic organization of the semantic network in the brain and enhances controlled search processing speed. In addition, McKay, Halperin, Schwartz, & Sharma (1994) stated the pivotal role of response organization in

output processing and noted that development of response organization largely accounts for improvement in information processing efficiency between 7 and 9 years of age. In the present article no significant age differences were found. In the analyses only a relatively narrow age range was included. Therefore, it would be recommendable to examine in more detail how test performance evolves over time (low and high effortful processing) and with further growth. It is relevant in this respect that the development of the frontal lobes is not finished until at least the age of 12 (Riva et al., 2000) or even extends into adult life. Furthermore, cross-sectional studies indicate that Word Fluency (WF) improves with increasing age to at least 13 years, with written WF increasing to 18 years (Levin, Song, Ewing-Cobbs, Chapman, & Mendelsohn, 2001).

Based on presented test results, environment and more specifically the occupational achievement of the caregiver of child seem to be of major influence on the fluency of speech over a period of 60 seconds. Children of parents with a lower occupational level (LOA) tend to produce fewer words on a verbal fluency task (and more specifically the performance on the, over-learned, semantic category fluency task) than the children of parents with a higher LOA. This is in agreement with the findings of McCulloch & Joshi (2001), who stated that residence in a low-income neighbourhood has negative effects on developmental outcomes in the first 4 - 5 years of children's lives and is associated with higher rates of drop out from high school and lower cognitive scores. Within our research design, only a limited number of variables influential on cognitive performance were included. It would, however, be of high interest to study the influence of other factors (both child- and environment-related) on fluency performance as well.

Because of the additional data gained by including the component of time while completing a fluency task, it would be interesting to see how children with learning problems and/or attention allocation deficits (like children with ADHD) perform on these tasks. From literature that already exists around this subject, inconclusive evidence is found related to acquired automatic processing (Ackerman, Anhalt, Holcomb, & Dykman, 1986; Van der Meere & Sergeant, 1988). Furthermore, it is believed that the effectiveness of controlled processes suffers from the syndrome 'ADHD' (Hazell et al., 1999). Therefore, the here presented experimental method of scoring performance on the verbal fluency tasks could be useful in acquiring more knowledge about the cognitive processes of children with a physical and/or cognitive disability. More research in this area is therefore suggested.

References

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Ackerman, P. T., Anhalt, J. M., Holcomb, P. J., & Dykman, R. A. (1986). Presumably innate and acquired automatic processes in children with attention and/or read-

- ing disorders. *Journal of Child Psychology and Psychiatry*, 27, 513-529.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3th ed.). Washington DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Bernstein, D. (1989). Language development: the school age years. In E. Tiegermen (Ed.), *Language and communication disorders in children*. Columbus, OH: Merrill/MacMillon.
- Butters, N., Granholm, E., Salmon, D., Grant, L., & Wolfe, J. (1987). Episodic and semantic memory: A comparison of amnesic and demented patients. *Journal of Clinical and Experimental Neuropsychology*, 9, 479-497.
- Crowe, S. F. (1996). The performance of schizophrenic and depressed participants on tests of fluency: support for a compromise in dorso-lateral pre-frontal functioning. *Australian Psychologist*, 31, 204-209.
- Crowe, S. F. (1998). Decrease in performance on the verbal fluency test as a function of time: Evaluation in a Young Healthy Sample. *Journal of Clinical and Experimental Neuropsychology*, 20 (3), 391-401.
- De Bruyn, E. E. J., Van der Steene, G., Van Haasen, P. P., Coetsier, P., Pijl, Y. J., Spoelders-Claes, R., Poortinga, Y. H., Stinissen, J., & Lutje Spelberg, H. C. (1986). *Wechsler Intelligence Scale for Children - Revised (WISC-R)*. Lisse: Swets & Zeitlinger.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functieanalyse*. Den Haag: SDU uitgeverij.
- Ezpeleta, L., De la Osa, N., Doménech, J. M., Navarro, J. B., Losilla, J. M., & Júdez, J. (1997). Diagnostic agreement between clinicians and the Diagnostic Interview for Children and Adolescents-DICA-R-in an outpatient sample. *Journal of Child Psychology and Psychiatry*, 38(4), 431-440.
- Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Granero Pérez, R., Ezpeleta Ascaso, L., Doménech Massons, J. M., & De la Osa Chaparro, N. (1998). Characteristics of the subject and interview influencing the test-retest reliability of the Diagnostic Interview for Children and Adolescents-Revised. *Journal of Child Psychology and Psychiatry*, 39(7), 963-972.
- Hazell, P. L., Carr, V. J., Lewin, T. J., Dewis, S. A. M., Heathcote, D. M., & Brucki, B. M. (1999). Effortful and automatic information processing in boys with ADHD and Specific Learning Disorders. *Journal of Child Psychology and Psychiatry*, 40, 275-286.
- Herjanic, B., & Reich, W. (1982). Development of a structured psychiatric interview for children: Agreement between child and parent on individual symptoms. *Journal of Abnormal Child Psychology*, 10, 307-324.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.

- Korkman, M., Kirk, U., & Kemp, S. L. (1998). *NEPSY. A developmental neuropsychological assessment*. San Antonio, TX: The Psychological Corporation.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKA). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Kroes, M., Kalf, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozen-daal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Levin, H. S., Song, J., Ewing-Cobbs, L., Chapman, S. B., & Mendelsohn, D. (2001). Word fluency in relation to severity of closed head injury, associated frontal brain lesions, and age at injury in children. *Neuropsychologia*, 39, 122-131.
- Lezak, M. D. (1995). *Neuropsychological assessment* (3 ed.). Oxford: Oxford University Press.
- Lupien, S. J., King, S., Meaney, M. J., & McEwen, B. S. (2001). Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. *Development and Psychopathology*, 13, 653-676.
- Martin, A., Wiggs, C. L., Lalonde, F., & Mack, C. (1994). Word retrieval to letter en semantic cues: A double dissociation in normal subjects using interference tasks. *Neuropsychologia*, 32, 1487-1494.
- McCulloch, A., & Joshi, H. E. (2001). Neighbourhood and family influences on the cognitive ability of children in the British National Child Development Study. *Social Science & Medicine*, 53, 579-591.
- McKay, K. E., Halperin, J. M., Schwartz, S. T., & Sharma, V. (1994). Developmental analysis of three aspects of information processing: Sustained attention, selective attention, and response organization. *Developmental Neuropsychology*, 10, 121-132.
- Monsch, A., Bondi, M. W., Butters, N., Salmon, D. P., Katzman, R., & Thal, L. J. (1992). Comparison of verbal fluency tasks in the detection of dementia of the Alzheimer type. *Archives of Neurology*, 49, 1253-1258.
- Monsch, A. U., Bondi, M. W., Butters, N., Paulsen, J. S., Salmon, D. P., Brugger, P., & Swenson, M. R. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology*, 8, 25-30.
- Ober, B. A., Dronkers, N. F., Koss, E., Delis, D. C., & Friedland, R. P. (1986). Retrieval from semantic memory in Alzheimer-type dementia. *Journal of Clinical and Experimental Neuropsychology*, 8, 75-92.
- Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, 71, 267-284.
- Rosser, A., & Hodges, J. (1994). Initial letter and semantic category fluency in Alzheimer's disease, Huntington's disease, and Progressive Supranuclear Palsy. *Journal of Neurology, Neurosurgery and Psychiatry*, 57, 1389-1394.
- Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 84, 1-66.
- Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information

- processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127-190.
- Smith, P. T., & Claxton, G. L. (1972). *Lexical search and phonemic organisation in memory*. Paper presented at the Paper presented to the Experimental Psychology Society London.
- Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, 22(3), 370-378.
- Van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & De Vries, J. R. (1994). *De Klepel*. Lisse: Swets & Zeitlinger.
- Van der Meere, J., & Sergeant, J. (1988). Acquisition of attention skill in pervasively hyperactive children. *Journal of Child Psychology and Psychiatry*, 29(3), 301-310.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Welner, Z., Reich, W., Herjanic, B., Jung, K. G., & Amado, H. (1987). Reliability, validity, and parent-child agreement studies of the diagnostic interview for children and adolescents (DICA). *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 649-653.

Verbal Fluency over time as a measure of automatic and controlled processing in children with ADHD¹

Abstract

The performance of ADHD children on semantic category fluency (SCF) versus initial letter fluency (ILF) tasks was examined. For each participant, word production was recorded for each 15-s time slice on each task. Performance on both fluency tasks was compared to test the hypothesis that children with ADHD are characterized by a performance deficit on the ILF task because performance on this task is less automated than performance on the SCF. Children classified with ADHD (N = 20) were compared to children with other psychopathology (N = 118) and healthy controls (N = 130). Results indicated that the groups could not be differentiated by the total number of words produced in 60 seconds in either fluency task. As hypothesized, a significant interaction of group by productivity over time by type of fluency task was found: ADHD children had more problems finding words in the first 15 seconds of the IFL than did children in the other two groups, and as compared with their performance on the SCF. Results were taken to indicate that children with ADHD symptoms show a delay in the development of automating skills for processing abstract verbal information.

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Introduction

Impulsive behavior, inattention, and overactivity in young children can be a risk factor for abnormal psychological development later (Sagvolden & Sergeant, 1998; Taylor, Chadwick, Heptinstall, & Danckaerts, 1996; Weiss & Trokenberg Hechtman, 1993). If these behaviors cause significant impairments in social or academic functioning and are inconsistent with the developmental level of the child, they may be indicative of the clinical diagnosis 'Attention-Deficit/Hyperactivity Disorder' (ADHD; American Psychiatric Association, 1994), a syndrome that affects approximately 1 - 5% of children (Barkley, 1998). Kroes et al. (2001) have estimated the prevalence of ADHD within a population of Dutch school-aged children at 3.8%. Over the years, several causes of ADHD have been proposed. For instance, neurological evidence is pointing towards an involvement of the frontal-striatal circuits in ADHD (Barkley, 1998; Oades, 1998; Sagvolden & Sergeant, 1998). Furthermore, from a neuropsychological perspective, ADHD is associated with deficits in well-defined cognitive domains, including sustained attention and executive functioning (Barkley, 1998; Pennington & Ozonoff, 1996). According to Lezak (1995), the term 'executive functioning' encompasses those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior. Examples of executive functioning are non-verbal working memory, internalization of speech, self-monitoring, and self-regulation (Barkley, 1998; Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). Another cognitive function highly correlated with executive functioning and attention capacity, which is often used to evaluate cognitive functioning in ADHD, both clinically and experimentally, is the fluency of speech (Barkley, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). This function is usually defined as the number of words produced, usually within a restricted category and over a limited period of time (usually 60 seconds) (Lezak, 1995). Two major categories of verbal fluency tasks can be distinguished, namely (A) *semantic category fluency* (SCF; that is, recitation of examples of a given category) and (B) *initial letter fluency* (ILF; that is, generating words beginning with a given initial letter).

Earlier studies of ADHD and verbal fluency provided inconclusive results. A number of studies found significant differences between children with ADHD and controls on either the SCF or the ILF, in that children with ADHD performed significant worse (Grodzinsky & Barkley, 1999; Grodzinsky & Diamond, 1992; Klorman et al., 1999; Koziol & Stout, 1992; Loge, Station, & Beatty, 1990; Pineda, Ardila, & Rosselli, 1999). In contrast, also a large number of studies found no differences between these groups (Barkley, Grodzinsky, & DuPaul, 1992; Fischer, Barkley, Edelbrock, & Smallish, 1990; Grodzinsky & Diamond, 1992; Kusche, Cook, & Greenberg, 1993; Loge et al., 1990; Pineda et al., 1999; Reader, Harris, Schuerholz, & Denckla, 1994; Weyandt & Willis, 1994), with the notice that the ILF tended to discriminate somewhat better between ADHD and

controls than the SCF (Sergeant, Geurts, & Oosterlaan, 2002). However, these studies included only the total number of words produced over a set period of 60 - 90 seconds as the main outcome variable, whereas recent experiments have shown that, in healthy adults, the pattern of word production over time is relevant (Troyer, 2000). For example, experiments have shown in healthy adults and children that the effectiveness of word production changes from approximately the first 15 - 20 seconds to the last 40 - 45 seconds of a 1-minute task. In the first period, a ready pool of frequently used words appears to be available and is automatically activated for production. As time passes, the pool becomes exhausted and the search for new words becomes both more effortful and less productive (Crowe, 1998; Hurks et al., Submitted for publication). By measuring performance over time, the fluency task can be used to measure the effectiveness of both automatic and controlled processing, in which automatic processing is believed to be generally fast and relatively unconscious and controlled processing slow, effortful, and attention-demanding (Fodor, 1983; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Both automatic and controlled information processing have been investigated in studies on the cognitive performance of children with ADHD, but results are inconsistent. Several authors have shown that children with ADHD perform less well than controls in situations demanding automatic and/or more controlled processing strategies (Ackerman, Anhalt, Holcomb, & Dykman, 1986; Borcharding et al., 1988; Hazell et al., 1999), whereas other authors have not (Van der Meere & Sergeant, 1988). Comparison of children with ADHD and controls on both types of fluency, evaluated by their performance over time, may contribute to these conflicting results. Given the deficits in executive functioning in ADHD, we hypothesize that children with ADHD perform significantly worse on both types of information processing (automatic vs. controlled) than do healthy control subjects.

In the present study, we evaluated verbal information processing in ADHD, using an extensive, two-fold controlled design. Children with ADHD were compared to healthy children and to a group of children with at least one DSM-classification (with the exception of ADHD). The second control group was included in view of recent evidence that children with ADHD are at risk of developing other psychiatric disorders and learning disabilities (Barkley 1998). Thus, we also compared the ADHD group with psychiatric controls, to determine the specificity of possible ADHD-related findings. Finally, because the behavioral expression of ADHD changes over time, and at least some symptoms are present before age 7 years (American Psychiatric Association, 1994), and because the period between the ages 5 and 7 years is believed to be critical for later cognitive (and more specifically language) development (Bernstein, 1989; Riva, Nichelli, & Devoti, 2000), language development may be influenced most by the early expression of ADHD (Levy, Hay, McLaughlin, Wood, & Waldman, 1996). For this reason, we decided to relate child psychiatric data gathered when the child was approxi-

mately 6 - 7 years to later cognitive functioning at an age when the child had been to school for 2 - 3 years. In sum, we investigated the performance of children with ADHD in a controlled design on two types of the fluency task and as a function of time.

Methods

Subjects and Procedure

The present study is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)' and is embedded in an extensive, longitudinal design. The SAM study consists of three separate phases (for an extensive description of the study see Kalff et al. [2001] and Kroes et al. [2001]). Stage 1 (months 1 - 9): selection of subjects. During this phase, all caregivers of children frequenting the second grade of normal kindergarten were asked to give permission for participation in the SAM study ($n = \pm 2300$). In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. Response rate was 57.5% ($n = 1317$). The children were examined as part of the routine health examination carried out by the school doctors. By law, these physicians are allowed to use medical information anonymously for epidemiological purposes. In this way, it was possible to compare two random samples of 200 non-responders with 200 responders with regard to child characteristics (sex, age), family variables (parental occupation, nationality, family structure), and environmental variables (living area), collected from the medical status of the Youth Health Care. This comparison was necessary because of the relative large percentage of non-responders; however, no significant differences between the groups were found (for a full description, see Kroes et al. [2001]). Next, based on the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), three groups were selected from the responders group for the second stage. Group E (externalizing group; $n = 173$, that is, approximately 7.5% of the total sample) consisted of children who scored high either on the CBCL externalizing broad-band scale ($> 90^{\text{th}}$ percentile) or on the CBCL Attention problems subscale ($> 95^{\text{th}}$ percentile). According to Chen, Faraone, Biederman, and Tsuang (1994), this selected group contains children with a putative risk for the development of ADHD. Next, group I (internalizing group; $n = 59$, that is, approximately 2.6% of the total sample) contained children scoring within a clinical range on the CBCL Internalizing scale ($> 90^{\text{th}}$ percentile), but did not fulfill the criteria for group E membership. Finally, a matched control group ($n = 220$, that is, approximately 9.6% of the total sample) was formed consisting of children with low CBCL total problem scores ($< 90^{\text{th}}$ percentile) and who were matched to group E and I in terms of age (± 2 months), sex and school (urban vs. rural). Stage 2 (months 15 - 25): caregivers of 403 children of the originally selected

group agreed to a semi-structured, psychiatric interview, using the Amsterdam Diagnostic Interview for Children and Adolescents (ADICA). This instrument assesses the presence of several DSM classifications for childhood psychopathology, including ADHD, using a systematic, horizontal approach. Based on these ADIKA results, three independent groups were formed: (a) children, who met during phase 2 all DSM-IV criteria for ADHD (*ADHD group*), (b) children, who met in stage 2 the DSM-criteria for psychopathology (other than ADHD; *psychiatric control group*), and (c) controls (*normal controls*). Children with both ADHD and any other psychopathology were submitted to group a. Furthermore, in stage 3 (months 39 - 49), all selected children were again asked to participate in the SAM study. In total, 284 of the 403 children for whom we had ADIKA results in phase 2 agreed to participate in the follow-up (70.5%). Because of the relative large dropout of participants in stage 3, responders and non-responders of stage 3 were tested for group differences in terms of sex, parental occupation, and ADIKA results (stage 2). Cramér's V testing revealed no significant differences between responders and non-responders on these variables (sex: value = .002, $p = .965$; parental occupation: value = .083, $p = .258$; ADIKA results: value = .109, $p = .091$). Next, all children were tested neuropsychologically by means of an extensive test protocol including assessment tools such as the Verbal Fluency Test, Vocabulary scores, and the Dutch Klepel Reading Test, which is a test for reading non-words. A neuropsychologist or one of three well-trained assistants administered the test battery. Testing took place in a room at the child's school. The examiner was blind to group membership of the children. Next, of the 284 cases included, fifteen children had to be excluded, because of (a) known use of Methylphenidate or Pipamperon (ADHD group $n = 5$; psychiatric control group $n = 4$; and control group $n = 2$) or (b) missing data in relation to LOA-codes ($n = 4$) or Klepel reading scores ($n = 1$). After this deletion of cases, data from 268 children were still available for the analyses: 20 children in the ADHD group, 118 children in the psychiatric control group, and 130 normal controls. Variables influential on research outcome were summed in Table 1, including age (as measured at *stage 3*), sex, the level of occupational achievement of the caregiver (LOA), and an estimate of verbal abilities and reading skills. Additionally, in table 2, the distribution of psychopathology other than ADHD was provided for each group (ADHD, psychiatric controls, and normal controls). No children were excluded from the ADHD-group and the psychiatric control group because of the (co-) occurrence of specified psychopathology.

Measurements

The Amsterdam Diagnostic Interview for Children and Adolescents (ADIKA; Kortenbout van der Sluijs, Levita, Manen, & Defares (1997): this is the Dutch translation of the Diagnostic Interview for Children and Adolescent (DICA; Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). The ADIKA is a semi-structured psychiatric interview that yields scores for several child psychiatric syndromes according to DSM-III-R guidelines and was adapted by using the criteria of DSM-IV for diagnosing ADHD (American Psychiatric Association, 1987; American Psychiatric Association, 1994). In line with these criteria, children were classified as ADHD if they showed a persistent pattern of inattention and/or hyperactivity-impulsivity that was more frequent and severe than that typically observed in individuals of comparable development (American Psychiatric Association, 1994). Children were included in the ‘psychiatric control group’ if they fulfilled the criteria for at least one child psychiatric syndrome (with the exception of ADHD)². Although the Dutch version of the DICA-III-R interview has not been separately validated, DICA and DICA-III-R have been demonstrated to have high test-retest reliability and moderate correlations with clinician based diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Table 1. Group characteristics and diagnostic data of the sample (n = 268).

	ADHD (n = 20)		Psychiatric (n = 118)		Controls (n = 130)		Contrasts
Sex (boys: girls)	14 : 6		71 : 47		65 : 65		n.s.
	Mean	SD	Mean	SD	Mean	SD	
Age	9.2	0.3	9.2	0.4	9.1	0.4	n.s.
Vocabulary-score	9.0	2.6	8.9	2.5	8.8	2.9	n.s.
Klepel-score	8.8	3.6	10.7	2.9	10.7	2.6	p = .019
LOA-score	3.0	1.7	3.7	2.0	4.5	1.9	p < .001

¹ Associations between ordinal and/or interval variables (group membership vs. age, Block design scores and LOA) were calculated by use of ANOVA. In contrast, chi square-tests were used to measure the associations between nominal (sex) and ordinal variables (groups).

² Such as major depression, dysthymia, bipolar syndrome, separation anxiety, phobia, overanxious disorder, avoidant disorder, oppositional disorder, conduct disorder, functional encopresis, functional enuresis, obsessive compulsive disorder, post traumatic stress disorder, pervasive developmental disorders.

Verbal fluency test (Korkman, Kirk, & Kemp, 1998): this test is a subtest of the NEPSY-battery and is believed to be a measure of retrieval from semantic memory. It includes two independent types of verbal fluency, namely, semantic category fluency (SCF) and initial letter fluency (ILF). SCF involves recitation of examples of a given category, whereas ILF involves the generation of words beginning with a given initial letter. The verbal fluency test consisted of (A) two trials of a SCF type task (e.g., to name as (1) many animals and (2) things you can eat or drink) and (B) two trials of an ILF type task (e.g., including the letters 'M' and 'S' [subtasks 3 & 4]). According to the Van Loon list presenting imageability ratings of Dutch words (Van loon, 1985), words that begin with the letters M or S are common in the Dutch language (respectively 4.3 % and 11.7 % of the Dutch words begin with these letters). Consistent with standard instructions, participants were asked each time to generate over 60 seconds as many words as possible of the above-mentioned categories, excluding the names of humans and cities. For each subtask, total number of correct responses, incorrect responses (e.g., words not beginning with the appropriate letter or not an exemplar of the category), and perservations (e.g., repetitions of correct words, morphological variants [for instance when a child says car and cars]) were recorded over (A) 1 - 15 seconds, (B) 16 - 30 seconds, (C) 31 - 45 seconds, and (D) 46 - 60 seconds. To reduce error variances, data were averaged over the time samples A, B, C, and D for each type of fluency.

Vocabulary test: this subtest of the Wechsler Intelligence Scales for Children – Dutch Version (WISC - Dutch Version by De Bruyn et al. [1986]) was used to provide an estimate of general ability (Lezak, 1995). The examiner asked the child to explain the meaning of certain words. The complexity of words increased with each item. Range of standard scores is 1 - 19 (mean score = 10, SD = 3). Reliability and validity are believed to be average to good (De Bruyn et al., 1986).

Klepel reading test (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994): this test provides a standardized measure of non-word decoding. For 2 minutes, the child had to read as many words as possible from a list of non-words. With each item the complexity of words increased. Standard scores range from 1 - 19 (mean score = 10, SD = 3). This task was included as a covariate because of the assumed relation between the development of the ability to organize and retrieve words phonemically and reading skills (Riva et al., 2000).

Level of Occupational Achievement of the caregiver (LOA): this variable was based on the full description of the parental occupation and was originally scored on a 7-point-scale, ranging from unskilled to scientific skilled labor (Directoraat-

Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded as a separate category. When the LOA differed between mother and father, the highest score was chosen. Finally, if data was missing for one caregiver, the score available was chosen for the analyses.

Table 2. Distribution of psychopathology, other than ADHD, found in the three groups (ADHD, psychiatric controls, normal controls).

Type of comorbidity (number of cases)	ADHD	Psychiatric	Controls
No psychopathology	-	-	130
No psychopathology other than ADHD	1	-	-
Anxiety disorders	2	42	-
Mood disorders	-	5	-
Mood disorders & anxiety disorders	1	7	-
Conduct disorders	4	17	-
Conduct disorders & anxiety disorders	3	12	-
Conduct disorders, mood disorders & anxiety disorders	-	1	-
Conduct disorders, mood disorders & anxiety disorders	4	3	-
Disorders of elimination	2	19	-
Disorders of elimination & anxiety disorders	-	3	-
Disorders of elimination & mood disorders	-	2	-
Disorders of elimination, mood disorders & anxiety disorders	-	1	-
Disorders of elimination & conduct disorders	1	5	-
Disorders of elimination, conduct disorders & anxiety disorders	1	-	-
Disorders of elimination, conduct disorders & mood disorders	-	1	-
Disorders of elimination, conduct disorders, mood disorders & anxiety disorders	1	-	-
Number of cases	20	118	130

Results

All statistical analyses were performed using the statistical package *SPSS for windows*. In all analyses, the child's sex, Klepel reading scores, vocabulary scores, and the LOA of the caregiver were included as covariates for they accounted for at least some variance in the verbal fluency scores. Preliminary experiments showed that the age of the child did not correlate with test performance over all groups, and thus age was not included as a covariate in the analyses. Corrections were made for unequal sample sizes within a non-experimental research design. The critical value for rejecting the null hypotheses was chosen at $p < 0.05$. Group performance on the fluency task, in terms of word production over

time for both SCF and ILF, was analyzed in a 2 x 4 (Type of fluency task x Time interval) General Linear Model (GLM) repeated measures design. The grouping variable consisted of three independent categories, namely (1) children with ADHD, (2) psychiatric controls, and (3) normal controls.

Word production over time and type of fluency

Significant main effects were found for type of fluency task (Type: $F(1,261) = 1138.80$, $p < .001$), word production as a function of time (Time: $F(3,259) = 982.67$, $p < .001$), and the interaction between these factors (Type x Time: $F(3,259) = 159.20$, $p < .001$). Overall, children produced significantly more words in the SCF (unadjusted for covariates: mean_{SCF} = 14.4 [SD = 3.6]) than on the ILF (mean_{ILF} = 7.1 [SD = 2.8]). Secondly, word productivity decreased significantly with each succeeding quartile of 60 seconds, averaged over types of fluency (unadjusted for covariates: mean_{1 - 15s} = 4.6 [SD = 1.0]; mean_{16 - 30s} = 2.6 [0.9]; mean_{31 - 45s} = 1.9 [0.8]; mean_{46 - 60s} = 1.6 [0.8]). Thirdly, the significant interaction of Type by Time indicated that the decrease in word production was not parallel in the SCF and ILF, although in both tests the number of words produced decreased with time. Fourthly, with regard to the covariates, significant interactions were found for Sex by Type of test ($F(1,261) = 4.23$, $p = .041$), Sex by Time samples ($F(3,259) = 2.65$, $p = .049$), and Klepel reading test scores by Time samples ($F(3,259) = 4.38$, $p = .005$). In addition, significant between-subjects effects were found for LOA ($F(1,261) = 25.43$, $p < .001$), Klepel reading scores ($F(1,261) = 22.35$, $p < .001$), and Vocabulary scores ($F(1,261) = 13.12$, $p < .001$). Fifth, using Pillai's trace criterion, the factor 'group' (ADHD, psychiatric controls, and controls) did not differ in the total number of words produced over 60 seconds, irrespective of the test used (Group x Type: $F(2,261) = 2.27$, $p = .106$). Furthermore, no interaction was found between group membership and number of words produced in different time intervals (Group x Time: $F(6,520) = 1.81$, $p = .094$). In contrast, there was an interaction of Group by Time by Type of test ($F(6,520) = 2.09$, $p = .052$). This finding indicated that performance of groups was not linear across different time intervals and types of fluency.

Additional GLM multivariate testing revealed only a significant interaction between groups and performance (words produced) as a function of time on the ILF task (ILF: Group x Time $F(6,520) = 3.53$, $p = .002$). This interaction could primarily be explained by the large group differences in test performance over the first 15 seconds of the ILF. Children diagnosed with ADHD in phase 2 produced significantly fewer words during the first 15 seconds of the ILF than did children in the control groups ($F(2,261) = 5.62$, $p = .004$; after Bonferroni correction, A vs. C: $p = .022$; A vs. B: $p = .003$; B vs. C: $p = .805$). Over the succeeding time intervals, all groups performed at a comparable level (16 - 30sec: $F(2,261) = 1.03$, $p = .357$; 31 - 45sec: $F(2,261) = 1.77$, $p = .172$; 46 - 60sec: $F(2,261) = 1.43$, $p = .241$). Figure 1 presents group performance for each type of fluency (ILF &

SCF). For all analyses, Levene's Test of Equality of Error Variances was not significant. To examine additionally whether these last-mentioned results are primarily attributable to concurrent phonological impairments, the relation between fluency, Klepel reading test scores, and group membership (ADHD, psychiatric controls, and healthy controls) was further examined. For this purpose, zero-order correlations between the variables were calculated. It was found that the correlations between the variable 'group' and the dependent variables (type of fluency x time sample) *before* correcting for Klepel scores were highly comparable with the correlations the variable 'group' and the dependent variables (type of fluency x time sample) *after* correction for Klepel scores. Based on these findings, it can be assumed that the results found in this study can not be solely described to phonological or reading impairments.

Perseverations and errors

Incorrect responses were analyzed within a 3 x 2 (Group x Type of fluency tasks) GLM repeated measures analysis for unequal sample sizes within a non-experimental research design. First of all, the analysis revealed a significant main effect for group ($F(2,261) = 42.90, p < .001$). Secondly, with regard to the covariates, significant interactions were found for Klepel reading test score by Type of test ($F(1,261) = 7.91, p = .005$). Thirdly, a significant interaction of Group by Type of fluency was found while studying the incorrect responses given ($F(2,261) = 3.65, p = .027$). Children with ADHD made significantly more incorrect responses than did the controls (After correction for Bonferoni, A vs. C: $p = .008$; A vs. B: $p = .005$; B vs. C: $p = 1.000$). Compared to either type of control group, children with ADHD tended to make more incorrect responses on the initial letter fluency tasks ($F(2,261) = 4.54, p = .012$; after Bonferoni correction, A vs. C: $p = .014$; A vs. B: $p = .010$; B vs. C: $p = 1.000$). No group differences in terms of incorrect responses were found on the semantic category fluency tasks (see figure 2). Caution is necessary when interpreting these results, because of Levene's Test of Equality of Error Variances was found to be significant. Next, a 3 x 2 (Group x Type of fluency task) GLM repeated measures analysis revealed no significant main effect or interaction while studying the total number of perseverations made (main effect: $F(2,261) = 1.27, p = .260$; interaction of Group by Type of fluency: $F(2,261) = 0.03, p = .975$). With regard to the covariates, significant interactions were found for LOA by Type of test ($F(1,261) = 5.71, p = .018$) and for Vocabulary by Type of test ($F(1,261) = 4.16, p = .042$). However, caution is again necessary when interpreting these results, because of Levene's Test of Equality of Error Variances was found to be significant.

Figure 1. Productivity-scores over different time samples, groups and type fluency tests. Note: Evaluated at covariates appeared in the model.

Discussion

In a clinical setting, verbal fluency tests are used to evaluate the cognitive performance of children with ADHD. Successful performance on these tasks relies strongly on attention capacity and executive functioning (Monsch et al., 1994; Rosser & Hodges, 1994), which are aspects of cognition frequently mentioned in relation to ADHD (Barkley, 1998). Unfortunately, evidence is still inconclusive with regard to the influence of ADHD on the performance on the verbal fluency tasks (e.g., Felton, Wood, Brown, Campbell, & Harter, 1987; Loge et al., 1990). Many studies used the total number of correct words generated over a set period of 60 - 90 seconds as the main outcome variable, whereas, in theory, the pattern of word production over time may provide additional information about the cognitive processes underlying fluency performance (Troyer, 2000). In our study, the number of correct words produced on both types of verbal fluency (semantic category fluency [SCF] and initial letter fluency [ILF]) decreased significantly with time (defined in quartiles of 15 seconds) in all groups of children. This is consistent with findings from previous studies of healthy adult participants (Crowe, 1998; Monsch et al., 1994; Rosser & Hodges, 1994). This decrease can be explained in terms of the model of lexical organization (Crowe, 1996; Smith & Claxton, 1972), which states that there are two types of stores, namely (1) a long-term store ('topicon') which is readily accessible and contains common words, and (2) a more extensive lexicon which is searched after the 'topicon' is exhausted. It can thus be hypothesized that, during the first time period (1 - 15 seconds) of either type of fluency task, a ready pool of frequently used words is available and automatically activated for production. As time passes the pool becomes exhausted and production becomes both more effortful and less productive (Crowe, 1998). Therefore to examine the link between test performance and ADHD, it may be relevant to include variables, such as automatic and controlled processes, as a function of time in addition to the overall performance on a fluency task. In this context, children with ADHD, psychiatric controls and controls

were found in the study presented in this chapter to produce over 60 seconds a similar total number of words on both verbal fluency tasks. Thus, the normal way of scoring performance on the verbal fluency task could not discriminate between ADHD children on the one hand and psychiatric and healthy controls on the other. In contrast, there was a significant interaction of groups by word production over time and as a function of type of fluency, after correction for sex, LOA, vocabulary, and reading skills. Analyses indicated that children classified as having ADHD earlier in life performed significantly less well than their controls (psychiatric or healthy) over the first 15 seconds of a complex, ILF task. In contrast, no significant interaction was found between groups, word production, and time samples on the SCF task.

Several explanations can be proposed based on these findings. For one, children who show behavior related to ADHD at age 7 years (that is, at a phase during which brain maturation occurs) may show a delay in performance on tests measuring recently acquired automatic processes at age 9, when compared with control children and children with one or more psychiatric problems other than ADHD. The idea of impaired automation of skills in ADHD is supported by research of Dykman et al. (in Ackerman et al. [1986]). Moreover, the disturbed pattern in performance over time seemed specific for ADHD: children classified as having ADHD performed significantly less well on the initial letter fluency than children assigned to the psychiatric or the healthy control groups. Also, when comparing an initial letter to semantic fluency tasks the difference may not only be in how much effort the task ‘requires’ but also in how ‘difficult’ the task is. Priming studies suggest that language is represented semantically (Mercer, 1976; Collins & Loftus, 1975; Jescheniak & Levelt, 1994), so when asked to generate words according to a category, this matches with the way in which language is stored. An initial letter fluency task is different in that language is not ‘organized’ alphabetically, thus this type of task is relatively novel to most participants and likely requires more executive function than does a semantic fluency task. For deficits in executive functioning are often mentioned in relation to ADHD, this may well add to the explanation of the finding that children suffering from ADHD perform less well than controls on the initial fluency tests and no differences were found between groups on the semantic fluency test. Additionally, the results emphasize the importance of ‘testing the limits’ when clinically assessing a child with ADHD characteristics. From the present results, it can be concluded that children classified as having ADHD are able to achieve on a similar level of performance as controls, if they are given sufficient time to do a task. Thus, the total time on task is relevant, in a way that children with ADHD seem to need extra time to ‘start the engine’. However, because of relative small samples and effect sizes additional research is needed to test the above-mentioned assumptions.

Figure 2. Incorrect responses over groups and type fluency tests (semantic vs. initial letter fluency). Note: Evaluated at covariates appeared in the model; SCF: = Semantic Category Fluency; ILF: = Initial Letter Fluency.

Finally, while studying the incorrect responses and perseverations made by the subjects, it was found that, compared to both normal controls and psychiatric controls, children with ADHD made more incorrect responses on the initial letter fluency tasks. No differences in terms of incorrect responses were found on the semantic category fluency tasks. These differences can again be explained by the complexity of the task. In our study, children, regardless of group membership, produced significantly more incorrect responses on the ILF tasks compared to the SCF. Several authors (e.g., Monsch et al., 1992; Ober, Dronkers, Koss, Delis, & Friedland, 1986; Riva et al., 2000) stated with respect to this subject that, although the instruction is identical for each type, the SCF and ILF are believed to involve different search strategies, in which SCF is less difficult and its search strategies are acquired earlier in development, compared to the strategies needed for letter-based tests. In line of this reasoning, it can be concluded based on the presently available data that in 9-year-old children the search for letter-based words is less well acquired or automated and demand more executive functioning than the search for words in the SCF. However, children with ADHD tended to make in proportion even more incorrect responses on the ILF than the controls. Therefore, the results of the present study also indicate that children with ADHD have additional problems with searching for letter-based words and executive functioning at age 9.

The present study includes some limitations. For instance, the DSM classifications were measured solely on basis of the outcome of a semi-structured interview with the caregivers of the child. Cross-informant reports, like Teacher Reports, were not included here. Therefore, it is possible that the number of children with externalizing behavior was overestimated. However, Barkley (1998) reported evidence of a 90% overlap between parent reports and teacher reports. An additional limitation is that the exclusion and drop out of children in the analyses

(37% of the selected sample) could limit the generalizability of the results to the population. Also, no measurement of broader based language abilities was included in the test protocol (e.g., standard test of semantic abilities and of general word retrieval abilities under a non-speeded condition): a limitation that is of concern given the known impairments in verbal fluency associated with specific language impairments. Lastly, the study used only a 2-year follow-up. McKay, Halperin, Schwartz, and Sharma (1994) reported that response organization was pivotal to output processing, and noted that the development of response organization largely accounted for the improvement in information processing efficiency between 7 and 9 years of age. Cross-sectional studies indicate that word fluency improves with increasing age to at least 13 years, with written word fluency increasing up to 18 years (Levin, Song, Ewing-Cobbs, Chapman, & Mendelsohn, 2001). Furthermore, significant deviations were found between the test performance of healthy children aged 9 and adults (Hurks et al, submitted). Over 60 seconds, healthy children produced more correct responses on the SCF task than on the ILF task, while with adults this relation was inverted. Over 60 seconds, adults appeared to be more successful in producing words in the ILF task (Butters, Granholm, Salmon, Grant, & Wolfe, 1987). Therefore, at the moment of neuropsychological testing (age 9), the cognitive development of the children in this study may have passed or was about to pass an important milestone in terms of controlled processing. From this perspective, these children should be tested again when they are older to see whether there are differences in, for example, automatic and effortful processing.

References

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Ackerman, P. T., Anhalt, J. M., Holcomb, P. J., & Dykman, R. A. (1986). Presumably innate and acquired automatic processes in children with attention and/or reading disorders. *Journal of Child Psychology and Psychiatry*, 27, 513-529.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders*. (3th ed.). Washington, DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders*. (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., Grodzinsky, G., & DuPaul, G. J. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. *Journal of Abnormal Child Psychology*, 20, 163-188.
- Bernstein, D. (1989). Language development: the school age years. In E. Tiegermen (Ed.), *Language and communication disorders in children*. Columbus, OH: Merrill/MacMillon.

- Borcherding, B., Thompson, K., Kruesi, M., Bartko, J., Rapoport, J. L., & Weingartner, H. (1988). Automatic and effortful processing in Attention Deficit/Hyperactivity Disorder. *Journal of Abnormal Child Psychology*, 16(3), 333-345.
- Butters, N., Granholm, E., Salmon, D., Grant, L., & Wolfe, J. (1987). Episodic and semantic memory: A comparison of amnesic and demented patients. *Journal of Clinical and Experimental Neuropsychology*, 9, 479-497.
- Chen, W. J., Faraone, S. V., Biederman, J., & Tsuang, M. T. (1994). Diagnostic accuracy of the Child Behavior Checklist scales for Attention-Deficit Hyperactivity Disorder: A receiver-operating characteristic analysis. *Journal of Consulting and Clinical Psychology*, 62, 1017-1025.
- Collins, A.M., & Loftus, E.F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, 82, 407-428.
- Crowe, S. F. (1996). The performance of schizophrenic and depressed participants on tests of fluency: support for a compromise in dorso-lateral pre-frontal functioning. *Australian Psychologist*, 31, 204-209.
- Crowe, S. F. (1998). Decrease in performance on the verbal fluency test as a function of time: Evaluation in a Young Healthy Sample. *Journal of Clinical and Experimental Neuropsychology*, 20 (3), 391-401.
- De Bruyn, E. E. J., Van der Steene, G., Van Haasen, P. P., Coetsier, P., Pijl, Y. J., Spoelsters-Claes, R., Poortinga, Y. H., Stinissen, J., & Lutje Spelberg, H. C. (1986). *Wechsler Intelligence Scale for Children - Revised (WISC-R)*. Lisse: Swets & Zeitlinger.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functieanalyse*. Den Haag: SDU uitgeverij.
- Ezpeleta, L., De la Osa, N., Doménech, J. M., Navarro, J. B., Losilla, J. M., & Júdez, J. (1997). Diagnostic agreement between clinicians and the Diagnostic Interview for Children and Adolescents-DICA-R in an outpatient sample. *Journal of Child Psychology and Psychiatry*, 38(4), 431-440.
- Felton, R. H., Wood, F. B., Brown, I. S., Campbell, S. K., & Harter, M. R. (1987). Separate verbal memory and naming deficits in Attention Deficit Disorder and Reading Disabilities. *Brain and Language*, 31, 171-184.
- Fischer, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: II. Academic, attentional, and neuropsychological status. *Journal of Consulting and Clinical Psychology*, 58, 580-588.
- Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Granero Pérez, R., Ezpeleta Ascaso, L., Doménech Massons, J. M., & De la Osa Chaparro, N. (1998). Characteristics of the subject and interview influencing the test-retest reliability of the Diagnostic Interview for Children and Adolescents-Revised. *Journal of Child Psychology and Psychiatry*, 39(7), 963-972.
- Grodzinsky, G. M., & Barkley, R. A. (1999). Predictive power of frontal lobe tests in the diagnosis of Attention Deficit Hyperactivity Disorder. *Clinical Neuropsychologist*, 13, 12-21.
- Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention deficit hyperactivity disorder. *Journal of Clinical Psychology*, 45, 427-446.

- Hazell, P. L., Carr, V. J., Lewin, T. J., Dewis, S. A. M., Heathcote, D. M., & Brucki, B. M. (1999). Effortful and automatic information processing in boys with ADHD and Specific Learning Disorders. *Journal of Child Psychology and Psychiatry*, 40, 275-286.
- Hurks, P. P. M., Vles, J. S. H., Hendriksen, J. G. M., Kalff, A. C., Feron, F. J. M., Kroes, M., Van Zeben, T. M. C. B., Steyaert, J., & Jolles, J. (Submitted for publication). Semantic category fluency versus letter fluency over time as a measure of automatic and controlled processing in healthy school-aged children.
- Jescheniak, J.D., & Levelt, W.J.M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 20, 824-843.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Klorman, R., Hazel-Fernandez, L. A., Shaywitz, S. E., Fletcher, J. M., Marchione, K. E., Holehan, J. M., Stuebing, K. K., & Shaywitz, B. A. (1999). Executive functioning deficits in Attention Deficit/Hyperactivity Disorder are independent of Oppositional Defiant or Reading Disorder. *Journal of the American Academy Child and Adolescent Psychiatry*, 38, 1148-1155.
- Korkman, M., Kirk, U., & Kemp, S. L. (1998). *NEPSY. A developmental neuropsychological assessment*. San Antonio, TX: The Psychological Corporation.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKa). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Koziol, L. F., & Stout, C. E. (1992). Use of a verbal fluency measure in understanding and evaluation ADHD as an executive function disorder. *Perceptual and Motor Skills*, 75, 1187-1192.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Kusche, C. A., Cook, E. T., & Greenberg, M. T. (1993). Neuropsychological and cognitive functioning in children with anxiety, externalizing, and comorbid psychopathology. *Journal of Clinical Child Psychology*, 22, 172-195.
- Mercer, N. (1976). Frequency and availability in the encoding of spontaneous speech. *Language and Speech*, 19, 129-143.
- Levin, H. S., Song, J., Ewing-Cobbs, L., Chapman, S. B., & Mendelsohn, D. (2001). Word fluency in relation to severity of closed head injury, associated frontal brain lesions, and age at injury in children. *Neuropsychologia*, 39, 122-131.
- Levy, F., Hay, D., McLaughlin, M., Wood, C., & Waldman, I. (1996). Twin sibling differences in parental reports of ADHD, speech, reading and behaviour problems.

- J Child Psychol Psychiatry*, 37(5), 569-78.
- Lezak, M. D. (1995). *Neuropsychological assessment*. (3 ed.). Oxford: Oxford University Press.
- Loge, D. V., Station, R. D., & Beatty, W. W. (1990). Performance of children with ADHD on tests sensitive to frontal lobe dysfunction. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29, 540-545.
- McKay, K. E., Halperin, J. M., Schwartz, S. T., & Sharma, V. (1994). Developmental analysis of three aspects of information processing: Sustained attention, selective attention, and response organization. *Developmental Neuropsychology*, 10, 121-132.
- Monsch, A., Bondi, M. W., Butters, N., Salmon, D. P., Katzman, R., & Thal, L. J. (1992). Comparison of verbal fluency tasks in the detection of dementia of the Alzheimer type. *Archives of Neurology*, 49, 1253-1258.
- Monsch, A. U., Bondi, M. W., Butters, N., Paulsen, J. S., Salmon, D. P., Brugger, P., & Swenson, M. R. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology*, 8, 25-30.
- Oades, R. D. (1998). Frontal, temporal and lateralized brain function in children with Attention-Deficit Hyperactivity Disorder: A psychophysiological and neuropsychological viewpoint on development. *Behavioural Brain Research*, 94, 83-95.
- Ober, B. A., Dronkers, N. F., Koss, E., Delis, D. C., & Friedland, R. P. (1986). Retrieval from semantic memory in Alzheimer-type dementia. *Journal of Clinical and Experimental Neuropsychology*, 8, 75-92.
- Pennington, B. E., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 37, 51-87.
- Perugini, E. M., Harvey, E. A., Lovejoy, D. W., Sandstrom, K., & Webb, A. H. (2000). The predictive power of combined neuropsychological measures for Attention-Deficit/Hyperactivity Disorder in children. *Child Neuropsychology*, 6(2), 101-114.
- Pineda, D., Ardila, A., & Rosselli, M. (1999). Neuropsychological and behavioural assessment of ADHD in 7- to 12-year-old children: A discriminant analysis. *Journal of Learning Disabilities*, 32(2), 159-173.
- Reader, M. J., Harris, E. L., Schuerholz, L. J., & Denckla, M. B. (1994). Attention Deficit Hyperactivity Disorder and executive dysfunction. *Developmental Neuropsychology*, 10, 493-512.
- Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, 71, 267-284.
- Rosser, A., & Hodges, J. (1994). Initial letter and semantic category fluency in Alzheimer's disease, Huntington's disease, and Progressive Supranuclear Palsy. *Journal of Neurology, Neurosurgery and Psychiatry*, 57, 1389-1394.
- Sagvolden, T., & Sergeant, J. A. (1998). Attention deficit/ hyperactivity disorder- from brain dysfunctions to behaviour. *Behavioural Brain Research*, 94, 1-10.
- Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 84, 1-66.
- Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive

- function for Attention-Deficit/Hyperactivity Disorder? *Behavioural Brain Research*, 130, 3-28.
- Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127-190.
- Smith, P. T., & Claxton, G. L. (1972). *Lexical search and phonemic organisation in memory*. Paper presented at the Paper presented to the Experimental Psychology Society London.
- Taylor, E., Chadwick, O., Heptinstall, E., & Danckaerts, M. (1996). Hyperactive and conduct problems as risk factors for adolescent development. *Journal of the American Academy of Child Psychiatry*, 35, 1213-1226.
- Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, 22(3), 370-378.
- Van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & De Vries, J. R. (1994). *De Klepel*. Lisse: Swets & Zeitlinger.
- Van der Meere, J., & Sergeant, J. (1988). Acquisition of attention skill in pervasively hyperactive children. *Journal of Child Psychology and Psychiatry*, 29(3), 301-310.
- Van Loon, A. (1985). *Voorstelbaarheidswaarden van Nederlandse woorden*. Lisse, The Netherlands: Swets & Zeitlinger.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children, adolescents and adults*. (2 ed.). New York: The Guilford Press.
- Welner, Z., Reich, W., Herjanic, B., Jung, K. G., & Amado, H. (1987). Reliability, validity, and parent-child agreement studies of the diagnostic interview for children and adolescents (DICA). *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 649-653.
- Weyandt, L. L., & Willis, W. G. (1994). Executive functions in school-aged children: Potential efficacy of tasks in discriminating clinical groups. *Developmental Neuropsychology*, 10(1), 27-38.

Controlled visuomotor preparation deficits in ADHD¹

Abstract

To the best of our knowledge, there are no published reports on visuomotor preparation in ADHD. This is unfortunate because research suggests that ADHD is an output-related deficit and sub-optimal execution of tasks may be the result of incomplete visuomotor preparation. Nineteen children with ADHD were compared with 124 healthy and 118 pathological controls in terms of their performance (speed, speed variability and accuracy) on the Finger Precuing Test (FPT), a test measuring (automatic and controlled) visuomotor preparation. The data implicated that children with ADHD have an impaired ability to engage in effortful, controlled visuomotor preparation activities. Fast, automatic response preparation was not affected by ADHD. Additionally, children with ADHD showed more variability in overall test performance than other children. No group differences were found in response accuracy.

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Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD), one of the most prevalent developmental disorders (Barkley, 1998; Biederman, 1998; Kroes et al., 2001), has been studied extensively in relation to performance on a wide variety of information processing tasks (see for a comprehensive review Douglas (1999)). Although several studies have failed to demonstrate a deficit in information input, there is evidence for an output-related processing dysfunction in ADHD (Borger & Van der Meere, 2000; Leth-Steensen, King Elbaz, & Douglas, 2000), especially of motor execution processes. However, only a few investigators have assessed the anticipation and preparation of motor behavior in relation to ADHD, which is unfortunate because preparation precedes motor execution, and faulty or incomplete preparation may lead to sub-optimal execution of movements (Hallet, 2000).

In healthy adults and children, preparation of motor behavior has typically been studied using a movement precuing paradigm (e.g., Rosenbaum, 1983; Adam, Backes et al., 2003; Adam et al., 1998; Deiber, Ibañez, Sadato, & Hallett, 1996; Olivier & Rival, 2002). This paradigm makes it possible to study the nature of the response preparation processes that occur during the precue or preparation interval (i.e., in the interval between the cue signal and the target signal). Effective motor preparation will lead to shorter reaction times (RTs) and greater accuracy, because the precue directs visual attention to the probable location of the target stimulus and thereby enhances perceptual processing by allowing resources to be allocated to the most relevant source of information (Adam et al., 1998; Eriksen, 1990; Koski, Paus, Hofle, & Petrides, 1999; Posner, 1994). Successful visuomotor preparation is, therefore, dependent on the efficiency of several cognitive processes, including visuo-perception, the selection and preparation of one or several possible categories of motor action, and the ability to allocate or focus attention effectively. In earlier studies, ADHD was found to be associated with a deficit in the covert attention system, which allows attention to be allocated to and manipulated within certain regions of visual space (McDonalds, Bennett, Chambers, & Castiello, 1999; Perchet, Revol, Fournieret, Mauguière, & Garcia-Larrea, 2001; Swanson et al., 1991). Taken together with the earlier discussed output-related processing dysfunction in ADHD, it seems plausible that ADHD symptomatology affects the effectiveness of visuomotor preparation, including the ability to use cues effectively. We therefore investigated visuomotor preparation in children with ADHD, using a study design which enabled us to take several confounders into consideration. For example, we compared children with ADHD with healthy children and with a group of children with psychopathology (DSM-III-R/DSM-IV classification) other than ADHD (American Psychiatric Association, 1987, 1994) in order to determine the specificity of ADHD-related findings, because children with ADHD are at risk of developing other psychiatric disorders and learning disabilities (Barkley 1998). Several authors

have stated that the period between the ages 5 and 7 years is critical for later cognitive development (Bernstein, 1989; Riva, Nichelli, & Devoti, 2000), and thus the expression of ADHD in this period, rather than later in life, may disrupt cognitive and social functioning. For this reason, we related the presence of possible psychopathology when the child was approximately 7 years to cognitive functioning when the child was 9, at which time it had completed 2 years of school education.

Methods

This report is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)', which has a longitudinal, population-based design. The SAM study consists of four separate phases (for a detailed description of the study, see Kalff et al. (2001) and Kroes et al. (2001)). For the present chapter, only three stages are relevant and are discussed here.

Stage 1 (months 1 - 9): Selection of subjects. During this phase, all caregivers of children who attended the second grade of normal kindergarten were asked to give permission for participation in the SAM study ($n = \pm 2300$). In the Netherlands, the second grade precedes the first class of elementary school, where children learn to read and write. The response rate was 57.5% ($n = 1317$). Parallel to inclusion, all children (both responders and non-responders) were examined as part of the routine health examination carried out by the school doctor. By law, school doctors are allowed to use medical information anonymously for epidemiological purposes. Therefore, it was possible to compare two random samples of 200 non-responders with 200 responders with regard to child characteristics (sex, age), family variables (parental occupation, nationality, family structure), and environmental variables (living area) collected from the medical records held by the Youth Health Care Organization. This comparison was necessary because of the relatively large percentage of non-responders; however, no significant differences between the groups were found (for a full description, see Kroes et al. (2001)). Next, a subgroup of 452 children was defined on the basis of scores for the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), and selected for further research (for more detail of the selection criteria, see Kalff et al. [2001] and Kroes et al. [2001]).

Stage 2 (months 15 - 25): Psychiatric interview. Caregivers of 403 of the originally selected 452 children agreed to a semi-structured, psychiatric interview, using the Amsterdam Diagnostic Interview for Children and Adolescents (ADICA). This instrument provides information about childhood psychopathology (DSM classifications, including ADHD). Based on the ADICA results collected in stage 2, three independent groups were formed: (A) children who in phase 2 met all DSM-IV criteria for 'ADHD' (*ADHD*), (B) children who in stage 2 met the criteria for any DSM classification except for ADHD (*pathological*

controls) and (C) healthy controls (*controls*).

Finally, in *stage 3* (*months 39 - 49*), all selected children were again asked to participate in a follow-up investigation. A total of 284 of the 403 children for whom we had ADIKA results in stage 2 agreed to participate in the follow-up (70.5%). Because of the relatively large drop out of participants in stage 3, responders and non-responders in stage 3 were tested for group differences in terms of sex, parental occupation, and ADIKA results. Cramer's V testing revealed no significant differences between responders and non-responders on these variables (sex: value = .002, $p = .965$; parental occupation: value = .083, $p = .258$; ADIKA results: value = .109, $p = .091$). In stage 3, all participating children were tested neuropsychologically by means of an extended test protocol, including assessment tools such as the computerized Finger Precuing test (FPT) and the paper-and-pencil task Block Design. Testing took place in a stimulus-free room at the child's school, and a neuropsychologist or one of three well-trained assistants administered the test battery. The examiner was blind to group membership of the children. Information about variables that could influence outcome, namely, age (during *stage 3*), sex, and level of occupational achievement of the caregiver (LOA), was collected. An overview of data collection is presented in figure 1.

Figure 1. A schematic representation of the data collection for the present study.

As mentioned above, 284 children completed all stages. For the analyses, however, the data for 13 children were excluded because of (a) a known use of Methylphenidate or Pipamperon (ADHD $n = 5$; pathological $n = 4$; controls $n = 2$) or (b) missing data in relation to LOA codes ($n = 2$). In addition, the data for ten children were excluded because their performance was unreliable (see description FPT in the *measures*-section), or because of other problems, such as too strict timetables or computer defects. Three sub-samples were formed from the remaining children ($n = 261$), namely (1) a group of children who were classified as having ADHD in stage 3 (ADHD; $n = 19$), (2) a group of children who were classified with any DSM classification for psychopathology other than ADHD (pathological controls; $n = 118$), (3) a group of children who did not belong to

group 1 or 2 (healthy controls; $n = 124$). Group characteristics are summarized in table 1.

Table 1. Group characteristics and diagnostic data of the sample.

	ADHD $n = 19$	Pathological $n = 118$	Controls $n = 124$	p-value ¹
Mean Age (SD)	9.3 (0.4)	9.2 (0.4)	9.1 (0.4)	n.s.
Sex (boys : girls)	13 : 6	70 : 48	62 : 62	n.s.
Mean Block Design (SD)	9.7 (4.0)	9.6 (3.4)	10.3 (3.5)	n.s.
LOA (high/middle/low)	2/2/15	35/27/56	43/44/37	$p = .027$

Note¹: Associations between ordinal and/or interval variables (group membership vs. age, Block design scores and LOA) were calculated by use of Spearman's rho. In contrast, chi square-tests were used to measure the associations between nominal (sex) and ordinal variables (groups).

Measures

The Amsterdam Diagnostic Interview for Children and Adolescents (ADIKA; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997): This is the Dutch translation of the Diagnostic Interview for Children and Adolescent (DICA; Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). The ADIKA is a semi-structured psychiatric interview that yields scores for several child psychiatric syndromes according to DSM-III-R guidelines and was adapted by using the criteria of DSM-IV for diagnosing ADHD (American Psychiatric Association, 1987, 1994). In line with these criteria, children were classified as 'ADHD' if they showed a persistent pattern of inattention and/or hyperactivity-impulsivity that was more frequent and severe than that typically observed in individuals of comparable development (American Psychiatric Association, 1994). Children were included in the 'pathological control group' if they fulfilled the criteria for at least one child psychiatric syndrome (with the exception of ADHD)². Although the Dutch version of the DICA-III-R interview has not been validated, DICA and DICA-III-R have been demonstrated to have high test-retest reliability and moderate correlations with clinical diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Block Design: A subtest of the Wechsler Intelligence Scales for children translated into Dutch by De Bruyn et al. (1986). Block design is a construction test in

² Such as major depression, dysthymia, bipolar syndrome, separation anxiety, phobia, overanxious disorder, avoidant disorder, oppositional disorder, conduct disorder, functional encopresis, functional enuresis, obsessive compulsive disorder, post traumatic stress disorder, pervasive developmental disorders.

which the subject is presented with 9 blocks. Each block has two white sides, two red sides and two half-red-half-white sides. The task is to use the blocks to construct copies of designs printed on paper in smaller scale (Lezak, 1995). Performance is highly correlated with general mental ability (Benton, 1984). Reliability and validity are believed to be average to good (Lezak, 1995). Range of standard scores is 1-19 (mean score = 10, SD = 3).

Level of Occupational Achievement of the caregiver (LOA): The occupation of the caregivers of the child was originally scored on a 7-point-scale, ranging from unskilled (score 1) to scientific labor (7) (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded separately and entered as a separate occupation category (score 0). When the LOA differed between mother and father or if data were missing for one caregiver, the highest available score was chosen. For the present study, the scale was reduced to a 3-point ordinal variable: low level (scores 0, 1, 2, & 3), medium level (4 & 5), and high level (6 & 7).

Finger Precuing Test (FPT). This test was originally developed by Miller (1982), and the Dutch version adjusted by Adam et al. (1998) is often used to test visuo-motor preparation in adults: The task is to respond as quickly as possible to the appearance of spatially oriented stimuli on a computer-screen. The FPT is a four-choice reaction time task with the index and middle fingers of both hands located on separate keys of the computer keyboard (more specifically, the buttons ‘z’, ‘x’, ‘>’, ‘?’). The fingers are placed on the keys before the test starts. In a predictable, temporal order of appearance, three horizontal rows of stimuli are projected on a computer screen (conform figure 2).

Figure 2. Schematic presentation of the steps as shown on the computer.

First, a warning signal appears on the screen, including four identical plus signs

on a horizontal row (step 1). Next, after a constant time interval, a hint or precue (*preparation condition*) is presented to the participant (step 2). This precue consists of two or four plus signs and provides information about which fingers to use for responding. Two plusses indicate that one of two fingers will be used to make the response (two-choice reaction task), and four that one of four fingers will be used (four-choice reaction task). Reaction times are shorter with two-choice task than for four-choice tasks (Adam et al., 1998). After a variable latency (termed the *preparation interval*), the target stimulus is presented on the screen (step 3), in response to which the subject has to press the corresponding key as quickly as possible. The preparation interval reflects the amount of time available to selectively prepare for the finger responses indicated by the precue, before the target stimulus is presented. After a response is given, the entire sequence of the three steps is repeated. Participants received a block of 80 trials; each block was preceded by 15 practice trials. The order of the cueing conditions within a block of 80 trials was at random and in the initial instruction emphasis on speed and accuracy was equally strong.

There are four types of preparation conditions (Figure 3). The *null cued condition* (see example A) is included as a control condition, because it leaves the basic, four-choice reaction task unaltered and hence allows no specific preparation of two finger responses; the *hand-cued condition* (example B) specifies two fingers on the same hand; the *finger-cued condition* (example C) specifies the same finger on different hands; and the *neither-cued condition* (example D) specifies different fingers on different hands. The preparation interval is an independent variable in the FPT and is believed to affect the activation state in subjects (Borger & Van der Meere, 2000). With short intervals, preparation proceeds relatively automatically (generally fast and relatively unconscious), whereas with longer intervals the subject is forced to process the cued information more consciously, that is, in a slower, effortful, and attention-demanding manner (Fodor, 1983; Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). By including both short (e.g., 100 ms) and long preparation intervals (1000 ms), the FPT can be used to obtain information about automatic and controlled information processing.

Statistics

FPT performance was evaluated statistically for the entire group and for differences between groups (ADHD children, pathological controls and healthy controls). Three outcomes were used: *speed* (i.e., mean reaction time of hits [RT]), *speed variability* (i.e., standard deviation (SD) of RT of hits) and *accuracy* (i.e., percentage of errors). Before data analysis, RT data were transformed logarithmically into a more normally distributed curve. This was necessary because the distribution of RTs is typically skewed in these tests (Luce, 1986), and this skewing tends to be more pronounced in children with ADHD (Leth-Steensen et al., 2000). All RTs that were shorter than 150 ms or longer than 3.0 s were consid-

ered outliers and were excluded from data analyses; 6% of the RTs were excluded for these reasons.

Figure 3. Different conditions of the Finger Percuing Paradigm (Adam et al., 1998).

All statistical analyses were done with the statistical package *SPSS for windows* version 9.0. For all outcome measures (speed, variability of speed, and accuracy), a General Linear Models (GLM) repeated measures was performed with group membership (ADHD, pathological controls, healthy controls) as the between-subjects variable and preparation condition (null-cued, hand-cued, finger-cued, neither-cued) and preparation interval (100 ms, 1000 ms) as within-subjects variables.

The critical value for rejecting the null hypotheses was defined at $p < 0.05$. Post-hoc corrections for Bonferroni were made if necessary. In addition, all analyses were corrected for sex, block design scores, and LOA, which were included as covariates. Preliminary experiments showed that hand preference did not correlate with test performance in healthy subjects, and thus hand preference was not included as a covariate.

Results

Speed

GLM analyses revealed that speed was affected by the factors ‘preparation condition’ ($F_{3,253} = 60.125$; $p < .001$), ‘preparation interval’ ($F_{2,255} = 49.073$; $p < .001$), and their interaction ($F_{3,253} = 9.753$; $p < .001$) (see figure 4^a). Post-hoc analyses indicated that 9-year-old children benefited from hand-cueing ($RT_{hand-cued}$ vs. $RT_{null\ cued}$; $p < .001$): RTs in the hand-cued condition were on average 59 ms (SD = 115) shorter than in the null-cued condition. In contrast, they appeared not to be able to make use of the finger-cued or the neither-cued conditions; that is, RTs for these conditions were not shorter than those for the null-cued condition. No significant differences were found between the finger-cued and neither-cued con-

ditions ($p = 1.000$). FPT performance was a function of both preparation interval and preparation condition. When the preparation interval was increased from 100 ms to 1000 ms, RTs became significantly longer (this was true for all preparation conditions, p values ranged from 0.000 to 0.004). For the short preparation interval (100 ms), RTs were significantly shorter ($P < 0.001$) in the hand-cued condition than in the null-cued, finger-cued, and neither-cued conditions, which did not differ significantly from each other. With the longer preparation interval (1000 ms), the shortest RTs were again seen with the hand-cued condition (for all: $p < .001$). The RTs for the finger-cued and neither-cued conditions were longer than those for the null-cued condition, suggesting that these cues hampered performance (for either finger or neither-cued: $p < .001$). No differences in RTs were found between the finger-cued and neither-cued conditions ($p = 1.000$). A significant three-way interaction was found for Group $\times$ Preparation condition $\times$ Preparation interval ($F_{6,508} = 2.405$; $p = .027$; see figure 4^{b,c,d}). Within-group analyses revealed identical patterns of RTs in both control groups of children. In contrast, the RTs of children with ADHD differed from those of the children in the two control groups. With the 100 ms preparation interval, children with ADHD reacted as the control children did, with significantly faster RTs in the hand-cued condition than in the null-cued condition. However, this effect was no longer seen with the 1000 ms preparation interval in the children with ADHD, whereas it was in the control children. Thus, when faster and more automatic information processing was required (with the 100 ms preparation interval), children with ADHD were able to benefit from hand-cuing to a similar extent as pathological and healthy controls. In contrast, they were not able to benefit from hand-cuing when there was sufficient time (preparation interval 1000 ms) to allow for effortful processing of the information.

Speed variability

For the entire group, speed variability was significantly affected by the factors 'preparation condition' ($F_{3,253} = 12.077$; $p < .001$), 'preparation interval' ($F_{1,255} = 60.992$; $p < .001$), and their interaction ($F_{3,253} = 3.699$; $p = .012$). Post-hoc analyses indicated that the variability in speed was lowest in the hand-cued condition (mean = 403 ms [SD = 11.6]) and highest in the neither-cued condition (433 ms [10.8]), with the null-cued (413 ms [10.8]) condition and the finger-cued (420 ms [10.9]) condition being intermediate. However, the difference in speed variability was only significant for the hand-cued condition and the neither-cued condition ($p = .019$). Speed variability increased significantly with a longer preparation interval (all p -values $< .001$, increases ranged from 49.8 ms to 63.2 ms), but not in the null-cued condition ($p = .067$). With the short preparation interval (100 ms), the variability was lowest in the hand-cued condition (mean = 357 ms [SD =

Figure 4. Speed as a function of Preparation interval and Preparation condition over (a) children in general, (b) healthy controls, (c) pathological controls and (d) ADHD children.

[9.8]) and highest in the neither-cued condition (mean = 389 ms [9.8]) with the null-cued condition (mean = 373 ms [9.6]) and the finger-cued (mean = 365 ms [9.4]) condition being intermediate. However, only the difference between the hand-cued condition and the neither-cued condition was significant ($p = .011$). With the long preparation interval (1000 ms), no significant differences were

found between the preparation conditions ($\text{mean}_{\text{null-cued}} = 430 \text{ ms}$ [$\text{SD} = 12.6$]; $\text{mean}_{\text{hand-cued}} = 435 \text{ ms}$ [14.2]; $\text{mean}_{\text{finger-cued}} = 447 \text{ ms}$ [12.4]; $\text{mean}_{\text{neither-cued}} = 451 \text{ ms}$ [13.1]).

A significant main effect was found for groups ($F_{2,255} = 5.526$; $p = .004$). Children with ADHD ($\text{Speed variability}_{\text{ADHD}} = 476 \text{ ms}$ [23.9]) showed a greater variability in speed, calculated over all preparation intervals and preparation conditions, than the pathological controls (391 ms [9.4]; $p = .006$) and the healthy controls (385 ms [9.3]; $p = .003$). The pathological and healthy control groups did not differ from each other in terms of speed variability ($p = 1.000$). GLM analyses revealed no significant interaction terms involving the factor 'group'.

Accuracy

Accuracy was significantly affected by the factors 'preparation interval' ($F_{1,255} = 18.31$; $p < .001$), 'preparation condition' ($F_{3,253} = 66.22$; $p < .001$), and their interaction ($F_{3,253} = 16.54$; $p < .001$). Averaged over both preparation intervals, children made significantly ($p < .001$) fewer errors in the hand-cued (Mean = 2.9% [$\text{SD} = 0.3$]) and the null-cued conditions (2.8 [0.3]) than in the finger-cued (5.9 [0.5]) and the neither-cued (6.0 [0.5]) conditions. No significant differences were found between the null-cued and hand-cued conditions or between the finger-cued and neither-cued conditions. In addition, children made more errors with the longer preparation interval (3.9 [0.3] for 100 ms vs. 4.9 [0.4] for 1000 ms). With regard to the preparation condition, with a short preparation interval (100 ms), accuracy was highest in the hand-cued condition (mean = 2.8% [$\text{SD} = 0.3$]) and lowest in the finger-cued condition (5.0 [0.4]), with the null-cued (3.0 [0.3]) and neither-cued (4.9 [0.4]) condition being intermediate. Accuracy in the hand-cued and null-cued conditions both differed significantly from that in the finger-cued and neither-cued conditions (all p values $< .001$). With a long preparation interval (1000 ms), accuracy decreased significantly (all p values $< .006$) in the null-cued, finger-cued, and neither-cued conditions, but not in the hand-cued condition ($p = .140$). Accuracy was higher in the hand-cued (3.4 [0.3]) and null-cued (2.1 [0.3]) conditions ($p < .001$) than in the finger-cued (7.5 [0.4]) and neither-cued (7.1 [0.5]) conditions. Accuracy in the null-cued condition was also significantly better than in the hand-cued condition ($p = .002$). No differences in accuracy were found between the finger-cued and neither-cued conditions ($p = 1.000$).

'Group membership' (ADHD vs. pathological controls vs. controls) did not affect the proportion of errors made. Over all preparation conditions and intervals averaged, children in all three groups made 4.4% inaccurate responses.

Discussion

In the present study, children with ADHD were compared in a double controlled design with healthy and pathological controls in terms of their performance

(speed, speed variability and accuracy) on the FPT task and its relation to visuomotor preparation. Because there are no data on the FPT performance of children, we had to compare our data with data for adults. We found that only the hand-cued condition led to an improvement in performance (in speed and speed variability; however, no improvements were found for accuracy), averaged over both preparation intervals. Performance on bimanual two-choice response tasks (as for the finger-cued and neither-cued conditions) did not improve in comparison to that in the null-cued condition. In contrast, Adam et al. (1998) found that young and middle-aged adults benefited from preparation (in terms of speed) in all FPT cuing conditions (hand-, finger- and neither-cued), when the preparation interval was relatively long (500, 1000, and 2000 ms). These data suggest that 9-year-old children are not able to benefit from preparation when performing the more complex, bimanual tasks, unlike young and middle adults. Interestingly, as with children, elderly individuals (aged 70 - 73 years) also had difficulty preparing for these bimanual tasks (such as the finger- and neither-cued condition), with hand-cued preparation still being intact (Adam et al., 1998).

Adam et al. (1998) interpreted the effects of aging in terms of the involvement of different brain mechanisms in hand-cued preparation on the one hand and finger-cued or neither-cued preparation on the other. Evidence for this hypothesis comes from a fMRI study of adults performing the FPT task (Adam, Backes et al., 2003). A specific anatomic substrate is suggested to underlie visuomotor preparation (including the frontal lobes [middle frontal gyrus, premotor and supplementary motor cortex], parietal cortex [inferior and superior parietal lobule, intraparietal sulcus] and basal ganglia [caudate nucleus and putamen]), and Adam and colleagues found differences in brain activity when comparing the different cuing conditions. Compared with the finger- or neither-cued condition, the hand-cued task was associated with more activity in the basal ganglia and less activity in the parietal cortex. The authors explained this difference in activity in the basal ganglia in terms of the inhibitory capacity of this area of the brain. Thus it would appear easier to inhibit the (pre-) motor cortex of one hemisphere (as in the unimanual hand-cued condition) than to inhibit two irrelevant responses represented in two hemispheres (as in the bimanual, finger- and neither-cued conditions). The decrease in parietal cortex activity was explained in the context of spatial grouping and Gestalt principles. The visual cue for preparation of the fingers on one hand represents a neutral, strong perceptual subgroup that is established quickly and automatically. In contrast, the less natural and more complex cues for the finger-cued and neither-cued conditions involve the fingers of both hands (and hence both hemispheres) and require more complex processing to create a subgroup, which is reflected by the increased activity detected by fMRI. According to this view, the benefit derived from hand-cuing reflects – at least in part – the stronger spatial grouping of the two leftmost and two rightmost cue elements, thus requiring minimal information processing. Moreover, the appearance of a

left/right cue might evoke a more reflexive attention orienting response than the finger-cued or neither-cued conditions, which may automatically prime or activate the appropriate response. It is possible that consciously processed higher-order functions (such as, fine-tuned spatial discrimination/inhibition and controlled attention orienting) develop later and are more sensitive to aging than the more reflexive information processes, which may explain the similarity in performance between young children and elderly.

Furthermore, over all preparation conditions (including the null-cued condition), speed and speed variability increased and accuracy decreased as the preparation interval increased (from 100 ms to 1000 ms). This indicates that, in 9-year-olds, FPT performance is adversely affected when the interval during which children can anticipate on a future action becomes longer. With the short preparation interval, children seemed to react fairly automatically to cued stimuli, whereas with the longer preparation interval, children acted more “consciously” and had more time to bring “controlled” processing resources to bear on the cues. Support for this distinction between automatic and controlled processing comes from the results for the more complex finger-cued and neither-cued conditions. It would appear that the processing involved in these cued conditions is too difficult for 9-year-old children. Interestingly, when processing was automatic (100 ms condition interval), no differences in performance were found between the null-cued condition and the finger-cued and neither-cued conditions

FPT performance in ADHD

Preparation interval and preparation condition had a different effect on test performance in the children with ADHD on one hand and the children in the two control groups on the other. While children from the control groups were able to benefit from hand-cuing compared with null-cuing irrespective of the preparation interval, children with ADHD were able to benefit from hand-cuing only when processing was fast and rather automatic (i.e., with a preparation interval of 100 ms) and not when processing was more conscious (i.e., with a with preparation interval of 1000 ms). The results indicate that fast, automatic response preparation is not affected by ADHD, whereas attention-demanding or controlled response preparation is. These results suggest that children with ADHD have a problem with allocating attention and effort. There is increasing evidence that at least two independent neural circuits are engaged in attention-demanding preparation, namely, the posterior attention system and the anterior attention system (Brown, 1996; Posner & Petersen, 1990; Shallice, 1988). The main function of the posterior system is to direct, focus and manipulate attention on a specific location within visual space in the absence of eye movements (i.e., *selection-for-perception*), and involves mainly the parietal cortex and the superior colliculus of the brain. The anterior attention system is primarily related to the selection and preparation of one or several possible categories of motor action (i.e., *selection-*

for-action) and seems to involve mainly the frontal lobe structures, including the motor cortex. Several authors have hypothesized that ADHD is associated with a deficit in the anterior attention system and more specifically with control processes involved in motor responses, mainly in the presetting or preparation stage (McDonalds et al., 1999; Perchet et al., 2001; Swanson et al., 1991). Although our results suggest that there is a deficit in the controlled preparation of a motor action in ADHD, we cannot say whether the anterior or the posterior attention system is affected. This is because the successful processing of cuing information in the FPT is a function of both perceptual processes concerned with cue identification and a set of processing operations concerned with planning or programming of relevant motor output (Adam, Hommel, & Umiltà, 2003; Adam et al., 1998; Rosenbaum, 1980). Therefore, more research is needed to understand why children with ADHD tend to perform significantly less well than controls on tasks measuring controlled visuomotor preparation.

The children with ADHD showed a greater variability in speed over all preparation conditions and intervals than the children in the control groups. The pathological control group did not deviate from the healthy controls. These findings are in line with the results of earlier studies (Douglas, 1999). By including this control group, we were able to conclude that this increased variability in speed is specific for ADHD. Douglas (1999) stated that the high degree of variability in ADHD performance on many cognitive tasks seems to signify a pervasive manifestation of regulatory problems involving the inconsistent allocation of effort.

The FPT is an appropriate instrument to study visuomotor preparation because the preparation intervals and preparation conditions can be changed spatially and because the compatible nature of the cues reduces the complexity of the cue decoding processes, thereby allowing the use of relatively short preparation intervals. Short preparation intervals have the advantage of diminishing the possibility of involving other processes, such as working memory (an aspect of cognition often related to ADHD) or mental imagery, and the motor action (namely, pressing a key) is identical for all preparation conditions. Despite using this instrument, our study had a number of limitations. For example, we had no information about the level of impairment the children had. Moreover, the diagnostic classifications were assessed solely on the basis of the outcome of a semi-structured interview conducted with help of the caregiver(s) of the child. Cross-informant reports, such as teacher reports, were not included. Therefore, it is possible that the number of children with externalizing behavior was overestimated, although Barkley (1998) reported that there was 90% overlap between parent reports and teacher reports.

In conclusion, the present study showed a deficit in controlled visuomotor preparation, as operationalized by the FPT paradigm, in children suffering from ADHD compared with both healthy and pathological control subjects. These data contribute to knowledge about the specificity of cognitive deficits in ADHD.

References

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Adam, J. J., Backes, W., Rijcken, J., Hofman, P., Kuipers, H., & Jolles, J. (2003). Rapid visuomotor preparation in the human brain: A functional MRI study. *Cognitive Brain Research*, 16, 1-10.
- Adam, J. J., Hommel, B., & Umiltà, C. (2003). Preparing for perception and action (I): The role of grouping in the response-cuing paradigm. *Cognitive Psychology*, 46, 302-358.
- Adam, J. J., Paas, F. G. W. C., Teeken, J. C., Van Loon, E. M., Van Boxtel, M. P. J., Houx, P. J., & Jolles, J. (1998). Effects of age on performance in a finger-precuing task. *Journal of Experimental Psychology: Human Perception and Performance*, 24(3), 870-883.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3th ed.). Washington DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Benton, A. (1984). Constructional apraxia: An update. *Seminars in Neurology*, 4, 220-222.
- Bernstein, D. (1989). Language development: the school age years. In D. Bernstein & E. Tiegermen (Eds.), *Language and communication disorders in children*. Columbus, OH: Merrill/MacMillan.
- Biederman, J. (1998). Attention-deficit/hyperactivity disorder: A life-span perspective. *The Journal of Clinical Psychiatry*, 59(Suppl 7), 4-16.
- Borger, N., & Van der Meere, J. (2000). Motor control and state regulation in children with ADHD: A cardiac response study. *Biological Psychology*, 51, 247-267.
- Brown, T. L. (1996). Attentional selection and word processing in Stroop and word search tasks: The role of selection for action. *American Journal of Psychology*, 109, 265-286.
- De Bruyn, E. E. J., Van der Steene, G., Van Haasen, P. P., Coetsier, P., Pijl, Y. J., Spoelers-Claes, R., Poortinga, Y. H., Stinissen, J., & Lutje Spelberg, H. C. (1986). *Wechsler Intelligence Scale for Children - Revised (WISC-R)*. Lisse: Swets & Zeitlinger.
- Deiber, M. P., Ibañez, V., Sadato, N., & Hallett, M. (1996). Cerebral structures participating in motor preparation in humans: A positron emission tomography study. *Journal of Neurophysiology*, 75, 233-247.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functie-analyse*. Den Haag: SDU uitgeverij.
- Douglas, V. I. (1999). Cognitive control processes in Attention Deficit Hyperactivity Disorder. In H. C. Quay & A. E. Hogan (Eds.), *Handbook of disruptive behavior disorders*. (pp. 105-138). New York: Plenum Press.
- Eriksen, C. W. (1990). Attentional research of the visual field. In D. Brogan (Ed.), *Visual search*. (pp. 3-19). London: Taylor & Francis.

- Ezpeleta, L., De la Osa, N., Doménech, J. M., Navarro, J. B., Losilla, J. M., & Júdez, J. (1997). Diagnostic agreement between clinicians and the Diagnostic Interview for Children and Adolescents-DICA-R in an outpatient sample. *Journal of Child Psychology and Psychiatry*, 38(4), 431-440.
- Fodor, J. (1983). *The modularity of mind*. Cambridge, MA: MIT Press.
- Granero Pérez, R., Ezpeleta Ascaso, L., Doménech Massons, J. M., & De la Osa Chaparro, N. (1998). Characteristics of the subject and interview influencing the test-retest reliability of the Diagnostic Interview for Children and Adolescents-Revised. *Journal of Child Psychology and Psychiatry*, 39(7), 963-972.
- Hallet, M. (2000). Disorder of movement preparation in dystonia. *Brain*, 9, 1765-1766.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKa). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Koski, L., Paus, T., Hofle, N., & Petrides, M. (1999). Increased blood flow in the basal ganglia when using cues to direct attention. *Experimental Brain Research*, 129, 241-246.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Leth-Steensen, C., King Elbaz, Z., & Douglas, V. I. (2000). Mean response times, variability, and skew in the responding of ADHD children: a response time distributional approach. *Acta Psychologica*, 104, 167-190.
- Lezak, M. D. (1995). *Neuropsychological assessment* (3 ed.). Oxford: Oxford University Press.
- Luce, R. D. (1986). *Response times: Their role in inferring elementary mental organisation*. New York: Oxford University Press.
- McDonalds, S., Bennett, K. M. B., Chambers, H., & Castiello, U. (1999). Covert orienting and focussing of attention in children with attention deficit hyperactivity disorder. *Neuropsychologia*, 37, 345-356.
- Miller, J. (1982). Discrete versus continuous models of human information processing: In search of partial output. *Journal of Experimental Psychology: Human Perception and Performance*, 8, 273-296.
- Olivier, I., & Rival, C. (2002). Foreperiod duration and motor preparation during childhood. *Neuroscience Letters*, 319, 125-128.
- Perchet, C., Revol, O., Fourneret, P., Mauguière, F., & Garcia-Larrea, L. (2001). Attention shifts and anticipatory mechanisms in hyperactive children: An ERP study using the Posner paradigm. *Biological Psychiatry*, 50, 44-57.
- Posner, M. I. (1994). Attention: The mechanisms of consciousness. *Proceedings of the*

- National Academy of Sciences of the United States of America*, 91(16), 7398-7403.
- Posner, M. I., & Petersen, S. E. (1990). The attention system of the human brain. *Annual Review of Neuroscience*, 13, 25-42.
- Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, 71, 267-284.
- Rosenbaum, D. A. (1980). Human movement initiation: Specification of arm, direction, and extent. *Journal of Experimental Psychology: General*, 109, 444-474.
- Rosenbaum, D. A. (1983). The movement precuing technique: Assumptions, applications, and extensions. In R. A. Magill (Ed.), *Memory and control of action*. (pp. 231-274). Amsterdam: North-Holland.
- Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 84, 1-66.
- Shallice, T. (1988). *From neuropsychology to mental structure*. New York: Cambridge University Press.
- Shiffrin, R. M., & Schneider, W. (1977). Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review*, 84, 127-190.
- Swanson, J. M., Posner, M., Potkin, S., Bonforte, S., Youpa, D., Fiore, C., Cantwell, D., & Crinella, F. (1991). Activating tasks for the study of visual-spatial attention in ADHD children: A cognitive anatomic approach. *Journal of Child Neurology*, 1991(6), s119-s127.
- Van der Meere, J., & Sergeant, J. (1988). Acquisition of attention skill in pervasively hyperactive children. *Journal of Child Psychology and Psychiatry*, 29(3), 301-310.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Welner, Z., Reich, W., Herjanic, B., Jung, K. G., & Amado, H. (1987). Reliability, validity, and parent-child agreement studies of the diagnostic interview for children and adolescents (DICA). *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 649-653.

Executive functioning and behavioral problems (ADHD, CD/ODD) in school-aged children¹

Abstract

Although many theories have been proposed to explain ADHD symptomatology, one of the main theories is that prefrontal circuits are dysfunctional in children suffering from ADHD. Research results provide evidence of a deficit in some aspects of executive functioning in ADHD children. Unfortunately, these results are not always consistent within the ADHD sample, possibly reflecting sample differences within the ADHD spectrum or differences in the definition of ADHD used between studies. To further our insight into this topic, an extensive study described in this chapter was performed according to a design in which several confounders were taken into consideration, to test executive functioning in ADHD and the specificity of a possible deficit. Children classified with ADHD were compared to children with Conduct Disorder or Oppositional Defiant Disorder (CD/ODD), children with pathology other than ADHD, CD, or ODD (Pathological controls), and normal controls. Five tests were administered to test diverse aspects of executive functioning, that is, the Stroop test, a concept shifting task, verbal fluency tasks, and working memory tasks. To reduce the numerous executive functioning measures to their principal dimensions, a principal components factor analysis was conducted. Five factors were identified, accounting for 74.1% of the variance, namely, attention capacity, Stroop inhibition, simple motor performance, cognitive flexibility, and working memory. In contrast to our expectations, some aspects of executive functioning (e.g., inhibition, working memory, and simple motor performance) did not differentiate between groups (ADHD, CD/ODD, pathological controls, and normal controls). In contrast, aspects of executive functioning that did differentiate between groups were attention capacity and cognitive flexibility. However, significant interactions of sex by group membership were found for these last-mentioned functions. Post-hoc analyses indicated that attention deficits were more prevalent in girls with ADHD, whereas boys with ADHD tended to perform significantly worse on tasks measuring cognitive flexibility and concept shifting. Furthermore, the deficits found in ADHD on tasks measuring executive functioning were specific for ADHD and not for childhood psychopathology in general and were not influenced by general ability and reading skills.

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Introduction

Over the last years, the increase in interest from neuroscientists into the mechanisms underlying of Attention-Deficit/Hyperactivity Disorder has been encouraging (ADHD; e.g., Sagvolden & Sergeant, 1998; Sergeant, Geurts, & Oosterlaan, 2002; Swanson et al., 1998; Tannock, 1998). Although many explanatory theories have been proposed, one of the primary models in research is the hypothesis of a dysfunctioning of the frontal circuits in children suffering from ADHD (Grodzinsky & Diamond, 1992; Papa, Berger, Sagvolden, Sergeant, & Sadile, 1998; Papa, Sergeant, & Sadile, 1998). In addition, this hypothesis of an underlying brain dysfunctioning has been supported by functional MRI (fMRI) research and neuropsychological evidence reflecting a higher order neuropsychological dysfunctioning (Vaijda et al., 1998). The link between neuropsychological dysfunction and specified brain dysfunctions has led to the referral of ADHD as an executive functioning (EF) disorder (Barkley, 1997; Tannock, 1998). Although many definitions exist (Eslinger, 1996), the term “executive functioning” encompasses, according to Lezak (1995), those capacities that enable a person to engage successfully in independent, purposive, self-serving behavior. A number of these executive functions have been studied extensively in ADHD, with among them: inhibition, working memory, planning, and fluency (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Pennington & Ozonoff, 1996; Schachar, Mota, Logan, Tannock, & Klim, 2000; Seidman, Biederman, Monuteaux, Weber, & Faraone, 2000; Stevens, Quittner, Zuckerman, & Moore, 2002). Based on the results of these studies, it can be concluded that evidence exists which supports a relation between ADHD and deficits in particular executive functions (e.g., a deficit in the internalization of speech, motor disinhibition, and a deficit in working memory). Unfortunately, the results are not always consistent within the ADHD sample, possibly reflecting sample differences of these studies with regard to, for instance, the definitions of executive functioning used or the criteria used to diagnose ADHD. In addition, most research concerning executive functioning in ADHD included small sample sizes and relatively large age ranges (e.g., 6 - 12 years). Further research to ascertain an executive functioning deficit in ADHD is, therefore, still needed.

Based on the results and limitations of earlier conducted studies in this field, a number of methodological adjustments seem to be in order to increase the reliability and the specificity of an executive functioning deficit in ADHD. A first point worth mentioning in this context, is the observation that ADHD often co-occurs with other syndromes (such as Conduct Disorder or Oppositional Defiant Behavior) and disabilities (such as learning disorders) (reviewed by August & Garfinkel, 1990; Biederman, Newcorn, & Sprich, 1991; Dykman & Ackerman, 1991; Jensen, Martin, & Cantwell, 1997; Semrud-Clikeman et al., 1992). From the literature, it is known that these co-occurring syndromes or disabilities can affect the cognitive abilities of the child. For instance, in children with conduct

disorder disturbed higher-order cognitive functions have also been reported (Pennington & Ozonoff, 1996; Seidman et al., 1995). Therefore, cognitive deficits found in children with both ADHD and conduct disorder (CD) - such as inhibitory deficits - may be due to the presence of the co-occurring symptoms in the group and more than to ADHD. To rule out this possibility, future studies using only a two groups comparison (ADHD vs. controls) should control for the presence of co-morbid disorders (e.g., CD) in the ADHD group using statistical techniques. This point also applies to other two-group comparison studies. Therefore, multiple clinical group comparisons are necessary to measure the specificity of findings for the ADHD group. Secondly, executive functioning studies should be corrected for intermediating factors such as IQ and age. It is a stronger case when EF differences still exist after accounting for certain factors which influence neuropsychological functioning, such as IQ differences between groups. Thirdly, in case of executive functioning measurement alternative processes may account for performance on these tasks. For example, successful performance on an inhibition test, such as the Stroop Color Word test, is also dependent on attention functions. To control for these factors, it is of high relevance to report and combine all dependent outcome measures in research reports concerning executive functioning and ADHD. The here suggested methodological adjustments with regard to the study of executive functioning in ADHD are in line with observations of other scientists (e.g., Sergeant et al. [2002]).

In addition, the behavioral expression of ADHD is believed to change over time (American Psychiatric Association, 1994). However, because the period between the ages 5 and 7 years is believed to be critical for later cognitive (and more specifically language) development (Bernstein, 1989; Riva, Nichelli, & Devoti, 2000), cognitive development may be influenced most by the early expression of ADHD. Unfortunately, most research covering the relation between behavior and neuropsychological functioning has been performed according to a cross-sectional design, whereas longitudinal studies have provided limited coverage in this field (Nigg, Quamma, Greenberg, & Kusche, 1999). Prospective studies in which the influence of behavioral problems manifested earlier in life (for example at age 7) on cognitive performance (and more specifically executive functioning) later in life (for example at age 9) is measured are therefore quite rare. For this reason, we decided to relate child psychiatric data gathered when the child is approximately 6 - 7 years to later cognitive functioning at an age when the child has been to school for 2 - 3 years. In sum, the aim of the present study has been to include the above-mentioned methodological improvements in ADHD research within a prospective, longitudinal design. For this purpose, a design was been chosen in which several confounding factors were taken into consideration (such as comorbidity, reading skills and IQ) to test the influence of early ADHD on later executive functioning. Aspects of executive functioning that have been included in the study are: inhibition of automated reading skills, cognitive flexi-

bility, working memory, and verbal fluency.

Methods

Procedure

The present study is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)' and is embedded in a longitudinal design. The SAM study consists of 4 separate phases (for a detailed description of the study, see Kalff et al. [2001] and Kroes et al. [2001]). For the present chapter, only three stages are relevant and will be discussed here. Stage 1 (months 1 - 9): Selection of subjects. During this phase, all caregivers of children who visited the second grade of normal kindergarten were asked to give permission for participation in the SAM-study ($n = \pm 2300$). In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. Response rate was 57.5% ($n = 1317$). Parallel to inclusion, all children (both responders and non-responders) were examined as part of the routine health examination carried out by the school doctor. By law, school doctors are allowed to use medical information anonymously for epidemiological purposes. Therefore, it was possible to compare two random samples of 200 non-responders with 200 responders with regard to child characteristics (sex, age), family variables (parental occupation, nationality, family structure), and environmental variables (living area) collected from the medical status of the Youth Health Care. This comparison was necessary because of the relative large percentage of non-responders, however, no significant differences between the groups were found (for a full description, see Kroes et al. [2001]). Next, a subgroup of 452 children was defined on the basis of the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), and selected for further research (for an extended description of the selection criteria, see Kalff et al. [2001] and Kroes et al. [2001]). Stage 2 (months 15 - 25): Caregivers of 403 children of the originally selected group agreed to a semi-structured, psychiatric interview, using the Amsterdam Diagnostic Interview for Children and Adolescents (ADICA). With this instrument, several DSM classifications for childhood psychopathology, including ADHD, were questioned systematically. Finally, in stage 3 (months 39 - 49): Follow-up. All selected children were again asked to participate in the SAM-study. In total, 284 of the 403 children for whom we had ADIKA results in phase 2 agreed to participate in the follow-up (70.5%). Because of the relatively large dropout of participants in stage 3, responders and non-responders of stage 3 were tested for group differences in terms of sex, parental occupation, and ADIKA results (stage 2). Cramér's V testing revealed no significant differences between responders and non-responders on these variables (sex: value = .002, $p = .965$; parental occupation: value = .083, $p = .258$; ADIKA results: value = .109, $p =$

.091). Next, all children were tested neuropsychologically by means of an extended test protocol including several paper-and-pencil tasks such as the Stroop Color Word Test, Kaufman's ABC Number Recall and Word Order, and the Concept Shifting Task. Testing took place in a stimulus-free room at the child's school. Mean testing time was estimated at 1.5 hours. A neuropsychologist or one of three well-trained assistants administered the test battery. The examiner was blind to group membership of the children. Finally, based on the ADIKA results collected in stage 2 and the neuropsychological data from stage 3, four independent groups were formed: (A) children, who met during phase 2 all DSM-IV criteria for 'ADHD' (*ADHD group*), (B) children, who met in stage 2 the criteria for the DSM classification Conduct Disorder or Oppositional Defiant Disorder (*CD/ODD group*), (C) children, who met in stage 2 the DSM-criteria for psychopathology (other than ADHD, CD, or ODD; *pathological control group*), and (D) healthy controls (*normal controls*). Children with both ADHD and CD/ODD or any other psychopathology were submitted to group A; children with both CD/ODD and psychopathology other than ADHD were submitted to group B. An overview of the data collection for answering the research questions included in the present chapter was presented in figure 1.

Figure 1. A schematic representation of the data collection for the present study.

Measures

All of the measures described below were administered in the same order to all participants. Measures were selected to evaluate the major domains of executive functioning typically recognized in neuropsychology: working memory, inhibition, attention, and cognitive flexibility or set shifting. The tests included in the present protocol have frequently been used in a wide variety of studies (both with adults and children) and are modestly, but significantly, associated with frontal lobe dysfunctions and behavioral disturbances.

Inhibition: Stroop Color and Word Task. Inhibition of automated reading skills has often been measured by use of the Stroop test. This Stroop test (Stroop, 1935) consists of three cards each containing ten rows of items. The first card requires the subject to read words, referring to certain colors, such as red, yellow, green, and blue. This card is succeeded by a card, on which squares are printed in different colors (e.g., a red square) and the subject has to name the colors. Finally, a card is used containing words that refer to names of different colors but these words are now printed in a color other than what the word means. The participant is asked during the third card to name the color the word is printed in. The Stroop test is believed to measure several aspects of information processing, including attention, response interference and inhibition (MacLeod, 1991). As main outcome variables for the present study were chosen: the total time to finish each card (Card I, II, and III) and an inhibition score (that is $\Delta = \text{Stroop}_{\text{card3}} - [(\text{Stroop}_{\text{card1}} + \text{Stroop}_{\text{card2}}) / 2]$).

Cognitive flexibility: Concept Shifting Task. An example of a task aiming at measuring cognitive flexibility is the Concept Shifting task (Houx, Vreeling, & Jolles, 1991; Vink & Jolles, 1985). The Concept Shifting Task is derived from the Trial Making Test (Reitan & Wolfson, 1985). The Concept Shifting task consists of 5 cards. During the administration of card A & B, the child is asked to cancel out consecutively numbered circles on a worksheet (in card A) and subsequently cancel out the same number of consecutively lettered circles (card B). In card C, the child has to cancel out the same number of consecutively numbered and lettered circles on another worksheet by alternating between the two sequences (e.g., 1 - A, 2 - B). Finally, in card O₁ and O₂, the child has to cancel out, as fast as possible, the same number of empty circles, to measure speed. Concept shifting tasks are believed to measure several aspects of information processing, including attention, motor skills, cognitive flexibility, and visual conceptual and visuomotor tracking (Reitan & Wolfson, 1985). As main outcome variables were chosen for the present study: the total time to finish each card (Card A, B, C, O₁, and O₂) and cognitive flexibility score (that is $\Delta = \text{CST}_{\text{card C}} - [(\text{CST}_{\text{card B}} + \text{CST}_{\text{card C}}) / 2]$).

Working Memory. Working memory can be defined as the simultaneous storage and processing of verbal information (Baddeley, 1986, 1992). Examples of tasks measuring working memory are the Number Recall-test and the Word Order test (Kaufman & Kaufman, 1983; Melchers & Preuss, 1994). The Number Recall was presented to the child, in which a series of increasingly longer strings of digits is presented at a rate of one per second. The participants must repeat the digits in the same numerical sequence. The participants are given a block of three trials at each span length. The test is concluded when the participant fails to repeat the

trials within one block. Secondly, the Word Order was assessed, in which the child has to point to silhouettes of common objects in the same order as the objects named by the examiner. For both subtests, standard scores were calculated based on the total number of correct trials and corrected for age (mean score = 10; SD = 3; range: 1 - 19).

Verbal Fluency. Verbal fluency is usually defined as the number of words a participant can produce, usually within a restricted category (e.g., animals, or all word beginning with the letter M) and over a limited period of time (usually 60 seconds) (Lezak, 1995). Two types of verbal fluency tasks are frequently chosen, namely the semantic category fluency (SCF) and the initial letter fluency (ILF). SCF involves recitation of examples of a given category, whereas ILF involves the generation of words beginning with a given initial letter. Cognitive processes involved in fluency tasks are speed of information processing, vocabulary size, inhibition of irrelevant words, and set maintenance (Sergeant et al., 2002). In the present study, the NEPSY Verbal fluency test (Korkman, Kirk, & Kemp, 1998) was chosen as a measure of retrieval from semantic memory. This test includes two independent types of verbal fluency, namely, semantic category fluency (SCF) and initial letter fluency (ILF). SCF involves recitation of examples of a given category, whereas ILF involves the generation of words beginning with a given initial letter. The verbal fluency test consisted of (A) two trials of a SCF type task (e.g., to name as (1) many animals and (2) things you can eat or drink) and (B) two trials of an ILF type task (e.g., including the letters 'M' and 'S' [subtasks 3 & 4]). Consistent with standard instructions, participants were asked to generate over 60 seconds as many words as possible of the above-mentioned categories, excluding the names of humans and cities. For each subtask, total number of correct responses, incorrect responses, and preservations (e.g., repetitions of correct words) were recorded over 1 - 60 seconds. As main outcome variables, the total correct words generated on (i) the SCF-condition and (ii) the ILF-condition were included in the analyses.

The Amsterdam Diagnostic Interview for Children and Adolescents (ADICA; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997: This is the Dutch translation of the Diagnostic Interview for Children and Adolescent (DICA; Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). The ADIKA is a semi-structured psychiatric interview that yields scores for several child psychiatric syndromes according to DSM-III-R guidelines and was adapted by using the criteria of DSM-IV for diagnosing ADHD (American Psychiatric Association, 1987, 1994). In line with these criteria, children were classified as 'ADHD' if they showed a persistent pattern of inattention and/or hyperactivity-impulsivity that was more frequent and severe than that typically

observed in individuals of comparable development (American Psychiatric Association, 1994). Children were included in the ‘pathological control group’ if they fulfilled the criteria for at least one child psychiatric syndrome (with the exception of ADHD)². Although the Dutch version of the DICA-III-R interview has not been separately validated, DICA and DICA-III-R have been demonstrated to have high test-retest reliability and moderate correlations with clinician based diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Vocabulary. The vocabulary test is a subtest of the Wechsler Intelligence Scales (Dutch Version: De Bruyn et al., 1986) was used to provide an estimate of general ability (Lezak, 1995). The examiner asked the child to explain the meaning of certain words. The complexity of words increased with each item. Range of standard scores is 1 - 19 (mean score = 10, SD = 3). Reliability and validity are believed to be average to good (De Bruyn et al., 1986).

Klepel reading test. The Klepel reading test (Van den Bos, Lutje Spelberg, Scheepstra, & De Vries, 1994) provides a measure of the technical reading skills of a child. For 2 minutes, the child had to read as many words possible from a list of non-existing words. With each item the complexity of words increases. Standard scores range from 1-19 (mean score = 10, SD = 3). This task was included as a covariate because, for a number of subtasks included in the protocol (e.g., the Stroop task and the Concept Shifting task), the child is assumed to be a competent reader. In addition, a relation between the development of the ability to organize and retrieve words phonemically and spelling skills is assumed (Riva et al., 2000).

Level of Occupational Achievement of the caregiver (LOA). This variable was based on the full description of the parental occupation and was originally scored on a 7-point-scale, ranging from unskilled to scientific skilled labor (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded separately and entered in the low-level occupation category. When the LOA differed between mother and father or if data was missing for one caregiver, the highest available score was chosen.

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² Such as mood disorders (e.g., major depression, dysthemia, bipolar syndrome), anxiety disorders (e.g., separation anxiety, phobia, overanxious disorder, avoidant disorder), conduct disorders (e.g., oppositional disorder), disorders of elimination (e.g., functional encopresis and functional enuresis), obsessive compulsive disorder, post traumatic stress disorder, pervasive developmental disorders.

Statistical analyses

To reduce the numerous EF measures to their principle dimensions, a principal components factor analysis was conducted with the entire sample using SPSS (version 11.0). The predictors included in the study were defined in the method-section. Finally, all analyses were conducted by use of the statistical package SPSS 11.0 for windows. All tests were performed at a .05 significance level. As a first step, it was tried to make an estimation of the missing data on the continuous variables ($n = 9$) by use of the Expectation Maximization (EM) algorithm through SPSS Missing Value Analyses (MVA). Because a statistically reliable deviation from randomness was found by use of Little's MCAR test, $p < .001$, the cases with missing values on continuous predictors could not be imputed by use of the EM algorithm. Therefore, it was chosen to estimate these missing values by use of the regression algorithm as defined in SPSS MVA. By doing this, data on the continuous variables was present for 284 cases. However, of these 284, 11 cases were eventually deleted because of medication usage. In addition, analyses for skewness, kurtosis, and univariate and multivariate extremes³ were conducted for each group (ADHD, CD/ODD, pathological controls, healthy controls). Because the reaction times on all cards of the Stroop Color Word task and the Concept Shifting task were significantly skewed, it was decided to apply a logarithmic transformation on these data. Next, based on these data, two cases were eventually removed from the analyses because of extreme values. After estimation of missing data on the continuous predictors and deletion of cases with medication usage or extreme values, data from 271 children were still available for the analyses: 20 ADHD children, 40 children with CD/ODD, 82 pathological controls, and 129 healthy controls. Variables influential on research outcome were summarized in Table 1, including age (as measured at *stage 3*), gender, the level of occupational achievement of the caregiver (LOA), and an estimate of performance intelligence. No significant group differences were found in terms of age, klepel scores, and vocabulary scores. In contrast, significant group differences were found in terms of LOA-scores. The parents of children with ADHD had in average the lowest LOA scores; control children the highest.

Further analyses were conducted in two steps. First, to reduce the numerous EF measures to their principle dimensions, a principal components factor analysis was conducted with the entire sample using SPSS. A varimax rotation was specified and factor scores were generated by the software program based on the factor loadings of measures on each factor. Finally, because of assumed high correlating independent variables, it was decided to conduct separate GLM univariate analyses for each latent variable. Standard, all analyses were tested for their sensitivity for inter-individual differences caused by age, sex, and Klepel reading

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³ Extremes were defined as values on subtasks that deviated more than three standard deviations from the mean.

scores, by including these variables in the analyses as covariates. After this, the analyses were repeated but with adding the estimate of general ability (Vocabulary scores) and the level of occupational achievement of the caregiver (LOA) also as covariates in the analyses. The reason for preferring this two-step-way of measuring the effect of covariates on the outcome (instead of including all covariates in one step in the analyses) is two-fold. First, some authors claim that between 3% and 10% of the variance in IQ may be a function of symptoms in ADHD (hyperactive-impulsive behavior), and hypothesized therefore that when a difference between ADHD and control groups in IQ is found, it should probably not be statistically controlled out in the analyses as this may remove some of the variation in the measures under study that is due to ADHD itself (Barkley, 1998). Second, relatively few studies investigating cognitive impairment in children with ADHD have included some measure of socio-economic status (SES). Therefore, little is still known about the relation between SES and ADHD (Stevens et al., 2002).

Table 1. Group characteristics and diagnostic data of the sample (n = 271)

	ADHD n = 20		CD/ODD n = 40		Pathological n = 82		Controls n = 129		p-value ¹
Sex (boys : girls)	14 : 6		26 : 14		48 : 34		65 : 64		n.s.
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Age	9.2	0.3	9.3	0.4	9.2	0.4	9.1	0.4	n.s.
Klepel	8.8	3.6	10.8	3.0	10.6	2.7	10.8	2.6	n.s.
Vocabulary	9.0	2.6	8.7	2.5	8.8	2.6	8.8	2.9	n.s.
LOA score	3.0	1.7	3.5	1.9	3.9	2.1	4.5	1.9	p = .001

¹ Associations between ordinal and/or interval variables (group membership vs. age, Klepel reading scores, Vocabulary scores, and LOA) were calculated by use of Spearman's rho. In contrast, chi square-tests were used to measure the associations between nominal (sex) and ordinal variables (groups).

Results

The means and standard deviations of test scores by groups are shown in table 2. To reduce the numerous EF measures to their principle dimensions, a principal components factor analysis was conducted. The results are shown in table 3. Five factors emerged accounting for 74.1% of the variance. Factor I, labeled *attention capacity*, comprised the Cards I and II of the Stroop Color Word task, the Cards A, B, and C of the Concept shifting Task, and the fluency tasks. Factor II, labeled *Stroop inhibition*, composed of the reaction times on card II, card III, and the interference-score calculated based on the performance on the three cards of the Stroop Color Word Task. Factor III, *simple motor performance*, is composed on basis of the RTs on the Card O1 and O2 of the Concept Shifting Task. Factor IV,

cognitive flexibility, is based on the score on the CST Card C and the concept shifting score calculated on basis of the cards A, B, and C of the CST. Finally, factor IV, *working memory*, was composed of the scores on the Number Recall and the Word Order test.

Table 3. Principal components factor structure.

Variable	Factor I	Factor II	Factor III	Factor IV	Factor V
Stroop Color Word Test					
Card I	.570	.472	.153		-.134
Card II	.455	.710			-.103
Card III	.191	.956	.117	.101	
Interference score		.898	.115	.121	
Concept Shifting Task					
Card A	.637	.108	.282	.102	
Card B	.751	.106	.170	.221	
Card C	.446	.152	.142	.848	-.117
Concept shifting score		.123		.950	
Card O ₁	.247	.104	.866		
Card O ₂	.157	.155	.888		
Number Recall					
Standard Score					.879
Word Order					
Standard Score	-.179				.863
Verbal Fluency task					
Correct responses SCF	-.618	-.119	-.181	-.100	.116
Correct responses ILF	-.662				.147

Subsequently the GLM analyses of variances revealed the following results: For factor I (attention capacity), no main effect for group was found while controlling for sex, age, LOA, Klepel reading scores and Vocabulary scores ($F(3,259) = 0.473$; $p = .701$). However, a significant interaction of Group x Sex was found ($F(3,259) = 2.797$; $p = .041$). Post-hoc analyses revealed that girls with ADHD performed significant less compared to all other groups ($F(3,110) = 2.696$; $p = .049$) on a scale measuring attention capacity (ADHD vs. CD/ODD, $p = .010$; ADHD vs. pathological controls, $p = .007$; ADHD vs. healthy controls, $p = .009$). No group differences were found on factor I when including only the boys of the sample (see figure 1; $F(3,145) = 0.575$; $p = .632$). Results were essentially the same without including LOA and Vocabulary scores as covariates. For factor II (Stroop inhibition), no main effect for group was found while controlling for sex, age, LOA, Klepel reading scores and Vocabulary scores ($F(3,259) = 0.019$; $p = .996$). In addition, no interaction of group x sex was found ($F(3,259) = 2.251$; $p =$

.083). Results were essentially the same without including LOA and Vocabulary scores as covariates. For factor III (simple motor performance), no main effect for group ($F(3,259) = 1.422$; $p = .237$) or any interaction of sex $\times$ group ($F(3,259) = .023$; $p = .995$) was found while controlling for sex, age, LOA, Klepel reading scores and Vocabulary scores. Results were comparable without including LOA and Vocabulary scores as covariates. For factor IV (cognitive flexibility), no main effect for group ($F(3,259) = 0.906$; $p = .439$). However, a significant interaction of sex $\times$ group ($F(3,259) = 2.750$; $p = .043$; figure 2) was found while controlling for sex, age, LOA, Klepel reading scores and Vocabulary scores. Results were comparable without including LOA and Vocabulary scores as covariates. Although no significant group effect was found possibly due to a low power size ($F(3,145) = 1.817$; $p = .147$), pare-wise comparisons revealed that boys with ADHD tended to score less well than the healthy controls ($p = .047$) and the pathological controls ($p = .087$). No differences were found in terms of girls and scores on factor IV. For factor V (working memory), no main effect for group ($F(3,259) = 1.464$; $p = .225$) or any interaction of sex $\times$ group ($F(3,259) = .063$; $p = .979$) was found while controlling for sex, age, LOA, Klepel reading scores and Vocabulary scores. Results were comparable without including LOA and Vocabulary scores as covariates.

Figure 1: Interaction of group membership $\times$ sex on factor I (Attention Capacity).

Discussion

The main objective of the study presented in this chapter was to deepen our insights with regard to the reliability and the specificity of earlier hypothesized executive functioning deficits in ADHD. For this purpose, five tests were administered in the present study in order to measure diverse aspects of executive functioning. To reduce the numerous executive functioning measures to their principle dimensions, a principal components factor analysis was conducted. Five factors emerged after factor analysis, which accounted for 74.1% of the variance,

namely (I) attention capacity, (II) Stroop inhibition, (III) simple motor performance, (IV) cognitive flexibility, and (V) working memory. Based on the data presented in this chapter, a number of conclusions can be made. For one, it can be concluded that the performance of children with ADHD did not differ from the controls on the factors 'inhibition' and 'working memory'. More specifically, the results of the present study indicated, for instance, that inhibition of automated reading skills, as measured by the Stroop test, was not affected negatively by ADHD. This result is in line with studies of Gaultney, Kipp, Weinstein, & McNeill (1999) and Miller, Kavcic, & Leslie (1996), but contradictory to evidence stating that the Stroop test differentiates between children with ADHD and controls in terms of interference deficits (Barkley, Grodzinsky, & DuPaul, 1992; Carter, Krener, Chaderjian, Northcutt, & Wolfe, 1995; Grodzinsky & Diamond, 1992; Houghton et al., 1999; Lufi, Gohen, & Parish-Plass, 1990; MacLeod & Prior, 1996; Seidman, Biederman, Faraone, Weber, Mennin et al., 1997; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997; Seidman et al., 2000; Seidman et al., 1995). Also, the present study revealed no significant differences between groups on the factor 'working memory'. This finding was contrary to earlier conducted studies that found a significant decreased performance for children with ADHD on digit span tasks, while comparing their performance to that of healthy controls (e.g., Barkley, Murphy, & Kwasnik, 1996; Johnston, 1986; Loge, Station, & Beatty, 1990; Milich & Loney, 1979). Compared to other studies, relatively new in the present study is that the effects of comorbidity, intelligence, and learning (dys-) abilities on the performance on working memory tasks were taken into consideration here. Furthermore, in the present study working memory is a latent variable that is based on factor analyses including several measures of working memory, whereas in other studies working memory is often measured by one task only.

Next, in the study presented in the current chapter, significant interactions of sex by group membership were found for the factors 'attention capacity' and 'cognitive flexibility'. Post-hoc analyses indicated that measures of attention differentiate girls with ADHD from female control children. Girls with ADHD were significant slower on these tasks compared to both pathological controls and healthy controls. In contrast, no significant group differences were found for boys on the factor 'attention capacity'. However, boys with ADHD tended to perform less well than the male controls on tasks measuring abilities in concept shifting. These boys with ADHD tended to need more time to make a shift in action (e.g., to alternate between letters and numbers, such as in 1 - a - 2 - b). No differences were found between girls with ADHD and female control subjects in terms of concept shifting. Caution in interpreting this last mentioned result is however needed. Successful performance on the concept shifting tasks is not only dependent on cognitive flexibility but also on functions such as attention. As discussed earlier, girls with ADHD performed significant worse (or slower) on tasks meas-

uring attention. It may, therefore, be that this deficit in attention capacity influences the scores on the cognitive flexibility-measure. To examine this, more research is needed. In sum, the finding of an interaction between sex and group membership on certain tasks suggest that the expression of ADHD is different in boys than in girls. Interestingly, there is some recent evidence which is in line with this notion (Abikoff et al., 2002).

Figure 2: Interaction of group membership x sex on factor IV (Concept shifting).

Next, as mentioned earlier, ADHD co-occurs in a large percentage of cases with other syndromes or disorders, such as Conduct Disorder, anxiety, depression, but also learning disabilities. These co-occurring syndromes are often associated with particular cognitive deficits by themselves. It is relevant for neuroscientists to control for this co-occurrence for the specificity of the genotype will depend both on screening and comparison groups (Sergeant et al., 2002). Unfortunately, little research has been conducted in this field. Therefore, the importance of the present study lies, for one, in the inclusion of three control groups, namely children with conduct disorder or oppositional defiant disorder (CD/ODD), pathological control children, and healthy control children. Based on the pair-wise comparisons described in the present study, it can be concluded that the specified deficits found in ADHD on the tasks measuring executive functioning as included in the present article are specific for ADHD and not so much for childhood psychology in general. However, more research is needed in this area for instance by including more aspects of executive functioning (such as motor inhibition). Likewise, it is important to control for the co-occurrence of disorders or disabilities next to ADHD (e.g., learning disabilities and highly functioning autistic children), and, finally it may be important to include neuroimaging data in the studies. In addition, as mentioned in the introduction, executive functioning studies should be corrected for possible mediating factors such as IQ and age. It is clearly a stronger case when group differences in terms of executive functioning still exist

after accounting for variables such as IQ differences between groups. After correction of reading scores, an estimate of general abilities, and the occupation level of the caregiver of the child, the results presented in the current chapter did not significantly change. This leads to the conclusion, that the results found in the present study are independent of the general abilities and the reading skills of the child or its environment.

The present studies included some limitations. For instance, the DSM classifications were measured solely on basis of the outcome of a semi-structured interview with the caregivers of the child. Cross-informant reports, like Teacher Reports, were not included here. Therefore, it is possible that the number of children with externalizing behavior was overestimated. However, Barkley (1998) reported evidence of a 90% overlap between parent reports and teacher reports, indicating that the caregiver reports are a good approximation for the purposes in the present paper. Another point worth mentioning is that the exclusion and drop out of children in the analyses (37% of the selected sample) could limit the generalizability of the results to the population. In contrast, post-hoc analyses revealed no significant differences between dropouts and remainders. Therefore, one may conclude that the groups are comparable in their outcome, and that the inferences made in the earlier paragraphs are justified. Finally, the sample size of the ADHD group was relatively low, especially for analyzing the interaction of sex by group membership. Caution is, therefore, warranted in interpreting these results for this sample size may influence the power of the study.

References

- Abikoff, H. B., Jensen, P. S., Arnold, L. L. E., Hoza, B., Hechtman, L., Pollack, S., Martin, D., Alvir, J., March, J. S., Hinshaw, S., Vitiello, B., Newcorn, J., Greiner, A., Cantwell, D. P., Conners, C. K., Elliott, G., Greenhill, L. L., Kraemer, H., W.E., P. J., Severe, J. B., Swanson, J. M., Wells, K., & Wigal, T. (2002). Observed classroom behavior of children with ADHD: Relationship to gender and comorbidity. *Journal of Abnormal Child Psychology*, 30, 349-359.
- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3th ed.). Washington DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- August, G. J., & Garfinkel, B. D. (1990). Comorbidity of ADHD and reading disability among clinic-referred children. *Journal of Abnormal Child Psychology*, 18, 29-45.
- Baddeley, A. (1986). *Working memory*. Oxford: Clarendon.
- Baddeley, A. (1992). Working memory. *Science*, 255, 556-559.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive function: Constructing a unified theory of ADHD. *Psychological Bulletin*, 121, 65-94.

- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (ODD). *Journal of abnormal Child Psychology*, 29(6), 541-556.
- Barkley, R. A., Grodzinsky, G., & DuPaul, G. J. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. *Journal of Abnormal Child Psychology*, 20, 163-188.
- Barkley, R. A., Murphy, K. R., & Kwasnik, D. (1996). Psychological adjustment and adaptive impairments in young adults with ADHD. *Journal of Attention Disorders*, 1, 41-54.
- Bernstein, D. (1989). Language development: the school age years. In D. Bernstein & E. Tiegermen (Eds.), *Language and communication disorders in children*. Columbus, OH: Merrill/MacMillon.
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety and other disorders. *American Journal of Psychiatry*, 148, 564-577.
- Carter, C. S., Krener, P., Chaderjian, M., Northcutt, C., & Wolfe, V. (1995). Asymmetrical visual-spatial attentional performance in ADHD: Evidence for a right hemispheric deficit. *Biological Psychiatry*, 37, 788-797.
- De Bruyn, E. E. J., Van der Steene, G., Van Haasen, P. P., Coetsier, P., Pijl, Y. J., Spoelers-Claes, R., Poortinga, Y. H., Stinissen, J., & Lutje Spelberg, H. C. (1986). *Wechsler Intelligence Scale for Children - Revised (WISC-R)*. Lisse: Swets & Zeitlinger.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functie-analyse*. Den Haag: SDU uitgeverij.
- Dykman, R. A., & Ackerman, P. T. (1991). Attention deficit disorder and specific reading disability: Separate but often overlapping disorders. *Journal of Learning Disabilities*, 24, 95-103.
- Eslinger, P. J. (1996). Conceptualizing, describing, and measuring components of executive function. In G. R. Lyons & N. A. Krasnegor (Eds.), *Attention, memory, and executive function* (pp. 367-395). Baltimore, MD: Brooks.
- Ezpeleta, L., De la Osa, N., Doménech, J. M., Navarro, J. B., Losilla, J. M., & Júdez, J. (1997). Diagnostic agreement between clinicians and the Diagnostic Interview for Children and Adolescents-DICA-R-in an outpatient sample. *Journal of Child Psychology and Psychiatry*, 38(4), 431-440.
- Gaultney, J. F., Kipp, K., Weinstein, J. A., & McNeill, J. (1999). Inhibition and mental effort in Attention Deficit Hyperactivity Disorder. *Journal of Developmental Physical Disabilities*, 11, 105-114.
- Granero Pérez, R., Ezpeleta Ascaso, L., Doménech Massons, J. M., & De la Osa Chaparro, N. (1998). Characteristics of the subject and interview influencing the test-retest reliability of the Diagnostic Interview for Children and Adolescents-Revised. *Journal of Child Psychology and Psychiatry*, 39(7), 963-972.
- Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention deficit hyperactivity disorder. *Journal of Clinical Psychology*, 45, 427-446.

- Houghton, S., Douglas, G., West, J., Whiting, K., Wall, M., Langsford, S., Powell, L., & Carroll, A. (1999). Differential patterns of executive function in children with Attention-Deficit Hyperactivity Disorder according to gender and subtype. *Journal of Child Neurology*, 14, 801-805.
- Houx, P. J., Vreeling, F. W., & Jolles, J. (1991). Age-associated cognitive decline is related to biological life events. In K. Iqbal & D. R. C. McLachlin & B. Winblad & H. M. Wisniewski (Eds.), *Alzheimer's disease: Basic mechanisms, diagnosis and therapeutic strategies* (pp. 353-358). Chichester, UK: Wiley.
- Jensen, P. S., Martin, B. A., & Cantwell, D. P. (1997). Comorbidity in ADHD: Implications for research, practice, and DSM-IV. *Journal of the American Academy Child and Adolescent Psychiatry*, 36, 1065-1079.
- Johnston, C. W. (1986). The neuropsychological evaluation of Attention Deficit Disorder. *Psychiatric Annals*, 16, 47-51.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kaufman, A. S., & Kaufman, N. L. (1983). *Kaufman Assessment Battery for Children (K-ABC)*. Minnesota, USA: American Guidance Service, Inc.
- Korkman, M., Kirk, U., & Kemp, S. L. (1998). *NEPSY. A developmental neuropsychological assessment*. San Antonio, TX: The Psychological Corporation.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKI). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Lezak, M. D. (1995). *Neuropsychological assessment* (3 ed.). Oxford: Oxford University Press.
- Loge, D. V., Station, R. D., & Beatty, W. W. (1990). Performance of children with ADHD on tests sensitive to frontal lobe dysfunction. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29, 540-545.
- Lufi, D., Gohen, A., & Parish-Plass, J. (1990). Identifying Attention Deficit Hyperactive Disorder with the WISC-R and the Stroop Color and Word Test. *Psychology in the Schools*, 27, 28-34.
- MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, 109, 163-203.
- MacLeod, C. M., & Prior, M. (1996). Attention deficits in adolescents with ADHD and other clinical groups. *Child Neuropsychology*, 21, 1-10.
- Melchers, P., & Preuss, U. (1994). *Kaufman-Assessment battery for children-German edition (K-ABC)*. Lisse: Swets & Zeitlinger.
- Milich, R., & Loney, J. (1979). The factor composition of the WISC for hyperki-

- netic/MBD males. *Journal of Learning Disabilities*, 12, 67.
- Miller, D. C., Kavcic, V., & Leslie, J. E. (1996). ERP changes induced by methylphenidate in boys with Attention-Deficit Hyperactivity Disorder. *Journal of Attention Disorders*, 1996(1), 95-113.
- Nigg, J. T., Quamma, J. P., Greenberg, M. T., & Kusche, C. A. (1999). A two-year longitudinal study of neuropsychological and cognitive performance in relation to behavioral problems and competencies in elementary school children. *Journal of Abnormal Child Psychology*, 27(1), 51-63.
- Papa, M., Berger, D. F., Sagvolden, T., Sergeant, J. A., & Sadile, A. G. (1998). A quantitative cytochrome oxidase mapping study, cross-regional and neurobehavioural correlations in the anterior forebrain of an animal model of attention deficit hyperactivity disorder. *Behavioural Brain Research*, 94(197-212).
- Papa, M., Sergeant, J. A., & Sadile, A. G. (1998). Reduced transduction mechanisms in the anterior accumbal interface of an animal model of the attention-deficit hyperactivity disorder. *Behavioural Brain Research*, 94, 187-196.
- Pennington, B. E., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 37, 51-87.
- Reitan, R. M., & Wolfson, D. (1985). *The Halstead-Reitan neuropsychological testbattery*. Tucson, AZ: Neuropsychology Press.
- Riva, D., Nichelli, F., & Devoti, M. (2000). Developmental aspects of verbal fluency and confrontation naming in children. *Brain and Language*, 71, 267-284.
- Sagvolden, T., & Sergeant, J. A. (1998). Attention deficit/ hyperactivity disorder- from brain dysfunctions to behaviour. *Behavioural Brain Research*, 94, 1-10.
- Schachar, R., Mota, V. L., Logan, G. D., Tannock, R., & Klim, P. (2000). Confirmation of an inhibitory control deficit in attention-deficit/hyperactivity disorder. *Journal of abnormal Child Psychology*, 28, 277-236.
- Seidman, L. J., Benedict, K., Biederman, J., Bernstein, J., Seiverd, K., Milberger, S., Norman, D., Mick, E., & Faraone, S. (1995). Performance of ADHD children on the Rey-Osterrieth complex figure: A pilot neuropsychological study. *Journal of Child Psychology and Psychiatry*, 36, 1459-1473.
- Seidman, L. J., Biederman, J., Faraone, S. V., Weber, W., Mennin, D., & Jones, J. (1997). A pilot study of neuropsychological function in girls with ADHD. *Journal of the American Academy Child and Adolescent Psychiatry*, 36(3), 366-373.
- Seidman, L. J., Biederman, J., Faraone, S. v., Weber, W., & Ouelette, C. (1997). Toward defining a neuropsychology of Attention Deficit-Hyperactivity Disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical psychology*, 65(1), 150-160.
- Seidman, L. J., Biederman, J., Monuteaux, M. C., Weber, W., & Faraone, S. V. (2000). Neuropsychological functioning in nonreferred siblings of children with attention deficit/hyperactivity disorder. *Journal of Abnormal Psychology*, 109, 252-265.
- Seidman, L. L., Biederman, J., Faraone, S. V., Milberger, S., Norman, D., Seiverd, K., Benedict, K., Guite, J., Mick, E., & Kiely, K. (1995). Effects of family history and comorbidity on the neuropsychological performance of children with ADHD: Preliminary findings. *Journal of the American Academy Child and Adolescent*

- Psychiatry*, 34, 1015-1024.
- Semrud-Clikeman, M., Biederman, J., Sprich-Buckminster, S., Lehman, B. K., Faraone, S. V., & Norman, D. (1992). Comorbidity between ADDH and learning disability: A review and report in a clinically referred sample. *Journal of the American Academy Child and Adolescent Psychiatry*, 31, 439-448.
- Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive function for Attention-Deficit/Hyperactivity Disorder? *Behavioural Brain Research*, 130, 3-28.
- Sternberg, S. (1969). Discovery of processing stages: Extensions of Donders' method. In W. G. Koster (Ed.), *Attention and performance II* (pp. 276-315). Amsterdam: Elsevier.
- Stevens, J., Quittner, A. L., Zuckerman, J. B., & Moore, S. (2002). Behavioral inhibition, self-regulation of motivation, and working memory in children with Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, 21(2), 117-139.
- Stroop, J. R. (1935). Studies of inference in serial verbal reactions. *Journal of Experimental Psychology*, 18, 643-662.
- Swanson, J. M., Sergeant, J. A., Taylor, E., Sonuga-Barke, E. J. S., Jensen, P. S., & Cantwell, D. P. (1998). Attention-Deficit Hyperactivity Disorder and Hyperkinetic Disorder. *The Lancet*, 351, 429-433.
- Tannock, R. (1998). Attention Deficit Hyperactivity Disorder: Advances in cognitive, neurobiological and genetic research. *Journal of Child Psychology and Psychiatry*, 39, 65-99.
- Vaijdyia, C. J., Austin, G., Kirkorian, G., Ridlehuber, H. W., Desmond, J. E., Glover, G. H., & Ganrieli, J. D. E. (1998). Selective effects of methylphenidate in attention deficit hyperactivity disorder: A functional magnetic resonance study. *Proceedings of the National Academy of Sciences of the United States of America*, 95, 14994-14999.
- Van den Bos, K. P., Lutje Spelberg, H. C., Scheepstra, A. J. M., & De Vries, J. R. (1994). *De Klepel*. Lisse: Swets & Zeitlinger.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Vink, M., & Jolles, J. (1985). A new version of the Trial Making Test as an information processing task. *Journal of Clinical Neuropsychology*, 7, 162.
- Welner, Z., Reich, W., Herjanic, B., Jung, K. G., & Amado, H. (1987). Reliability, validity, and parent-child agreement studies of the diagnostic interview for children and adolescents (DICA). *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 649-653.

Table 2. Executive functioning of actual test results by group: Means and standard deviations.

Variable	ADHD		CD/ODD		Pathological Controls		Normal Controls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stroop Color Word Test								
Card I (in seconds)	75.65	31.38	61.58	10.42	62.23	11.31	61.71	9.38
Card II (in seconds)	103.60	34.94	91.30	16.06	93.00	17.38	91.45	17.79
Card III (in seconds)	184.50	61.68	166.95	39.08	170.62	34.33	168.80	38.29
Interference score	94.87	53.42	90.51	30.84	93.01	27.36	92.22	30.30
Concept Shifting Task								
Card A (in seconds)	32.30	10.44	29.68	8.34	30.76	9.88	28.38	7.19
Card B (in seconds)	45.65	21.71	38.77	13.98	39.14	12.38	38.25	16.55
Card C (in seconds)	62.75	22.41	55.65	19.92	54.15	15.63	51.74	18.19
Card O ₁ (in seconds)	9.95	2.54	8.40	1.99	9.02	1.98	8.81	2.07
Card O ₂ (in seconds)	8.65	2.46	7.45	1.49	7.90	1.77	7.72	1.63
Concept shifting score	23.77	20.73	21.42	16.72	19.21	12.46	18.42	13.95
Number Recall								
Standard Score	8.55	3.30	10.33	2.89	9.63	2.39	10.36	2.62
Word Order								
Standard Score	7.85	3.36	9.08	3.32	8.95	2.85	9.55	3.20
Verbal Fluency task								
Correct responses SCF	28.05	9.20	28.07	6.98	28.63	7.03	29.52	7.00
Correct responses ILF	11.2	6.35	13.85	4.78	14.60	5.77	14.62	5.40

Information processing in ADHD children with or without Learning Disabilities¹

Abstract

Although the additive value of neuropsychological tests for diagnosing ADHD is increasingly acknowledged, more research into the cognitive functioning of these children is still needed. Therefore, the first objective of the study presented in this chapter was to test the value of cognitive tests in differentiating ADHD children from control children. The second objective was related to comorbidity in ADHD. From the literature it is known that ADHD often co-occurs with other disabilities (such as learning disabilities) and that these co-occurring disabilities by themselves can affect the cognitive abilities of a child. Distinguishing between the neuropsychological performance of children with ADHD and learning disabilities (LD) on the one hand and children with ADHD without LD on the other is therefore crucial. By studying this distinction, it can be concluded with more certainty whether a certain cognitive profile is specific for ADHD. Therefore, the second aim of the study presented in this chapter was to study the specificity of a certain profile of cognitive functioning for ADHD. To fulfill these aims, three groups were included in the analyses, namely (i) a group of children with ADHD (aged 8.9 ± 1.9 years), (ii) a group of children with ADHD and co-occurring learning disabilities in either mathematics or reading (ADHD/LD; aged 9.3 ± 1.5 years), and (iii) a group of control children (aged 9.1 ± 1.8 years). As a main outcome variable, information processing as measured by the Kaufman Achievement Battery of Children (K-ABC) was chosen. Results indicated that children with ADHD (with or without Learning Disabilities) performed significantly worse on the Mental Processing scale of the K-ABC (as a measure of general abilities) than the controls. Additional analyses revealed that, while controlling for sex, age, and type of school the child attended, the groups did not differ in performance on tasks measuring perceptual abilities, reasoning, and visual-constructive abilities. In contrast, children with ADHD and with ADHD/LD scored significantly less well than the controls on tests measuring (verbal) working memory and temporal processing skills. With respect to the second objective of the study, no significant differences were found between children with ADHD and children with ADHD/LD. Based on this last result, it can be concluded with more certainty that the cognitive deficits in working memory and temporal processing skills seen in children with ADHD are caused primarily by ADHD and

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¹ P.P.M. Hurks, J.G.M. Hendriksen, F.J.M. Feron, J. Jolles, J.S.H. Vles

that learning disabilities have only a minor role.

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) is a syndrome characterized by inattention, increased restlessness, and/or impulsivity (American Psychiatric Association, 1994). Prevalence rates estimate that 2 - 5% of the childhood population is affected by the syndrome (Barkley, 1998; Kroes et al., 2001). The consequences for the child and its environment are believed to be high, as the symptoms of ADHD affect the cognitive, social, and academic functioning of the child. Although researchers have sought long for objective measures, that can be individually administered to determine the presence of ADHD, the success is still limited (Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). Therefore, a continuing need for objective measures of, for instance, inattention and impulsive behavior is still warranted.

In recent years, neuroimaging studies have shown abnormalities in brain structure and brain function in children with ADHD when compared to healthy controls. For instance, several neuro-imaging techniques have found evidence for an involvement of the frontal cortical regions and other interconnected subcortical structures, such as the cerebellum, corpus callosum, and globus pallidus (Baumgardner et al., 1996; Castellanos et al., 1994; Castellanos et al., 1996; Filippek et al., 1997; Hynd et al., 1993; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopoulos, 1990; Hynd et al., 1991; Sagvolden & Sergeant, 1998).

The hypothesis of an underlying brain dysfunctioning has also been supported by neuropsychological evidence reflecting a higher order neuropsychological dysfunctioning in ADHD (Vaijdya et al., 1998). As a group, children suffering from ADHD tend to exhibit sub-average or relatively weak performance on various neuropsychological tests measuring both input-and output-related information processes. For example, deficiencies have been found in terms of sustained attention or vigilance as observed by an increased variability in test performance and a decreased accuracy (Barkley, 1998). In addition, children with ADHD were marked by a lesser performance on several aspects of executive functioning (such as organization and complex problem solving), non-verbal working memory, internalization of speech, self-monitoring and self-regulation (Barkley, 1998; Perugini et al., 2000). Based on these findings, it can be concluded that cognitive-neuropsychology can contribute to improve the process of diagnosing and measuring the strengths and weaknesses of children suffering from ADHD. However, the presently available results concerning the weaknesses in the cognitive profile of children suffering from ADHD are not always straightforward in their outcome and information processing models and/or theories underlying the choice of including neuropsychological tests in experimental designs are often lacking. Therefore, although the additive value of (cognitive) neuropsychological tests for diagnosing ADHD is increasingly acknowledged within both the scien-

tific and the clinical setting, more research into the cognitive profile of these children is still needed. Therefore, the first aim of the study presented in this chapter is to further test the value of cognitive tests in differentiating ADHD children from control children.

Another point is that ADHD often co-occurs with other syndromes (such as Conduct Disorder or Oppositional Defiant Behavior) and disabilities (such as Learning Disorders) (reviewed by (August & Garfinkel, 1990; Biederman, Newcorn, & Sprich, 1991; Dykman & Ackerman, 1991; Jensen, Martin, & Cantwell, 1997; Semrud-Clikeman et al., 1992). From the literature, it is known that these co-occurring syndromes or disabilities can affect the cognitive abilities of the child. For instance, studies have reported that children with learning disabilities (LD) scored less well on tests measuring higher-order cognitive functions than healthy control subjects (Pennington & Ozonoff, 1996; Seidman et al., 1995). Therefore, in children with both ADHD and learning disabilities, cognitive deficits, such as inhibitory deficits, may be due to the presence of the co-occurring symptoms in the group and not so much due to ADHD. Distinguishing between the neuropsychological performance of children with ADHD and learning disabilities (LD) on the one hand and children with ADHD without LD on the other is therefore crucial. By studying this distinction, it can be concluded with more certainty whether a found cognitive profile is specific for ADHD or that the results are -at least also- attributable to the co-occurring disorder, such as learning disabilities. Unfortunately, a disadvantage of the existing studies relating ADHD to general capacity or cognitive processes is often the lack in control for co-occurring disorders (for instance learning disabilities), thereby, the second aim of the study presented in this chapter was to study the specificity of a specific profile of cognitive functioning for ADHD.

In sum, a continuing need for objective measures of ADHD-related behavior (such as attention capacity and impulsive behavior) still exists. Within this perspective, the input- and output-related information processes in ADHD and the specificity of this profile of information processes for ADHD will be studied more thoroughly in the present study. More specifically, children aged 6 - 12,5 years and suffering from ADHD (with or without a co-morbid learning disabilities [LD]) have been compared to healthy controls on their performance on an array of standardized cognitive tests measuring information processing.

In this perspective, the mental processing scale of the Kaufman ABC (K-ABC) has been chosen as a measure of input- and output-related aspects of information processing. The K-ABC is based on empirical neuro- and cognitive psychology and measures the ability to solve unfamiliar problems in a differentiated way (Kaufman & Kaufman, 1983; Melchers & Preuss, 1992a, 1992b). From this perspective, the scale is believed to measure the 'fluid' ability of being adaptable and flexible when faced with unfamiliar problems. Accordingly, this Mental Processing scale includes tasks such as model matching, Gestalt Closure, and

sequential and spatial memory, which do not require fluency and verbal understanding (Cahan & Noyman, 2001). In addition, two types of information processing can be tested by the K-ABC, namely sequential processing and simultaneous processing. Sequential processing refers to solving problems in which the emphasis is on the serial or temporal order of the stimuli (Kaufman & Kaufman, 1983) and to measure the child's ability to tackle and solve problems in turn and with logical consistency (Von Gontard et al., 2002). Simultaneous processing is defined as 'using a gestalt-like or holistic approach to integrate many stimuli to solve problems' (Kaufman & Kaufman, 1983). Finally, some readers will hypothesize about how the results gathered by use of the K-ABC should be viewed in light of the more familiar test batteries are used to measure childhood intelligence (e.g., the Wechsler test batteries). In previous studies, the K-ABC was compared to the, more familiar, Wechsler test batteries in a population of healthy children and children with learning disabilities. According to the original test instructions, the WISC-R focuses on the content of intelligence (i.e., verbal IQ and performal IQ), whereas the K-ABC is primarily directed at mental processes involved in problem-solving activities (i.e., sequential and simultaneous operations; (Gabel, Oster, & Butnik, 1986)). However, correlation studies showed that the WISC-R scales and the K-ABC scales tap approximately the same constructs (Heath & Obrzut, 1988; Meesters, Van Gastel, Ghys, & Merckelbach, 1998; Melchers & Preuss, 1991). Therefore, similar results are assumed while conducting the Wechsler test batteries instead of the K-ABC.

In sum, the aim of the present study was to investigate the input- and output-related information processes in 6- to 12.5-year-old children with ADHD and to test the specificity of the profile of cognitive functions found in ADHD children.

Procedure

Two clinical groups - group I consisting of children diagnosed with ADHD and group II consisting of children with ADHD and co-occurring learning disabilities in either mathematics or reading (ADHD/LD) - were compared with a group of healthy control children.

From 1999 till 2002, all subjects from the clinical ADHD groups were referred to the multidisciplinary ADHD-team of Maastricht (The Netherlands) for diagnostic purposes. Based on the recommendations of (Goldman, Genel, Bezman, & Slanetz, 1998), the assessment protocol for diagnosing ADHD (with or without a learning disability) included an interview with the caregiver of the child, a screening of the cognitive functions of the child, a physical health examination, and a neurological examination. On basis of the data collected by use of this protocol, the diagnosis 'ADHD' or 'ADHD/LD' could eventually be given to the children. In addition, learning disabilities included all deficits in scholar functioning, as in reading and mathematics and were diagnosed by use of information provided by the caregiver and the teacher of the child and neuropsychological

data. Furthermore, all subjects of the ADHD groups had a Dutch nationality and were visiting elementary schools. They had no physical handicaps, normal intellectual capacities, and were not using any type of medication at any stage of the experiment. Children with attention deficits who also revealed deficits in the domains of motor functioning and perception (Gillberg, 1987; Gillberg & Rasmussen, 1982) or children known with specified medical disorder and/or psychiatric syndromes (such as epilepsy, brain traumata, post-operative dysfunctioning, and autism) were excluded from either the ADHD or the ADHD/LD group.

In addition, a group of control children was randomly sampled within the area of Maastricht. None of the children in the control group met the criteria for the ADHD or ADHD/LD groups. In addition, the control subjects had a Dutch nationality and were visiting elementary schools. They had normal intellectual capacities, no physical handicaps, and were not using any type of medication at any stage of the experiment.

For all three groups held that, after inclusion, a standard neurocognitive test battery was administered to each child in an isolated testing room. A neuropsychologist or two research assistants carried out the testing procedure, which took approximately 1.5 hours for each child individually. Additionally, the caregivers and teachers of the children completed the Dutch translation of Achenbach's behavior checklists (both the caregiver's and teacher's version) to test for behavioral differences between groups.

Measurements

Cognitive measures

In the present experiment, the German version of the *Kaufman Assessment Battery for Children* (K-ABC; (Kaufman & Kaufman, 1983; Melchers & Preuss, 1994)) was included to test information processing in children. This battery is designed for testing children aged 2;06 years to 12;06 years, and includes eight subtests for children older than 6 years. A brief description of the eight subscales for children older than 6 years is provided in table 1. For each subtest, standard scores were calculated based on the total number of correct trials while correcting for age (mean score = 10; SD = 3; range: 1 - 19).

Based on these eight subscales, two other scales can be derived, namely the *sequential processing scale* and the *simultaneous processing scale*. Sequential processing refers to solving problems in which the emphasis is on the serial or temporal order of the stimuli (Kaufman & Kaufman, 1983) and to measure the child's ability to tackle and solve problems in turn and with logical consistency (Von Gontard et al., 2002). Simultaneous processing is defined as 'using a gestalt-like or holistic approach to integrate many stimuli to solve problems' (Kaufman & Kaufman, 1983). For both types of information processing, standard scores on these main scales were calculated based on the scores of predefined

subtests, while correcting for age (mean score = 100, SD = 15, range: 40 - 160). The ‘simultaneous information processing’ scale has been derived from the performance on the subtasks ‘Gestalt Closure, Triangles, Matrix Analogies, Spatial Memory, and Photo Series’. Based on scores on the subscales ‘Hand Movements, Number Recall, and Word Order’ the main scale ‘sequential information processing’ was calculated.

Table 1. Short description of eight subtests of the Kaufman ABC (K-ABC).

Name Subtest	Description of subtest
<i>Sequential information processing:</i>	
1. Hand Movement:	A visual-kinesthetic span task, in which the child must reproduce the exact sequence of taps on the table with the fist, the palm, or the side of the hand as demonstrated by the examiner.
2. Number Recall:	A digit span task, in which series of increasingly longer strings of digits is presented at a rate of one per second. The participants must repeat the digits in the same numerical sequence.
3. Word Order:	A cross-modal span task, in which the child has to point to silhouettes of common objects in the same order as the objects named by the examiner.
<i>Simultaneous information processing:</i>	
4. Gestalt Closure:	A perceptual task, in which the child is asked to name or describe a drawing that is only partially completed.
5. Triangles:	A visual-constructive task, in which a picture shown to the child has to be assembled by several identical, two-colors (blue on one side and yellow on the other) rubber triangles.
6. Matrix Analogies:	A reasoning task. The child must select from an array of pictures or designs that bests completes a 2 x 2 visual analogy.
7. Spatial Memory:	A visual span task. The child must recall the location of pictures arranged randomly on a page.
8. Photo Series:	A temporal ordering task, in which a child must arrange a series of photographs in proper time sequence.

Finally, based on the raw scores of the sequential and simultaneous processing scales, a score on a *mental processing scale* was derived. This last scale is believed to be a measure of intelligence, in the sense of the ability to solve unfamiliar

iar problems (Kaufman & Kaufman, 1983). Again, for this scale holds that standard scores were calculated based on the scores of predefined subtests, while correcting for age (mean score = 100; SD = 15, range: 40 - 160).

Behavioral measures

Two adaptations of Achenbach's behavioral checklist were included in the test protocol, as a control measure for actual attention problems within the groups, namely the *Child Behavior Checklist (CBCL*; caregiver version) and the *Teacher Report Form (TRF*; teacher version). Originally, these checklists were developed by (Achenbach & Edelbrock, 1983) and revised and translated into Dutch by (Verhulst, Koot, & Van der Ende, 1996). A total problem-scale, two broadband scales (that is, *externalizing* and *internalizing behavior problems*) and subsequently nine narrowband scales (that is, *withdrawal*, *physical complaints*, *anxiety/depression*, *social problems*, *thought problems*, *attention problems*, *delinquent behavior*, *aggressive behavior*, and *sexual problems*) were derived for each checklist² with the help of a pre-set algorithm. Based on norms correcting for sex and age, T-scores (mean = 50; SD = 10) for all scales were calculated. In literature, children, who score high on the attention problem scale, have been associated with a putative risk for the development of ADHD (Chen, Faraone, Biederman, & Tsuang, 1994). Therefore, in the current study, only the attention problems scales of either questionnaire were included. The T-scores on the attention problem scales of the TRF and CBCL were summarized and divided by two.

Results

As a first step, an estimation of the missing data on the continuous variables was made by use of the Expectation Maximization (EM) algorithm through SPSS Missing Value Analyses (MVA). Because no statistically reliable deviation from randomness was found by use of Little's MCAR test, $p < .405$, the cases with missing values on continuous variables were imputed by use of the EM algorithm as defined in SPSS MVA. By doing this, data on the continuous variables were present for 66 cases. Next, analyses for skewness, kurtosis, and univariate and multivariate extremes were conducted for each group (ADHD, ADHD/LD, healthy controls).

After the above-mentioned analyses (missing value, extremes etcetera), data of 66 children were available for the analyses: 28 ADHD children, 20 children with co-occurring ADHD and learning disabilities, and 18 healthy controls. In table 1, the characteristics of all groups were summarized and tested for significant group differences. In sum, no significant group differences were found in terms of age and sex, although there were three times more boys than girls in the ADHD

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² With the exception of the 'sexual problems' subscale. For this scale was only included in the parents version of the questionnaire.

groups, whereas the control group consisted of 1.25 more boys than girls. Furthermore, a significant large percentage of children with ADHD (with and without learning disabilities) attended special schools, whereas all of the control children were attending normal elementary schools. Based on these found group differences, it was decided to include the variables sex, type of school (normal vs. special schools), and age in the following analyses.

Finally, the groups were objectively tested for group differences in terms of attention functioning as measured with the above-mentioned behavioral checklists. As could be expected, a 3 x 2 x 2 Group (ADHD, ADHD/LD, controls) x Sex (boys vs. girls) x Type of school (normal vs. special schools) General Linear Model (GLM) Univariate analysis for unequal sample sizes within an experimental design revealed that, according to the caregiver/teacher, children with ADHD (with or without learning disabilities) showed more attention problems than the healthy controls ($F(2,55) = 19.82$, $p < .001$; after Bonferroni correction ADHD vs. controls: $p < .001$; ADHD/LD vs. controls: $p < .001$; ADHD vs. ADHD/LD: $p = 1.000$). Also, a trend was found for attention to be related to the type of school the child is visiting ($F(1,55) = 3.64$, $p = .062$). Children who visited special schools (mean t-score = 74.51; SD = 2.66) tended to have higher t-scores on the attention scales than the children who visited normal schools (mean t-score = 66.74; SD = 1.19). No significant main effect for sex was found ($F(1,55) = 0.80$; $p = .376$) and no interactions were found for Group x Sex ($F(2,55) = 1.57$; $p = .217$), Group x Type of school ($F(1,55) = 0.05$; $p = .828$), Sex x Type of school ($F(1,55) = 0.34$; $p = .561$), and Group x Sex x Type of school ($F(1,55) = 0.06$; $p = .810$). The Levene's test of equality of error variances was non-significant ($p = .228$), stating that the variances between groups were equal.

Table 1. Characteristics of groups.

	ADHD (n = 28)		ADHD/LD (n = 20)		Controls (n = 18)		p-value ¹
Sex (boys : girls)	21 : 7		15 : 5		10 : 8		p = .310
Type of school (normal : special education)	21 : 7		13 : 7		18 : 0		p = .025
	Mean	SD	Mean	SD	Mean	SD	
Age in years	8.9	1.9	9.3	1.5	9.1	1.8	p = .743
Attention Problems	71.3	8.0	72.9	8.8	58.6	6.9	p < .001

Note¹: Association between ordinal and/or interval variables (group membership vs. age) were calculated by use of Spearman's rho. The association between Attention problems and group membership was measured by use of a GLM Univariate test. Finally, chi square-tests were used to measure the associations between nominal (sex, type of school) and ordinal variables (groups).

Information processing: Sequential vs. simultaneous

Test scores on the Kaufman scales, sequential processing and simultaneous processing, and the mental processing scale are summarized as a function of group membership in table 2. Possible group differences on these main scales were tested in two steps. First, group differences on the mental processing scale were tested by use of a 3 x 2 x 2 Group x Sex x Type of school GLM univariate analysis for unequal sample sizes within an experimental design. In this analysis, age was entered as a covariate in the model. The results revealed a main effect for group on the mental processing scale ($F(2,55) = 11.17$; $p < .001$). After Bonferroni correction, it was found more specifically that children with ADHD (either with or without learning disabilities) performed significantly less well than the control children (ADHD vs. control children: $p < .001$; ADHD/LD vs. controls: $p = .001$; ADHD vs. ADHD/LD: $p = 1.000$). In addition, a main effect for school type was found on this scale ($F(1,55) = 9.04$, $p = .004$). Children who visited special schools (mean standard score = 82.7; $SD = 3.33$) scored lower on the mental processing scale than the children who visited normal schools (mean standard score = 96.68; $SD = 1.49$). No significant main effect for sex was found ($F(1,55) = 2.44$; $p = .124$) and no interaction was found for Group x Sex ($F(2,55) = 0.97$; $p = .385$), Group x Type of school ($F(1,55) = 0.04$; $p = .839$), Sex x Type of school ($F(1,55) = 0.06$; $p = .802$), and Group x Sex x Type of school ($F(2,55) = 2.10$; $p = .153$).

Secondly, sequential (SEQ) and simultaneous (SIM) information processes were analyzed. By use of Pearson's correlation, the correlation between the two main scales was estimated at 0.54 ($p < .001$). Because of this moderate correlation, two separate 3 x 2 x 2 Group x Sex x School type GLM univariate tests for unequal sample sizes within an experimental design were conducted to test for group differences among each of these main scales, with age included as covariates and post-hoc corrections of the Bonferroni-type. In sum, univariate analyses revealed significant group differences for either type of information processing (SEQ: $F(2,55) = 9.46$, $p < .001$; SIM: $F(2,49) = 7.26$, $p = .002$). After Bonferroni correction it was found, that children with ADHD (with or without learning disabilities) performed significant less on the sequential information processing scale compared to the controls (ADHD vs. controls: $p < .001$; ADHD/LD vs. controls: $p = .006$; ADHD vs. ADHD/LD: $p = .841$). In addition, on the simultaneous information processing scale comparable results were found (ADHD vs. controls: $p = .001$; ADHD/LD vs. controls: $p = .004$; ADHD vs. ADHD/LD: $p = 1.000$). Furthermore, a main effect for school type was found on both types of information processing (SEQ: $F(1,55) = 3.31$, $p = .074$; SIM: ($F(1,55) = 9.14$, $p = .004$). Children who visited special schools scored lower on either type of information processing than the children who visited normal schools (SEQ: average standard scores are for normal school children 90.27 ($SD = 1.90$) and for special school children 78.34 (4.22), SIM: average standard scores are for normal school chil-

dren 101.27 (1.79) and for children visiting special schools 84.79 [4.00]). Finally, on the sequential processing scale, a main effect for sex was found ($F(1,55) = 5.29$; $p = .025$). Boys tended to score higher on this scale of information processing than girls ($\text{mean}_{\text{boys}} = 89.8$, $SD = 2.0$; $\text{mean}_{\text{girls}} = 81.2$, $SD = 3.56$). No significant main effect for sex was found on the simultaneous processing scale and no interactions were found for either type of information processing.

Table 2. Groups differences in the level of information processing.

	ADHD n = 28		ADHD/LD n = 20		Controls n = 18		Contrast ¹
	Mean	SD	Mean	SD	Mean	SD	
Mental processing	90.6	11.9	93.3	9.1	104.0	9.7	1,2 < 3
SEQ	84.7	14.7	87.3	12.6	100.2	9.5	1,2 < 3
SIM	94.7	13.7	97.4	10.5	107.2	12.4	1,2 < 3

Note¹: 1: = ADHD children; 2: = ADHD/LD children; 3: = control children

Performance on specific aspects of information processing

Test scores on the Kaufman main scales as a function of group membership (ADHD vs. ADHD/LD vs. Controls) were graphically represented in figure 1. By use of Pearson's correlation, the correlations between the eight subscales of the K-ABC were estimated and displayed in table 3, ranging from 0.04 ~ 0.66.

Table 3. Inter-correlations among dependent variables

	HM	NR	WO	GC	T	MA	SM	P
HM	-							
NR	.360**	-						
WO	.469**	.664**	-					
GC	.097	.335**	.199	-				
T	.502**	.233	.281*	.229	-			
MA	.227	.238	.301*	.146	.315*	-		
SM	.630**	.252*	.361**	.117	.534**	.535**	-	
P	.380**	.166	.275*	.042	.325**	.501**	.425**	-

Note: * : $p < .05$ (two-tailed), **: $p < .01$ (two-tailed), HM: = Hand Movements, NR: = Number Recall, WO: = Word Order; GC: = Gestalt Closure; T: Triangles; MA: = Matrix Analogies; SM: = Spatial Memory; P: = Photo Series.

Because of these moderate correlations, 3 x 2 x 2 Group membership x Sex x Type of school GLM univariate analyses for unequal sample sizes within an experimental design were conducted to test for group differences among each of the eight subscales, with age included as a covariate and post-hoc corrections of the Bonferroni-type. The results revealed five subtests to discriminate between groups (Hand Movements: $F(2,55) = 6.49$, $p = .003$; Number Recall: $F(2,55) =$

3.92, $p = .026$; Word Order: $F(2,55) = 4.433$, $p = .016$; Spatial Memory: $F(2,55) = 4.90$, $p = .011$; Photo Series: $F(2,55) = 9.04$, $p < .001$). After a Bonferroni correction, post-hoc analyses revealed that children with ADHD (with and without LD) scored significantly lower on four out of five tests compared to controls (Hand Movements: ADHD vs. controls: $p < .001$; ADHD/LD vs. controls: $p = .042$; ADHD vs. ADHD/LD: $p = .488$; Word Order: ADHD vs. controls: $p = .003$; ADHD/LD vs. controls: $p = .022$; ADHD vs. ADHD/LD: $p = 1.000$; Spatial Memory: ADHD vs. controls: $p = .001$; ADHD/LD vs. controls: $p = .004$; ADHD vs. ADHD/LD: $p = 1.000$; Photo Series: ADHD vs. controls: $p = .001$; ADHD/LD vs. controls: $p = .042$; ADHD vs. ADHD/LD: $p = 1.000$). Children with only ADHD (without LD) performed significantly less than controls on the Number Recall test (ADHD vs. controls: $p = .004$; ADHD/LD vs. controls: $p = .107$; ADHD vs. ADHD/LD: $p = 1.000$). In contrast, none of the other tests were found statistically discriminating between groups (Gestalt Closure: $F(2,55) = 0.63$, $p = .535$; Triangles: $F(2,55) = 1.59$, $p = .212$; Matrix Analogies: $F(2,55) = 0.93$, $p = .338$).

With regard to the type of school the child is visiting, significant main effects have been found on almost all cognitive tasks (Hand Movements: $F(1,55) = 5.08$, $p = .028$; Number Recall: $F(1,55) = 3.33$, $p = .073$; Word Order: $F(1,55) = 6.37$, $p = .015$; Gestalt Closure: $F(1,55) = 1.83$, $p = .181$; Triangles: $F(1,55) = 10.49$, $p = .002$; Matrix Analogies: $F(1,55) = 10.00$, $p = .003$; Spatial Memory: $F(1,55) = 8.00$, $p = .007$; Photo Series: $F(1,55) = 3.28$, $p = .075$). A general trend was found for children who visited special schools to score lower on input- and output-related aspects of information processing than the children who visited normal schools.

Finally, no significant main effects for sex (except for the number recall task ($F(1,55) = 5.24$, $p = .026$), on which boys scored significant better than girls) and no interactions were found on input- and output-related aspects of information processing.

Discussion

The study discussed in chapter 8 revealed differences in the cognitive profiles of children with ADHD, children with ADHD and co-occurring learning disabilities in reading or mathematics (ADHD/LD), and controls children. Based on the data collected here several conclusions can be made. First, it was found that children with ADHD (with or without a learning disability) performed significantly less well on the mental processing scale than the controls, while controlling for age, sex, and the type of school the child was visiting. No significant differences were found between the ADHD group and the combined ADHD/LD group. These results are partly in line with other studies investigating the general abilities of these children. For instance, studies relating IQ to ADHD have revealed that children with ADHD were likely to be behind in their intellectual development

compared to healthy controls or even the siblings of the ADHD children (Barkley, DuPaul, & McMurray, 1990; Faraone, Biederman, Krifcher Lehman et al., 1993; Faraone, Biederman, Lehman et al., 1993; Fischer, Barkley, Edelbrock, & Smallish, 1990; McGee, Williams, Moffitt, & Anderson, 1989; Prior, Leonard, & Wood, 1983). However, based on the data presented in this chapter, the link between a decreased IQ and ADHD can be made with more certainty, because of the inclusion of both a group of children with ADHD and learning disabilities and a group of children with ADHD but without learning disabilities.

Figure 1. Test scores on the Kaufman Achievement Test for Children (K-ABC) over all groups. *Note.* HM: = Hand Movements; NR: = Number Recall; WO: = Word Order; GC: = Gestalt Closure; T: Triangles; MA: = Matrix Analogies; SM: = Spatial Memory; P: = Photo Series; *: = $p < .05$; **: = $p < .01$.

In addition, testing of the subtasks of the K-ABC, of which this mental processing scale is composed, revealed that not all subtasks of the K-ABC differentiated significantly between groups. For instance, no significant group effects were found in school-aged children on a task measuring perceptual abilities (Gestalt Closure), which is in line with earlier conducted studies in this area, e.g., Kalff et al. (2002) found no group differences in preschool-aged children on this cognitive function. In the present study, also, no significant differences between ADHD children and controls were found in terms of reasoning (Matrix Analogies) or visual-constructive abilities (Triangles).

In contrast to these non-significant findings on the subtasks of the K-ABC, the children with ADHD (with or without LD) tended to achieve less well on the K-ABC subtasks 'Hand Movements', 'Number Recall', and 'Word Order'. These found differences may be explained in terms of a deficit in verbal working memory (defined as "the simultaneous storage and processing of verbal information" (Baddeley, 1992)). In addition, significant group differences were found on

the subtask 'Spatial Memory'. Children with ADHD (with or without LD) performed significantly less well than the control group on this task. Again, it is assumed that these differences can be explained in terms of a deficient verbal working memory in ADHD. The component of working memory seems evident here, for the child has to process visual information actively in its mind. However, it is also presumed that, during this task, children also made greater use of verbal strategies to recall the positions of the pictures. The stimuli for this subtest involve pictures that may be easily labeled with verbal words (e.g., a doll or a fish), and therefore may be conducive to such verbal mediation (Conant et al., 1999). However, it should be kept in mind that the verbal orientation on this Spatial Memory task is believed to be dependent on a universal, developmentally timed cerebral change in functional asymmetry. At a younger age (e.g., 5 years), this subtask tended to load higher on visual spatial/gestalt ability. Children learn with time to remember the pictures with verbal support instead of remembering the sequence only visually (Conant et al., 1999). Thereby concluding that at an age similar to that of the participants included in the present study, Spatial Memory is more a measure of verbal working memory next to visual working memory.

Finally, significant group differences were found on the subtask 'Photo Series'. Again, children with ADHD (with or without LD) scored lower on this task than the control. No differences were found between children with ADHD/LD and children with ADHD. Several earlier-conducted studies have found the K-ABC Photo Series subtask to load high on a factor 'verbal sequential and working memory abilities', after conducting a principle factor analysis over all subtests of the K-ABC. The sequential nature of this task and/or its relation to working memory seem evident for the child has to order a number of pictures so that the story is complete on the one hand and the child has to keep actively in mind the mental representations of events on the other (Kaplan, Dewey, Crawford, & Fisher, 1998). In addition, several authors have speculated that verbal analysis is necessary for a successful ordering of the stories (Conant et al., 1999; Giordani, Boivin, Opel, Nseyila, & Lauer, 1996; Kaufman, Kaufman, Kamphaus, & Naglieri, 1984; Wechsler, 1991). Clinical observations of children with an inefficient internalization of speech (who still talk out loud) confirm this hypothesis of a needed verbal support for successful performance on the Photo Series task. However, the significant group differences found on the Photo Series subtask may well be explained by factors other than a deficit in verbally oriented working memory. A function that may well be involved in (successful) performance on this subtask is time perception and/or temporal processing. As mentioned in the method-section, the Photo Series subtask is a temporal ordering task, in which a child must arrange a series of photographs in proper time sequence. In this context, the results of the study presented in this chapter claim that temporal processing skills (such as temporal ordering, time estimation time, reproduction, and

time discrimination) may play a significant role in the deficits observed in ADHD. This idea of a deficit in temporal processing skills has been hypothesized before and linked to the impulsive behavior often seen in children suffering from ADHD (Barkley, 1997; Barkley, Koplowitz, Anderson, & McMurray, 1997; Douglas & Parry, 1983; Gorestein & Newman, 1980; Rubia, Taylor, Taylor, & Sergeant, 1999; Rubia et al., 2001; Smith, Taylor, Rogers, Newman, & Rubia, 2002; Sonuga-Barke, Saxton, & Hall, 1998; Sonuga-Barke, Taylor, Sembi, & Smith, 1992; Stevens, Stover, & Backus, 1970). In this perspective, impulsive behavior is defined as a behavioral style which belongs to an earlier phase in cognitive development, during which responses are made early, inaccurately, and without consideration of future consequences (Smith et al., 2002). Examples of impulsive behavior, in which temporal processing skills are believed to play a significant role, are the found problems with waiting, delaying responses, motor output control, and impulsive executive cognitive styles.

The data presented in the current chapter carry two additions to the present literature. First, as mentioned earlier, relatively few researchers have addressed the aspect of comorbidity in ADHD research. From literature it is known that ADHD often co-occurs with other disabilities (such as learning disabilities) and that these co-occurring disabilities by themselves can affect the cognitive abilities of the child. Distinguishing between the neuropsychological performance of children with ADHD and learning disabilities (LD) on the one hand and children with ADHD without LD on the other is therefore crucial. By studying this distinction, it can be concluded with more certainty whether a found cognitive profile is specific for ADHD or that the results are attributable to the co-occurring disorder, such as learning disabilities. Because no significant differences were found in the present study between children with ADHD and children with ADHD/LD, it can be concluded with more certainty that the found cognitive deficits in for instance working memory and temporal processing skills are caused primarily by ADHD and not so much by learning disabilities.

Secondly, as shown in the present study, a relatively high percentage of children with ADHD is visiting special schools. Unfortunately, many of the tasks measuring input- and output-related information processes included in other research protocols require a certain level of academic achievement, whereas the intention of measuring specified processes (e.g., working memory) is to isolate and evaluate that process, rather than skills or knowledge in academic areas (e.g., math, reading) (Stevens, Quittner, Zuckerman, & Moore, 2002). In our study, the group differences in terms of academic achievement are controlled for two-fold. First, the tests included in the protocol are less dependent on skills acquired in specific academic domains, such as reading. In addition, in the present study, type of school the child was visiting was controlled for. Therefore, it can be said with more certainty that the found group differences are explained by the factor 'ADHD' and not so much an assumed difference in schooling. Compared to the

existing literature, these data are additive.

The research design presented in this chapter includes limitations. For instance, the sample sizes of the included clinical and control groups were relatively low, thereby possibly decreasing the power of the analyses. However, when comparing the standard scores of the control group with the standard scores of the group screened by (Kaufman & Kaufman, 1983; Melchers & Preuss, 1994), it was found that performance of the control children in the present study were highly comparable to the norm data. Also, as in all of the studies relating IQ to ADHD, it is most often unclear whether the differences in total functioning found in scores represent real deficits in, for instance, working memory or that it represents differences in test-taking behavior (that is, children with ADHD may perform more poorly due to their inattentive-impulsive response style). For instance, several authors have found subtests of a memory scale to be sensitive to attention/concentration (Aylward, Gioia, Verhulst, & Bell, 1995; Burton, Donders, & Mittenberg, 1996; Dewey, Kaplan, & Crawford, 1997). Caution in interpreting these results is therefore necessary. For the clinical setting, in which the 'testing-the-limits'-principle holds, it is necessary to measure the relative strengths and weaknesses in the cognitive profile but also the level of impulsivity of the child. Qualitative observations are in this perspective equally relevant as quantitative data.

For clinical purposes, we find five subtests suitable for discriminating ADHD and control subjects, namely the Number Recall, Word Order, Hand Movements, Spatial Memory, and Photo Series. In line of reasoning on working memory and temporal processing skills, the lower scores of ADHD can be explained theoretically. Still, more research in the area of information processes in children with ADHD is necessary and the Kaufman ABC has proven to be a useful instrument to test weaknesses and strengths within a cognitive profile.

References:

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- August, G. J., & Garfinkel, B. D. (1990). Comorbidity of ADHD and reading disability among clinic-referred children. *Journal of Abnormal Child Psychology*, 18, 29-45.
- Aylward, G. P., Gioia, S. J., Verhulst, S. J., & Bell, S. (1995). Factor structure of the Wide Range Assessment of Memory and Learning in clinical populations. *Journal of Psychoeducational Assessment*, 13, 132-142.
- Baddeley, A. (1992). Working memory. *Science*, 255, 556-559.
- Barkley, R. A. (1997). Attention-deficit/hyperactivity disorder, self-regulation, and time: Toward a more comprehensive theory. *Journal of Developmental and Behav-*

- Journal Pediatrics*, 18, 271-279.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). A comprehensive evaluation of attention deficit disorder with and without hyperactivity. *Journal of Consulting and Clinical Psychology*, 58, 775-789.
- Barkley, R. A., Koplowitz, S., Anderson, T., & McMurray, M. B. (1997). Sense of time in children with ADHD: Effects of duration, distraction, and stimulant medication. *Journal of International Neuropsychological Society*, 3, 359-369.
- Baumgardner, T. L., Singer, H. S., Denckla, M. B., Rubin, M. A., Abrams, M. T., Colli, M. J., & Reiss, A. L. (1996). Corpus callosum morphology in children with Tourette syndrome and attention deficit hyperactivity disorder. *Neurology*, 4, 477-482.
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety and other disorders. *American Journal of Psychiatry*, 148, 564-577.
- Burton, D. B., Donders, J., & Mittenberg, W. (1996). A structural equation analysis of the Wide Range Assessment of Memory and Learning in the standardization sample. *Child Neuropsychology*, 2, 39-47.
- Cahan, S., & Noyman, A. (2001). The Kaufman ability battery for children mental processing scale: A valid measure of "pure" intelligence. *Educational and Psychological Measurement*, 61(5), 827-840.
- Castellanos, F. X., Giedd, J. N., Eckburg, P., Marsh, W. L., Vaituzis, A. C., Kaysen, D., Hamburger, S. D., & Rapoport, J. L. (1994). Quantitative morphology of the caudate nucleus in Attention Deficit Hyperactivity Disorder. *American Journal of Psychiatry*, 151, 1791-1796.
- Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D., Vaituzis, A. C., Dickstein, D. P., Sarfatti, S. E., Vauss, Y. C., Snell, J. W., Lange, N., Kaysen, D., Krain, A. L., Ritchie, G. F., Rajapakse, J. C., & Rapoport, J. L. (1996). Quantitative brain Magnetic Resonance Imaging in Attention-Deficit Hyperactivity Disorder. *Archives of General Psychiatry*, 53, 607-616.
- Chen, W. J., Faraone, S. V., Biederman, J., & Tsuang, M. T. (1994). Diagnostic accuracy of the Child Behavior Checklist scales for Attention-Deficit Hyperactivity Disorder: A receiver-operating characteristic analysis. *Journal of Consulting and Clinical Psychology*, 62, 1017-1025.
- Conant, L. L., Fastenau, P. S., Giordani, B., Boivin, M. J., Opel, B., & Dia Nseyila, D. (1999). Modality specificity of memory span tasks among Zairian children: A developmental perspective. *Journal of Clinical and Experimental Neuropsychology*, 21(3), 375-384.
- Dewey, D., Kaplan, B. J., & Crawford, S. (1997). Factor structure of the WRAML in children with ADDH or reading disabilities: Further evidence of an attention/concentration factor. *Developmental Neuropsychology*, 13, 501-506.
- Douglas, V. I., & Parry, P. A. (1983). Effects of reward on delayed reaction time task performance of hyperactive children. *Journal of Abnormal Child Psychology*, 11, 313-326.
- Dykman, R. A., & Ackerman, P. T. (1991). Attention deficit disorder and specific read-

- ing disability: Separate but often overlapping disorders. *Journal of Learning Disabilities*, 24, 95-103.
- Faraone, S. V., Biederman, J., Krifcher Lehman, B., Spencer, T., Norman, D., Siedman, L., Kraus, I., Perrin, J., Chen, W., & Tsuang, M. T. (1993). Intellectual performance and school failure in children with attention deficit hyperactivity disorder and in their siblings. *Journal of Abnormal Psychology*, 102(616-623).
- Faraone, S. V., Biederman, J., Lehman, B., Keenan, K., Norman, D., Seidman, L. J., Kolodny, R., Kraus, I., Perrin, J., & Chen, W. (1993). Evidence for independent familial transmission of attention deficit hyperactivity disorder and learning disabilities: Results from a family genetic study. *American Journal of Psychiatry*, 150, 891-895.
- Filipek, P. A., Semrud-Clikeman, M., Steingard, R. J., Renshaw, P. F., Kennedy, D. N., & Biederman, J. (1997). Volumetric MRI analysis comparing subjects having attention-deficit hyperactivity disorder with controls. *Neurology*, 48, 589-601.
- Fischer, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: II. Academic, attentional, and neuropsychological status. *Journal of Consulting and Clinical Psychology*, 58, 580-588.
- Gabel, S., Oster, G. D., & Butnik, S. M. (1986). *Understanding psychological testing in children: A guide for health professionals*. New York: John Wiley & Sons.
- Gillberg, I. C. (1987). *Deficits in attention, motor control, and perception: Follow-up from pre-school to early teens*. University of Uppsala.
- Gillberg, I. C., & Rasmussen, P. (1982). Perceptual, motor, and attentional deficits in seven-year-old children: Background factors. *Developmental Medicine and Child Neurology*, 24, 752-770.
- Giordani, B., Boivin, M. J., Opel, B., Nseyila, D. D., & Lauer, R. E. (1996). Use of the K-ABC with children in Zaïre, Africa: An evaluation of the sequential-simultaneous processing distinction within an intercultural context. *International Journal of Disability, Development and Education*, 43(1), 5-24.
- Goldman, L. S., Genel, M., Bezman, R. J., & Slanetz, P. J. (1998). Diagnosis and treatment of attention-deficit/hyperactivity disorder in children and adolescents. *JAMA*, 279(14), 1100-1107.
- Gorestein, E. E., & Newman, J. P. (1980). Disinhibitory psychopathology: A new perspective and a model for research. *Psychological Review*, 87, 301-315.
- Heath, C. P., & Obrzut, J. E. (1988). An investigation of the K-ABC, WISC-R, and W-JPB, part two, with learning disabled children. *Psychology in the Schools*, 25, 358-364.
- Hynd, G. W., Hern, K. L., Novey, E. S., Eliopoulos, D., Marshall, R., Gonzalez, J. J., & Voeller, K. K. (1993). Attention Deficit-Hyperactivity Disorder and asymmetry of the caudate nucleus. *Journal of Child Neurology*, 8(339-347).
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., & Eliopoulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder with hyperactivity. *Archives of Neurology*, 919-926.
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., Eliopoulos, D., & Lyytinen, H. (1991). Corpus callosum morphology in Attention Deficit-Hyperactivity Disorder: Morphometric analysis of MRI. *Journal of Learning Disabilities*, 24,

141-146.

- Jensen, P. S., Martin, B. A., & Cantwell, D. P. (1997). Comorbidity in ADHD: Implications for research, practice, and DSM-IV. *Journal of the American Academy Child and Adolescent Psychiatry*, 36, 1065-1079.
- Kalff, A. C., Hendriksen, J. G. M., Kroes, M., Vles, J. S. H., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., & Jolles, J. (2002). Neurocognitive performance of 5- and 6-year-old children who met criteria for Attention Deficit/Hyperactivity Disorder at 18 months follow-up: Results from a prospective population study. *Journal of Abnormal Child Psychology*, 30(6), 589-598.
- Kaplan, B. J., Dewey, S. G., Crawford, S. G., & Fisher, G. C. (1998). Deficits in long-term memory are not characteristic of ADHD. *Journal of Clinical and Experimental Neuropsychology*, 20 (4), 518-528.
- Kaufman, A. S., & Kaufman, N. L. (1983). *Kaufman Assessment Battery for Children (K-ABC)*. Minnesota, USA: American Guidance Service, Inc.
- Kaufman, A. S., Kaufman, N. L., Kamphaus, R. W., & Naglieri, J. A. (1984). Sequential and simultaneous factors at ages 3-12 1/2: Developmental changes in neuropsychological dimensions. *Clinical Neuropsychology*, 4, 74-81.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- McGee, R., Williams, S., Moffitt, T., & Anderson, J. (1989). A comparison of 13-year old boys with attention deficit and/or learning disorder on neuropsychological measures. *Journal of Abnormal Child Psychology*, 17, 37-53.
- Meesters, C., Van Gastel, N., Ghys, A., & Merckelbach, H. (1998). Factor analyses of WISC-R and K-ABC in a Dutch sample of children referred for Learning Disabilities. *Journal of Clinical Psychology*, 54(8), 1053-1061.
- Melchers, P., & Preuss, U. (1991). *K-ABC Interpretationshandbuch*. Amsterdam: Swets and Zeitlinger.
- Melchers, P., & Preuss, U. (1992a). Bearbeitung der Kaufmann Assessment Battery for Children (K-ABC) für den deutschsprachigen Raum. Teil 1: Vorstellung des verfahrens. *Zeitschrift für Kinder und Jugendpsychiatrie*, 20(2), 85-93.
- Melchers, P., & Preuss, U. (1992b). Bearbeitung der Kaufmann Assessment Battery for Children (K-ABC) für den deutschsprachigen Raum. Teil 2: Anwendungsbe- reich und gutekriterien. *Zeitschrift für Kinder und Jugendpsychiatrie*, 20(4), 223-231.
- Melchers, P., & Preuss, U. (1994). *Kaufman-Assessment battery for children-German edition (K-ABC)*. Lisse: Swets & Zeitlinger.
- Pennington, B. E., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 37, 51-87.
- Perugini, E. M., Harvey, E. A., Lovejoy, D. W., Sandstrom, K., & Webb, A. H. (2000). The predictive power of combined neuropsychological measures for Attention-Deficit/Hyperactivity Disorder in children. *Child Neuropsychology*, 6(2), 101-

114.

- Prior, M., Leonard, A., & Wood, G. (1983). A comparison study of preschool children diagnosed as hyperactive. *Journal of Pediatric Psychology*, 8, 191-207.
- Rubia, K., Taylor, A., Taylor, E., & Sergeant, J. A. (1999). Synchronization, anticipation, and consistency in motor timing of children with dimensionally defined attention deficit hyperactivity behaviour. *Perceptual and Motor Skills*, 89, 1237-1358.
- Rubia, K., Taylor, E., Smith, A., Oksannen, H., Overmeyer, S., Bullmore, E., & Newman, S. (2001). Neurophysiological analyses of impulsiveness in childhood hyperactivity. *British Journal of Psychiatry*, 179, 138-143.
- Sagvolden, T., & Sergeant, J. A. (1998). Attention deficit/ hyperactivity disorder- from brain dysfunctions to behaviour. *Behavioural Brain Research*, 94, 1-10.
- Seidman, L. J., Benedict, K., Biederman, J., Bernstein, J., Seiverd, K., Milberger, S., Norman, D., Mick, E., & Faraone, S. (1995). Performance of ADHD children on the Rey-Osterrieth complex figure: A pilot neuropsychological study. *Journal of Child Psychology and Psychiatry*, 36, 1459-1473.
- Semrud-Clikeman, M., Biederman, J., Sprich-Buckminster, S., Lehman, B. K., Faraone, S. V., & Norman, D. (1992). Comorbidity between ADDH and learning disability: A review and report in a clinically referred sample. *Journal of the American Academy Child and Adolescent Psychiatry*, 31, 439-448.
- Smith, A., Taylor, E., Rogers, J. W., Newman, S., & Rubia, K. (2002). Evidence for a pure time perception deficit in children with ADHD. *Journal of Child Psychology and Psychiatry*, 43(4), 529-542.
- Sonuga-Barke, E. J., Saxton, T., & Hall, M. (1998). The role of interval underestimation in hyperactive children's failure to suppress responses over time. *Behavioural Brain Research*, 94, 45-50.
- Sonuga-Barke, E. J., Taylor, E., Sembi, S., & Smith, J. (1992). Hyperactivity and delay aversion - II. The effect of self versus externally imposed stimulus presentation periods on memory. *Journal of Child Psychology and Psychiatry*, 33, 387-398.
- Stevens, D. A., Stover, C. E., & Backus, J. T. (1970). The hyperkinetic child: Effects of incentives on the speed of rapid tapping. *Journal of Consulting and Clinical Psychology*, 34, 56-59.
- Stevens, J., Quittner, A. L., Zuckerman, J. B., & Moore, S. (2002). Behavioral inhibition, self-regulation of motivation, and working memory in children with Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, 21(2), 117-139.
- Vaijdyia, C. J., Austin, G., Kirkorian, G., Ridlehuber, H. W., Desmond, J. E., Glover, G. H., & Ganrieli, J. D. E. (1998). Selective effects of methylphenidate in attention deficit hyperactivity disorder: A functional magnetic resonance study. *Proceedings of the National Academy of Sciences of the United States of America*, 95, 14994-14999.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL/4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis/Academisch Ziekenhuis Rotterdam/Erasmus Universiteit Rotterdam.
- Von Gontard, A., Zerres, K., Backes, M., Laufersweiler-Plass, C., Wendland, C.,

Melchers, P., Lehmkuhl, G., & Rudnik-Schöneborn, S. (2002). Intelligence and cognitive function in children and adolescents with spinal muscular atrophy. *Neuromuscular Disorder, 12*, 130-136.

Wechsler, D. (1991). *Manual for the Wechsler Intelligence Scale for Children* (3rd ed.). San Antonio, TX: Psychological Corporation.

Longitudinal follow-up on the cognitive performance of children with ADHD¹

Abstract

An aspect of research that has received limited coverage is the cognitive development of children with ADHD. It is still unclear whether the neuropsychological abnormalities found in relation to ADHD reflect an underlying brain dysfunction that endures over a longer period in the life of the individual, or whether, in contrast, it is possible that a child suffering from ADHD outgrows the neuropsychological abnormalities. The aim of this chapter was, therefore, to study the cognitive performance of children suffering from ADHD in a longitudinal design. In total, three groups were selected, namely (a) a group of children classified as having ADHD ($n = 19$), (b) a group of children classified with psychopathology other than ADHD ($n = 105$), and (c) a group of healthy control children ($n = 120$). All groups were subjected to two neuropsychological evaluations (evaluation I when the children were approximately 5 / 6 years old and evaluation II at 9 / 10 years of age). Three cognitive tasks were included in the design as within-subjects variables, measuring either working memory or visual motor integration capabilities. Within-group analyses showed that the performance of all groups improved as time passed. Between-group comparisons revealed that children with ADHD performed at neuropsychological evaluation I significantly less well than children in both control groups on tasks measuring working memory and / or visual-motor integration. Three years later (at evaluation II) this trend was only still observable for tasks measuring working memory. No differences in test performance at follow-up were found on the task measuring visual motor integration. In summary, it can be concluded that while children with ADHD outgrow certain deficits (e.g., cross-modal transfer of information) as they grow up, other deficits remain.

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Introduction

Attention-Deficit / Hyperactivity Disorder (ADHD) is a prevalent and serious syndrome affecting the entire life span of an individual suffering from it. According to the latest edition of the DSM (American Psychiatric Association, 1994), ADHD can best be defined as a syndrome affecting the attentiveness of the child, the activation state, and / or the impulsiveness in (motor) action. The diagnosis can only be given if the inefficient or deviated behavior of the child leads to severe disruptions in terms of social, cognitive, or scholar functioning. The influence of the syndrome on society is enormous in terms of financial costs, stress to families, disruption in schools, and its potential for a development leading to antisocial behavior, criminality, and substance abuse (Seidman, Biederman, Faraone, Weber, & Ouellette, 1997).

Over the years, several causes of ADHD have been proposed, including changes in structure or function of the brain. Neuro-imaging studies, including SPECT, EEG, PET, and (f)MRI, have revealed that only more pronounced deviations in specified brain areas and / or networks (e.g., the frontal striatal circuit) are involved in ADHD (Tannock, 1998). Interestingly, the deviations in brain mechanisms found are part of the anatomical substrate regulating the higher-order cognitive processes, such as working memory, rule based learning, and planning (e.g., Middleton & Strick [1994]).

In line with these findings, cognitive deficits, particularly impairments in attention and executive or higher-order functioning, are hypothesized to be a core part of ADHD, and are thought to play a major role in the difficult adaptation of children with ADHD at school age (Douglas, 1972; Seidman et al., 1997). In average, children with ADHD exhibit at school age a sub-average or relatively weak performance on various information processing tasks (e.g., vigilance and sustained attention, motor inhibition, executive functioning (such as organization and complex problem solving) and verbal learning and memory, controlled visual motor preparation) (Aman, Roberts, & Pennington, 1998; Barkley, 1997; Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Borger & Van der Meere, 2000; Douglas, 1999; Hazell et al., 1999; Kalff et al., Accepted for publication, Subject to revision; Kalff et al., 2002; Oosterlaan & Sergeant, 1995; Seidman et al., 1997; Sergeant, Geurts, & Oosterlaan, 2002). In addition, some of these cognitive deficits have been found to be specific for ADHD and not so much for psychopathology in general (e.g., chapters 6, 7, and 8 of this thesis).

However, an aspect of research, that has received a limited coverage, is the developmental profile of cognitive functions in ADHD (Nigg, Quamma, Greenberg, & Kusche, 1999). It is therefore still unclear whether the neuropsychological abnormalities found in relation to ADHD reflect an underlying brain dysfunction that endures over a longer period in the life of the individual, or that in contrast, it is possible that the child suffering from ADHD outgrows the neuropsychological abnormalities. Only few data, regarding the neuropsychological pro-

files in older children, adolescents and young adults, is presently available to provide more clarity in this matter. For instance, Seidman et al. (1997) compared boys with ADHD aged (I) 9 - 14 years or (II) 15 - 22 years on their neuropsychological functioning to aged-matched controls. The results revealed that both younger and older groups of boys with ADHD were neuropsychologically impaired, suggesting that neuropsychological deficits are probably not restricted to younger children with ADHD. These data were in accordance to the results of (Fischer, Barkley, Edelbrock, & Smallish, 1990), who studied neuropsychological functioning in a mixed-sex sample of adolescents suffering from ADHD. In conclusion, these results implicate that the found neuropsychological deficits associated with ADHD may well be enduring.

Unfortunately, the information that is available with regard to the cognitive development of ADHD children is most often collected within a cross-sectional design. There is still a growing need for prospective, longitudinal data regarding this subject. Based on the Study of Attention Disorders Maastricht (SAM) (discussed more explicitly in the previous chapters), it was possible to examine prospectively the cognitive development of children with or without psychopathology, and children with ADHD more specifically. The advantage of the SAM-study is that the cognitive functioning of children with or without psychopathology (and more specifically ADHD) is assessed both relatively early in life (at age 5 / 6 years; before the child learns to read and write) and after the child has attended several years of education (aged 9 - 10 years).

Unfortunately, only few tests are suitable for assessing both the very young children and the older children. Therefore, only a limited test battery is available for the purpose of longitudinal comparison of the test performance of children who belong to the ADHD-group, the pathological control group or the healthy controls. The three tests that are included in the protocols for both neuropsychological evaluations of the SAM-study have been designed primarily to measure (A) working memory, and (B) visual motor integration. However, based on data described by (Kalff et al., 2002), it can be concluded that at pre-school age the performance on these aspects of cognition (working memory, visual motor integration) are predictive for being classified as having ADHD later in time.

In sum, the aim of the present chapter is to test whether the average cognitive profile of children with ADHD as a function of time differs from that of pathological controls and / or healthy controls or that these cognitive profiles are identical for all groups.

Methods

As mentioned earlier, this chapter is based on data collected within a research program entitled 'Study of Attention Disorders Maastricht (SAM)' (Kalff et al., 2001; Kroes et al., 2001) and is embedded in a longitudinal, population-based design. The SAM study consists of 4 separate phases (for an expanded descrip-

tion of the study see Kalff et al. (2001) and Kroes et al. (2001)).

Stage 1: Selection of participants (during months 1 - 9). A sample of ± 2300 Dutch children attending second grade of normal kindergarten and living in the providence South Limburg of the Netherlands was approached to participate in the present study. In the Netherlands, the second grade precedes the first class of elementary school in which children learn to read and write. It is during this grade that the Youth Health Care invites the children for a Periodic Health Examination, which is usually attended by the vast majority (around 98%) of children. The initial approach of participants took place in conjunction with this Periodic Health Examination for the examination provides a perfect opportunity to reach a large sample of healthy young children. During the visit to the Youth Health Care for the periodic health examination, the caregivers of these children were asked to participate in the study and, in case of approval, to fill in an informed consent and a questionnaire as part of a large longitudinal cohort study. Caregivers could return the papers by mailing. Response rate of the written informed consent and the filled-in questionnaires was 57.5% ($n_{\text{responders}} = 1317$). Next, based on the Dutch version of the Child Behavior Checklist (CBCL; Achenbach & Edelbrock, 1983; Verhulst, Koot, & Van der Ende, 1996), three groups were selected from the responders group for the second stage. Group E (externalizing group; $n = 173$) consisted of children who scored high either on the CBCL externalizing broad-band scale ($> 90^{\text{th}}$ percentile) or on the CBCL Attention problems subscale ($> 95^{\text{th}}$ percentile). According to Chen, Faraone, Biederman, & Tsuang (1994), this selected group contains children with a putative risk for the development of ADHD. Next, group I (internalizing group; $n = 59$) contained children scoring within a clinical range on the CBCL Internalizing scale ($> 90^{\text{th}}$ percentile), but did not fulfill the criteria for group E membership. Finally, a matched control group ($n = 220$) was formed consisting of children with low CBCL total problem scores ($< 90^{\text{th}}$ percentile) and who were matched to group A and B in terms of age (± 2 months), sex and school (urban vs. rural).

Stage 2: First neuropsychological evaluation (evaluation I: months 4 - 9). After inclusion, cognitive evaluation of 400 of the originally selected 452 children was completed by a neuropsychologist and well-trained assistants (see for an extended description: Kalff et al. (2002)).

Stage 3: Child Psychiatric Interview (months 15 - 25). The caregivers of 403 children of the originally selected 452 children agreed to a semi-structured, psychiatric interview, using the Amsterdam Diagnostic Interview for Children and Adolescents (ADICA) (Dutch translation of the DICA (caregiver version); Herjanic & Reich, 1982; Kortenbout van der Sluijs, Levita, Manen, & Defares, 1997). Finally,

stage 4: Second neuropsychological evaluation (evaluation II: months 39 - 49). The original selected group of children was three years after the initial inclusion in stage 1 again asked to participate in the SAM-study. In total, 284 of the 403 children of whom ADIKA results were collected in phase 2 agreed to participate in the follow-up

and therefore remained in the study (70.5%). Because of the relative large drop-out (30%) of participants in stage 3, remainders and dropouts of stage 3 were tested for group differences in terms of sex, parental occupation, and ADIKA results (stage 2). Cramér's V testing revealed no significant differences between remainders and dropouts on these variables (sex: value = .002, $p = .965$; parental occupation: value = .083, $p = .258$; ADIKA results: value = .109, $p = .091$).

Next, all remainders were tested neuropsychologically by use of several tests measuring functions like verbal skills, attention, visuo-spatial performance, and scholar performance. A neuropsychologist or one of three well-trained assistants administered the test battery.

In total, 256 children successfully passed all stages (without missing data at any of the stages). Variables influential on research outcome were additional collected, including age (during *stage 3*), gender, the level of occupational achievement of the caregiver (LOA), and an estimate of general abilities. For the analyses, twelve children of the 256 were excluded, because of (a) a known use of Ritalin or Dipiperon (ADHD $n = 4$; pathological $n = 3$; controls $n = 2$) or (b) missing data in relation to LOA-codes ($n = 3$). Of this out-filtered group ($n = 244$), three sub-samples were formed, namely (1) a group of children who were classified as having ADHD in stage 3 (ADHD; $n = 19$), (2) a group of children who were classified with any DSM classification for psychopathology, but who did not fulfill the criteria for group 1 (pathological controls; $n = 105$), (3) a group of children who did not belong to group 1 or 2 (healthy controls; $n = 120$). Group characteristics of this specified sample were summarized in table 1.

Table 1. Group characteristics and diagnostic data of the sample ($n = 244$).

	ADHD $n = 19$		Pathological $n = 105$		Controls $n = 120$		p-value ¹
Sex (boys : girls)	14 : 5		62 : 43		58 : 62		$p = .063$
	Mean	SD	Mean	SD	Mean	SD	
Age	9.2	0.3	9.1	0.4	9.1	0.4	n.s.
Vocabulary	9.0	2.7	8.9	2.5	8.9	2.9	n.s.
LOA	3.0	1.7	3.7	2.0	4.5	1.9	$p = .003$

Note¹: Associations between ordinal and / or interval variables (group membership vs. age, Vocabulary scores, and LOA) were calculated by use of Spearman's rho. In contrast, chi square-tests were used to measure the associations between nominal (sex) and ordinal variables (groups).

Measurements

Independent variable

The Amsterdam Diagnostic Interview for Children and Adolescents (ADIKa; Kortenboud van der Sluijs et al., 1997): This is the Dutch translation of the Diagnostic Interview for Children and Adolescents (DICA; Ezpeleta et al., 1997; Granero Pérez, Ezpeleta Ascaso, Doménech Massons, & De la Osa Chaparro, 1998; Kortenboud van der Sluijs et al., 1997). The ADIKa is a semi-structured psychiatric interview that originally yielded scores for several child psychiatric syndromes² according to DSM-III-R guidelines (American Psychiatric Association, 1987). Later, the interview was adapted for diagnosing ADHD by use of criteria defined in the DSM-IV (American Psychiatric Association, 1994). In line with these criteria, children were classified as 'ADHD' if they showed a persistent pattern of inattention and / or hyperactivity-impulsivity that was more frequent and severe than that typically observed in individuals of a comparable level of development (American Psychiatric Association, 1994). In addition, ADHD was only scored when these persistent patterns were expressed in more than one situation. Children were included in the 'pathological control group' if they fulfilled the criteria for at least one child psychiatric syndrome (with the exception of ADHD) on the ADIKa. Although the Dutch version of the DICA-III-R interview has not been separately validated, DICA and DICA-III-R have been demonstrated to have high test-retest reliability and moderate correlations with clinician based diagnoses (Ezpeleta et al., 1997; Welner, Reich, Herjanic, Jung, & Amado, 1987).

Outcome variables

The working memory tests included in the protocol were part of the Kaufman assessment battery for children (K-ABC; (Kaufman & Kaufman, 1983; Melchers & Preuss, 1994). First, the Number Recall consisted of a series of strings of digits (e.g., 4-5-7-8) that were presented verbally to the child at a rate of one per second. The child was subsequently asked to repeat the digits in the same numerical sequence. Secondly, the Word Order was assessed, in which the child had to point to silhouettes of common objects in the same order as the objects were named by the examiner (e.g., tree, moon, heart, star). For both subtests, standard scores were calculated based on the total number of correct trials while correcting for the age of the child (mean standard score = 10; SD = 3; range: 1 - 19). These instruments seem to measure aspects of sequential information processing, and

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² Such as major depression, dysthymia, bipolar syndrome, separation anxiety, phobia, overanxious disorder, avoidant disorder, oppositional disorder, conduct disorder, functional encopresis, functional enuresis, obsessive compulsive disorder, post traumatic stress disorder, pervasive developmental disorders.

more specifically verbal working memory.

The Beery Developmental test of Visual Motor Integration (Beery VMI) included in the protocol was a standardized copying test. For this task, the child was asked to copy a series of printed figures as identical as possible. The included 24 designs intend to follow a developmental gradient of difficulty starting with a vertical line for 2-year-olds and progressing to three-dimensional cube and star designs for 14- and 15-year-olds (Spreen & Strauss, 1998). For this test, t-scores were calculated based on the total number of correct trials, while correcting for age (mean t-score = 50; SD = 15; range: 1 - 100). The instrument seems especially useful in exploring the visual-perceptual and motor skills in children (Spreen & Strauss, 1998). Reliability and validity are believed to be average to good (Armstrong & Knopf, 1982; Breen, 1982; Cosden, 1985; Liemohn & Wagner, 1975).

Covariates

Vocabulary is a subtest of the Wechsler Intelligence Scales (Dutch Version: De Bruyn et al., 1986) and is useful for estimating the general ability of the child (Lezak, 1995). The examiner asked the child to explain the meaning of certain words (e.g., umbrella, to wither). The complexity of words increased with each item. Range of standard scores is 1 - 19 (mean standard score = 10, SD = 3). Reliability and validity are believed to be average to good (De Bruyn et al., 1986).

Level of Occupational Achievement of the caregiver (LOA) is based on a full description of the parental occupation and was scored on a 7-point-scale, ranging from unskilled to scientific skilled labor (Directoraat-Generaal voor de Arbeidsvoorziening, 1989). Housewives and househusbands were coded as a separate category. When the LOA differed between mother and father or if data was missing for one caregiver, the highest available score was chosen.

Statistical analyses

Box plots were drawn to test for normal distribution and outliers. Next, the standardized scores of outcome variables were transformed into z-scores (mean score = 0; SD = 1) to compare the scores of the diverse tests (that had originally different distributions of scores; e.g., mean VMI is equal to 100 [SD = 15; range: 45-155] whereas the mean of the Kaufman subscales is 10 [SD = 3; range: 1 - 19]) and to minimize skewness of the distribution of scores. The z-scores were derived from the formula defined in figure 1.

As a next step, cognition as a function of time (evaluation I vs. evaluation II) was calculated for each group individually (ADHD, pathological controls, healthy controls; see figure 2^{a,b,c}). The aim was to test whether the developmental profiles of children with ADHD differ from pathological controls and healthy controls or

that the profiles as a function of time are identical on the tests included in this project. These questions were analyzed within a 3 x 2 x 2 (group x sex x time of cognitive testing) GLM Repeated Measures design for unequal sample sizes within a non-experimental design. In case of significant interactions or main effects, post hoc univariate analyses were conducted.

For test i and individual j holds: $z_{ij} = \frac{\mu_{ij} - \bar{x}_i}{\sigma_i}$

z_{ij} : = the transformed score on test i and for individual j ; $\bar{x}_i$: = the mean score on test i , calculated over the norm group; μ_{ij} : = the score on test i of the individual j ; σ_i : = the standard deviation on test i , calculated over the norm group.

Figure 1: Transformation of standardized test scores.

For each type of test (VMI, Number recall, and Word Order), the above-mentioned procedure was used. Standard, all analyses were tested for their sensitivity for inter-individual differences caused by age, by including this variable in the analyses as covariate. After this, the analyses were repeated but with adding the estimate of general ability (Vocabulary scores) and the level of occupational achievement of the caregiver (LOA) also as covariates in the analyses. The reason for preferring this two-step-way of measuring the effect of covariates on the outcome (instead of including all covariates in one step in the analyses) is two-fold. First, some authors claim that between 3% and 10% of the variance in IQ may be a function of symptoms in ADHD (hyperactive-impulsive behavior), and hypothesized therefore that when a difference between ADHD and control groups in IQ is found, it should probably not be statistically controlled out in the analyses as this may remove some of the variation in the measures under study that is due to ADHD itself (Barkley, 1998). Second, relatively few studies investigating cognitive impairment in children with ADHD have included some measure of socio-economic status (SES). Therefore, little is still known about the relation between SES and ADHD (Stevens, Quittner, Zuckerman, & Moore, 2002). The statistical package 'SPSS for windows' was used to conduct the above-mentioned analyses. The critical value for rejecting the null hypotheses was defined at $p < 0.05$, post-hoc corrections for Bonferroni were made if necessary.

Results

Number recall

Performance on the Number Recall as a function of both the time of evaluation

and group membership is displayed in figure 2^a. A 3 x 2 x 2 (group by sex by test period) GLM revealed firstly a significant main effect for test periods ($F(1,237) = 65.42$, $p < .001$). Over all groups, performance was significantly better on evaluation II compared to evaluation I. Post-hoc analyses further revealed that, within each group, the performance on the Number Recall task increased significantly as a function of time – while comparing evaluation I (at preschool age) with evaluation II (age 9 years) (healthy control children: $F(1,117) = 35.11$; $p < .001$); pathological control children: $F(1,102) = 25.20$ ($p < .001$), ADHD children: $F(1,16) = 6.91$; $p = .018$)³. Secondly, no significant interactions for group by test period ($F(2,237) = .32$; $p = .726$) and for group by sex by test period ($F(2,237) = .60$; $p = .548$)² were found, while conducting the 3 x 2 x 2 GLM analysis. Thirdly, a significant interaction was found for sex by test period ($F(1,237) = 4.82$; $p = .029$) (see figure 3a). Fourth, a significant main effect was found for group membership ($F(2,237) = 4.62$; $p = .013$). Post-hoc, a 3 x 2 (group by sex) GLM univariate analyses revealed a significant main effect of sex on the first evaluation of the Number Recall test ($F(1,237) = 4.98$, $p = .005$). After bonferroni-correction it was found that, at preschool age, girls scored significantly higher on this subtask than boys. In addition, a trend was found for groups (ADHD, pathological controls, healthy controls) to differ in performance on the first evaluation of the Number Recall test, while correcting for age ($F(2,237) = 2.80$; $p = .063$). Children with ADHD tended to perform less well on this subtask than the pathological controls and the healthy controls. Next, a 3 x 2 (group x sex) GLM univariate analyses revealed no sex differences three years later (at evaluation II) ($F(1,237) = 0.40$, $p = .528$). In contrast, the analyses revealed that differences in group membership (ADHD, pathological controls, and normal controls) were again prevalent at evaluation II ($F(2,237) = 2.98$; $p = .018$). Children with ADHD performed significantly worse than both control groups, whereas no differences were found between the pathological control group and the normal controls. For all of these analyses held that while including general ability and occupational level of the caregiver as covariates in the analysis, the results stayed essentially the same. Levene's tests of equality of error variances were not significant.

In sum, compared to the norm scores of the Kaufman ABC, the children of all groups (including the group of ADHD children) improved in their performance. However, children with ADHD tended to perform significantly worse than both the healthy and the pathological control groups on the Number Recall-subtask both on preschool ages as well as after 2 or 3 years of education.

Word Order

Performance on Word Order as a function of evaluation time and groups was

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³ After correction for norm data (as is done when standard scores are recoded into z-scores), sex, and age.

displayed in figure 2^b. A 3 x 2 x 2 (group x sex x test period) GLM revealed firstly a significant main effect for test periods ($F(1,237) = 22.37, p < .001$). Over all groups, performance was significantly better on evaluation II compared to evaluation I. Post-hoc analyses further revealed that, within each group, the performance on the Word Order task increased significantly as a function of time - while comparing evaluation I (at preschool age) with evaluation II (age 9 / 10 years) (healthy control children: $F(1,117) = 7.49; p = .007$); pathological control children: $F(1,102) = 10.32 (p = .002)$, ADHD children: $F(1,16) = 7.19; p = .016$)⁴. Secondly, the 3 x 2 x 2 (group x sex x test period) GLM revealed no significant interactions for group by test period ($F(2,237) = .41; p = .665$) and for group by sex by test period ($F(2,237) = 1.07; p = .346$)². Thirdly, a significant interaction was found for sex by test period ($F(1,237) = 8.89; p = .003$) (see figure 3b). Fourth, a significant main effect was found for group membership ($F(2,237) = 4.58; p = .011$). Post-hoc, a 3 x 2 (group by sex) GLM univariate analyses revealed a significant main effect of sex on the first evaluation of the Word Order test ($F(1,237) = 15.94, p < .001$; figure 4). After bonferroni-correction it was found that, at preschool age, girls scored higher on this subtask than boys. In addition, groups (ADHD, pathological controls, healthy controls) were found to differ in performance on the first evaluation of the Word Order test, while correcting for age ($F(2,237) = 5.37; p = .005$). Children with ADHD performed less well on this subtask than the pathological controls and the healthy controls. Finally, a significant sex by group interaction was found on this first evaluation ($F(2,237) = 3.18; p = .043$). For both the control and pathological groups, girls tended to perform better than boys on evaluation I. In contrast, for the ADHD group the association between sex and performance was inverted, a finding that may be due to sample sizes. Next, a 3 x 2 (group by sex) GLM univariate analyses revealed no sex differences ($F(1,237) = 0.53, p = .466$), no group differences ($F(2,237) = 2.15, p = .119$), and no interaction of sex by group ($F(2,237) = 0.48, p = .617$) three years later (at evaluation II). During evaluation II, the ADHD children still remained to have the lowest mean score on this task, however, the group differences were no longer significant ($F(2,239) = 2.212; p = .112$). For all of these analyses held that while including general ability and occupational level of the caregiver as covariates in the analysis, the results stayed essentially the same. Levene's tests of equality of error variances were not significant.

In sum, the performance on the Word Order task improved for all groups as a function of time equally. Although children with ADHD tended to perform significantly worse than both the healthy and the pathological control groups on the Word Order-subtask at preschool ages, no significant differences were found

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⁴ After correction for norm data (as is done when standard scores are recoded into z-scores), sex, and age.

after 2 or 3 years of education.

Beery Visual Motor Integration Test (VMI)

Performance on Beery VMI as a function of evaluation time and groups was displayed in figure 2^c. A 3 x 2 x 2 (group x sex x test period) GLM revealed firstly no main effect for test periods ($F(1,237) = 0.01$, $p = .902$). Post-hoc analyses revealed that, in contrast to the earlier discussed tests, only the performance of ADHD children increased significantly on the Beery VMI over time ($F(1,16) = 8.17$; $p = .011$). The performance of control children and pathological controls did not increase significantly on this test when comparing the test results of evaluation I and evaluation II (control children: $F(1,117) = 0.18$ ($p = .676$); pathological control children: $F(1,102) = 0.05$, $p = .826$)². Secondly, no significant interactions for group by test period ($F(2,237) = 2.32$; $p = .100$), sex by test period ($F(1,237) = 0.05$, $p = .819$), and for group by sex by test period ($F(2,237) = 0.47$; $p = .625$)² were found by use of a 3 x 2 x 2 GLM analysis. Thirdly, a trend was found for a main effect of group membership ($F(2,237) = 2.75$; $p = .066$).

Figure 3a,b: Sex differences measured in performance on the Word Order and Number Recall subtasks as a function of time.

Post-hoc, a 3 x 2 (group x sex) GLM univariate analyses revealed a significant main effect of group membership on the first evaluation of the Beery VMI test ($F(2,237) = 5.34$, $p = .005$). After bonferroni-correction it was found that, children with ADHD performed less well on this subtask than the pathological con-

trols and the healthy controls. Next, a 3 x 2 (group x sex) GLM univariate analyses revealed no group differences ($F(2,237) = 0.56$, $p = .575$) three years later (at evaluation II). For all of these analyses held that while including general ability and occupational level of the caregiver as covariates in the analysis, the results stayed essentially the same. Levene's tests of equality of error variances were not significant.

In sum, although children with ADHD tended to perform significant less well than the controls (either healthy or pathological control groups) on evaluation I, standard scores were approximately identical across groups at evaluation II. However, children with ADHD improved during this period of three years significantly in their performance on the Beery VMI, whereas children from the control groups stayed on an equal level when time passed.

Figure 4: Performance on the Word Order as a function of sex and group membership at evaluation I.

Discussion

The aim of the present chapter was to expand the current knowledge about the development of children with ADHD. From earlier studies it was known, that children, whose behavioral patterns are sufficiently severe to warrant an ADHD diagnosis, are increased at risk for receiving the diagnosis again 5 - 8 years later (e.g., Barkley, Fischer, Edelbrock, & Smallish, 1990; Beitchman, Wekerle, & Hood, 1987). Also it has been shown that behaviourally a high percentage of cases does not outgrow the problems related to ADHD while transcending from childhood to adolescent or adult (Hechtman, Weiss, Perlman, & Amsel, 1984; Weiss & Trokenberg Hechtman, 1993). The problems, that adults have to face as an outcome of earlier ADHD symptoms in childhood, range from residual ADHD symptoms that impair home or work adjustments to depression, substance abuse, low self-esteem, accident proneness and anti-social personality (Weiss & Trokenberg Hechtman, 1993; Wender, Reimherr, & Wood, 1981).

Relatively little is known today about the cognitive development of children with ADHD. The designs chosen in earlier conducted studies measuring the cognitive

functioning of children with ADHD can often be categorized in two types of studies. First, several studies have measured cognition at one moment in time either parallel to behavioral evaluation or non-parallel to behavioral evaluation (before, parallel or after the evaluation of psychopathology [e.g., chapters 5, 6, 7, & 8 of the present thesis]). The studies included children of different ages, with the highest percentage included at school age (that is, children aged 6-12 years old). Second, a number of studies have evaluated the longitudinal cognitive development of children with ADHD within a cross-sectional design (Nigg et al., 1999; Seidman et al., 1997).

In contrast, the study described in the present chapter has the advantage of a prospective longitudinal design including two cognitive evaluations over a period of 3 years. Based on the data presented in this chapter, several conclusions can be drawn. The data collected at preschool age were earlier described by Kalff et al. (2002), with the inclusion of several groups (1. ADHD, 2. comorbid ADHD and ODD / CD, 3. ODD / CD, 4. Healthy controls). From the spectrum of neurocognitive tests administered by the authors at preschool age, three tests revealed significant differences between these groups, namely the Number Recall, the Word Order, and the Beery VMI. In contrast, no significant differences were found at preschool age comparing the groups in performance on tests measuring visual perception, verbal fluency (only the semantic category over 60 seconds), and the visual inference ability. Based on these data, the deficient performance on the Beery VMI was attributed to the cross-modal transfer of information, particularly at the level of motor control output or psychomotor planning (Kalff et al., 2002). In addition, Kalff et al. (2002) concluded that the significant differences found at preschool age in terms of performance on the Number Recall and the Word Order test were caused presumably by a deficit in working memory, and in case of the word order also by the translation of information recalled from memory into a motor plan in order to obtain the correct answer.

Due to a relatively large percentage of dropouts and therefore small sample sizes, it was decided in the present chapter to regroup the data described by Kalff et al. (2002). Three new groups were formed, namely a group of children with ADHD, a group of pathological controls, and a group of healthy controls. Test performance of these groups revealed again that the three tests (Number Recall, Word Order, and Beery VMI) to discriminate between groups at preschool age, and that the children suffering from ADHD perform significantly worse on these tests compared to control subjects (either healthy or pathological).

As described in this chapter, the children tested by Kalff et al. (2002) at preschool age were again tested three years later by use of the tests Number Recall, Word Order, and Beery VMI. At the 3-years follow-up, several observations were made. First, a trend was found for children, regardless of group membership and type of cognitive test included, to improve in performance at evaluation II compared to evaluation I, as measured within the context of overall better neuro-

psychological performance. These findings are in accordance with the results of cross-sectional studies conducted earlier (Grodzinsky & Diamond, 1992; Seidman et al., 1997). Based on these results it can be concluded that although the cognitive function level at baseline may be different, all groups (whether ADHD, pathological or healthy controls) improved as a function of time. Secondly, when measured at the 3-years follow-up, the differences in working memory were still found, although the difference found at preschool age for the visual motor integration task had disappeared. It may well be that the ADHD children improved in their ability to transfer information across different modalities, whereas the deficiencies in working memory remained present over time. It is believed that it is highly unlikely that the results can be explained solely by a ceiling-effect for the cognitive abilities of the control groups for a number of reasons. First of all, the Beery VMI is suitable for children aged 3 - 17 years, whereas the children in the present study were in average 9 years old at the second evaluation. Secondly, the complexity of the items of this test increases with each succeeding item and the authors of the test claim that the items 21 - 24 (the last items of the test) are in average correctly drawn not before the children are 9 years and 6 months or older (Spreeen & Strauss, 1998). Therefore, it seems unlikely that there is a ceiling-effect for the performance of the control children (aged 9) included in the present study. The performance of these children supports this assumption with regard to a possible ceiling-effect because the mean t-scores of both control groups – healthy and pathological- were approximately 50 (while correcting for age) and thereby near to average, whereas a maximum t-score on this test is approximately 100. Similar conclusions hold for the Number Recall test and the Word Order test of the Kaufman ABC. Based on this finding, it can be concluded that longitudinally ADHD children show specific deficits in their cognitive profile, which may be manifest over a longer period of time (e.g., a diminished working memory as seen at evaluation I and evaluation II). These neuropsychological abnormalities seem to reflect an underlying brain dysfunction that endures through important stages of the child's development. These findings related to cognitive functioning were in line with the longitudinal studies involving the behavioral component. However, it is also found that the performance of children suffering from ADHD can improve over time and that particular cognitive functions improve to a level equal to that of the controls, as seen on the Beery Visual Motor Integration Task. Several components of influence on ADHD persistence should be considered in future research. For instance, parental characteristics and more specifically the parent-child interaction (e.g., the negative, critical, and commanding style) is of high influence on the persistence of ADHD over development (Cameron, 1978; Campbell, 1990; Earls & Jung, 1987). More research concerning extended follow-up data is necessary.

Figure 2^{a,b, c}: Longitudinal performance on Number Recall (Kaufman), Word Order (Kaufman), Beery VMI of children with ADHD, psychopathology otherwise defined, and healthy controls.

However, the present study included some limitations. For instance, the DSM

classifications were measured solely on basis of the outcome of a semi-structured interview with the caregivers of the child. Cross-informant reports, like Teacher Reports, were not included here. Therefore, it is possible that the number of children with externalizing behavior was overestimated. However, Barkley (1998) reported evidence of a 90% overlap between parent reports and teacher reports, indicating that the caregiver reports are a good approximation for the purposes in the present paper.

Another point worth mentioning is that the exclusion and drop out of children in the analyses (37% of the selected sample) could limit the generalizability of the results to the population. In contrast, post-hoc analyses revealed no significant differences between dropouts and remainders. Therefore, one may conclude that the groups are comparable in their outcome, and that the inferences made in the earlier paragraphs are justified. Finally, the sample size of the ADHD group was relatively low, especially for analyzing the interaction of sex by group membership. Caution is, therefore, warranted in interpreting these results for this sample size may influence the power of the study.

References

- Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile*. Burlington: University of Vermont Department of Psychiatry.
- Aman, C. J., Roberts, R. J., & Pennington, B. (1998). A Neuropsychological examination of the underlying deficit in Attention Deficit Hyperactivity Disorder: Frontal Lobe versus Right Parietal Lobe Theories. *Developmental Psychology*, 34(5), 956-969.
- American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3th ed.). Washington DC: American Psychiatric Association.
- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Armstrong, B. B., & Knopf, K. F. (1982). Comparison of the Bender-Gestalt and Revised Developmental Test of Visual-Motor Integration. *Perceptual and Motor Skills*, 56, 164-166.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive function: Constructing a unified theory of ADHD. *Psychological Bulletin*, 121, 65-94.
- Barkley, R. A. (1998). *Attention-Deficit / Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (ODD). *Journal of abnormal Child Psychology*, 29(6), 541-556.
- Barkley, R. A., Fischer, M., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: I. An 8-year prospective follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29, 546-557.
- Beitchman, J. H., Wekerle, C., & Hood, J. (1987). Diagnostic continuity from preschool

- to middle childhood. *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 694-699.
- Borger, N., & Van der Meere, J. (2000). Motor control and state regulation in children with ADHD: A cardiac response study. *Biological Psychology*, 51, 247-267.
- Breen, M. J. (1982). Comparison of educationally handicapped students' scores on the Revised Developmental Test of Visual-Motor Integration and Bender Gestalt. *Perceptual and Motor Skills*, 54, 1227-1230.
- Cameron, J. R. (1978). Parental treatment, children's temperament, and the risk of childhood behavioral problems: II. Initial temperament, parental attitudes, and the incidence and form of behavioral problems. *American Journal of Orthopsychiatry*, 48, 140-147.
- Campbell, S. B. (1990). *Behavior problems in preschool children*. New York: Guilford Press.
- Chen, W. J., Faraone, S. V., Biederman, J., & Tsuang, M. T. (1994). Diagnostic accuracy of the Child Behavior Checklist scales for Attention-Deficit Hyperactivity Disorder: A receiver-operating characteristic analysis. *Journal of Consulting and Clinical Psychology*, 62, 1017-1025.
- Cosden, M. (1985). Developmental Test of Visual-Motor Integration. In D. J. Keyser & R. C. Sweetland (Eds.), *Test Critiques* (Vol. IV, pp. 229-237). Kansas City: Test Corporation of America.
- De Bruyn, E. E. J., Van der Steene, G., Van Haasen, P. P., Coetsier, P., Pijl, Y. J., Spoelers-Claes, R., Poortinga, Y. H., Stinissen, J., & Lutje Spelberg, H. C. (1986). *Wechsler Intelligence Scale for Children - Revised (WISC-R)*. Lisse: Swets & Zeitlinger.
- Directoraat-Generaal voor de Arbeidsvoorziening. (1989). *Handleiding voor de functie-analyse*. Den Haag: SDU uitgeverij.
- Douglas, V. I. (1972). Stop, look and listen: The problem of sustained attention and impulse control in hyperactive and normal children. *Canadian Journal of Behavioral Science*, 4, 259-282.
- Douglas, V. I. (1999). Cognitive control processes in Attention Deficit Hyperactivity Disorder. In H. C. Quay & A. E. Hogan (Eds.), *Handbook of disruptive behavior disorders*. (pp. 105-138). New York: Plenum Press.
- Earls, F., & Jung, K. G. (1987). Temperament and home environment characteristics as causal factors in the early development of childhood psychopathology. *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 491-498.
- Ezpeleta, L., De la Osa, N., Doménech, J. M., Navarro, J. B., Losilla, J. M., & Júdez, J. (1997). Diagnostic agreement between clinicians and the Diagnostic Interview for Children and Adolescents-DICA-R-in an outpatient sample. *Journal of Child Psychology and Psychiatry*, 38(4), 431-440.
- Fischer, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: II. Academic, attentional, and neuropsychological status. *Journal of Consulting and Clinical Psychology*, 58, 580-588.
- Granero Pérez, R., Ezpeleta Ascaso, L., Doménech Massons, J. M., & De la Osa Chaparro, N. (1998). Characteristics of the subject and interview influencing the test-retest reliability of the Diagnostic Interview for Children and Adolescents-

- Revised. *Journal of Child Psychology and Psychiatry*, 39(7), 963-972.
- Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention deficit hyperactivity disorder. *Journal of Clinical Psychology*, 45, 427-446.
- Hazell, P. L., Carr, V. J., Lewin, T. J., Dewis, S. A. M., Heathcote, D. M., & Brucki, B. M. (1999). Effortful and automatic information processing in boys with ADHD and Specific Learning Disorders. *Journal of Child Psychology and Psychiatry*, 40, 275-286.
- Hechtman, L., Weiss, G., Perlman, T., & Amsel, R. (1984). Hyperactives as young adults: Initial predictors of adult outcome. *Journal of the American Academy of Child Psychiatry*, 23, 250-260.
- Herjanic, B., & Reich, W. (1982). Development of a structured psychiatric interview for children: Agreement between child and parent on individual symptoms. *Journal of Abnormal Child Psychology*, 10, 307-324.
- Kalff, A. C., De Sonnevile, L. M. J., Hurks, P. P. M., Hendriksen, J. G. M., Kroes, M., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., Vles, J. S. H., & Jolles, J. (Accepted for publication). Low- and high-level controlled processing in executive motor control tasks in 5 / 6-year-old children at risk of ADHD. *Journal of Clinical Psychology and Psychiatry*.
- Kalff, A. C., De Sonnevile, L. M. J., Hurks, P. P. M., Hendriksen, J. G. M., Kroes, M., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., Vles, J. S. H., & Jolles, J. (Subject to revision). Speed, speed variability, and accuracy of information processing in 5 / 6-year-old children at risk of ADHD. *Journal of the American Academy Child and Adolescent Psychiatry*.
- Kalff, A. C., Hendriksen, J. G. M., Kroes, M., Vles, J. S. H., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., & Jolles, J. (2002). Neurocognitive performance of 5- and 6-year-old children who met criteria for Attention Deficit / Hyperactivity Disorder at 18 months follow-up: Results from a prospective population study. *Journal of Abnormal Child Psychology*, 30(6), 589-598.
- Kalff, A. C., Kroes, M., Vles, J. S. H., Bosma, H., Feron, F. J., Hendriksen, J. G., Steyaert, J., Van Zeben, T. M., Crolla, I. F., & Jolles, J. (2001). Factors affecting the relation between parental education as well as occupation and problem behaviour in Dutch 5- to 6-year-old children. *Social Psychiatry and Psychiatric Epidemiology*, 36, 324-331.
- Kaufman, A. S., & Kaufman, N. L. (1983). *Kaufman Assessment Battery for Children (K-ABC)*. Minnesota, USA: American Guidance Service, Inc.
- Kortenbout van der Sluijs, M. J., Levita, D. J., Manen, R., & Defares, P. B. (1997). Test bespreking: Amsterdams Diagnostisch Interview voor Kinderen (ADIKa). *Nederlands Tijdschrift voor de Psychologie*, 52, 135-138.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeben, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Lezak, M. D. (1995). *Neuropsychological assessment* (3 ed.). Oxford: Oxford University Press.

- Liemohn, W., & Wagner, P. (1975). Motor and perceptual determinants of performance on the Bender-Gestalt and the Beery Developmental Scale by retarded males. *Perceptual and Motor Skills*, 40, 524-526.
- Melchers, P., & Preuss, U. (1994). *Kaufman-Assessment battery for children-German edition (K-ABC)*. Lisse: Swets & Zeitlinger.
- Middleton, F. A., & Strick, P. L. (1994). Anatomical evidence for cerebellar and basal ganglia involvement in higher cognitive functioning. *Science*(266), 458-461.
- Nigg, J. T., Quamma, J. P., Greenberg, M. T., & Kusche, C. A. (1999). A two-year longitudinal study of neuropsychological and cognitive performance in relation to behavioral problems and competencies in elementary school children. *Journal of Abnormal Child Psychology*, 27(1), 51-63.
- Oosterlaan, J., & Sergeant, J. A. (1995). Response choice and inhibition in ADHD, anxious and aggressive children: The relationship between S-R compatibility and the stop signal task. In J. A. Sergeant (Ed.), *Eunethydis: European approaches to hyperkinetic disorder*. (pp. 225-240). Amsterdam: JA Sergeant.
- Seidman, L. J., Biederman, J., Faraone, S. v., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of Attention Deficit-Hyperactivity Disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical psychology*, 65(1), 150-160.
- Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive function for Attention-Deficit / Hyperactivity Disorder? *Behavioural Brain Research*, 130, 3-28.
- Spree, O., & Strauss, E. (1998). *A compendium of neuropsychological tests: Administration, norms, and commentary*. (2 ed.). New York: Oxford University Press, Inc.
- Stevens, J., Quittner, A. L., Zuckerman, J. B., & Moore, S. (2002). Behavioral inhibition, self-regulation of motivation, and working memory in children with Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, 21(2), 117-139.
- Tannock, R. (1998). Attention Deficit Hyperactivity Disorder: Advances in cognitive, neurobiological and genetic research. *Journal of Child Psychology and Psychiatry*, 39, 65-99.
- Verhulst, F. C., Koot, J. M., & Van der Ende, J. (1996). *Handleiding voor de CBCL / 4-18*. Rotterdam, The Netherlands: Afdeling Kinder- en Jeugdpsychiatrie, Sophia Kinderziekenhuis / Academisch Ziekenhuis Rotterdam / Erasmus Universiteit Rotterdam.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children, adolescents and adults*. (2 ed.). New York: The Guilford Press.
- Welner, Z., Reich, W., Herjanic, B., Jung, K. G., & Amado, H. (1987). Reliability, validity, and parent-child agreement studies of the diagnostic interview for children and adolescents (DICA). *Journal of the American Academy Child and Adolescent Psychiatry*, 26, 649-653.
- Wender, P. H., Reimherr, F. W., & Wood, D. R. (1981). Attention deficit disorder ('minimal brain dysfunction') in adults. A replication study of diagnosis and drug treatment. *Archives of General Psychiatry*, 38(4), 449-456.

Implications for the future from a scientific and clinical perspective

Abstract

Several issues were discussed in the preceding chapters of this thesis. A central topic was the cognitive functioning of children with Attention-Deficit/Hyperactivity Disorder (ADHD). Even though awareness and knowledge of ADHD have increased over the years, there is still confusion and misunderstanding about the disorder and a continuing need for up-to-date, comprehensive discussions about ADHD. Therefore, the final chapter of this thesis provides an outline of the studies performed and the implication of findings for scientific research and possible clinical applications. A main focus is on the increasingly recognized role of the neuropsychologist, and neuropsychological tools and insights used for cognitive assessment and training.

Introduction

Over the last decades, many articles have been written about the cognitive, biological, and social processes underlying childhood psychological development. Additional research is, however, still needed and should focus specifically on the following domains, as stated by several authors (e.g., Verhulst [1999]). First, it is important to further our understanding of the processes underlying normal development and to examine factors that are of influence on these processes (goal a). Secondly, functioning in children is believed to lie on a continuum with normal functioning on the one end and abnormal functioning on the other, with children who display minor or subclinical problems in functioning being intermediate. To increase our knowledge concerning childhood development, it is therefore necessary to learn more of the etiology, course, prevalence, and treatment of sub-clinically or clinically abnormal functioning (goal b).

The results of the studies described in preceding chapters of this thesis contribute to our knowledge on both aspects. Topics such as prevalence rates, etiology, and developmental profile, were investigated in relation to ADHD, which is a syndrome characterized by an abnormal behavioral pattern (chapters 1, 5, 6, 7, 8, & 9). Aspects of normal and sub-clinical development were also studied. Topics such as sleep, school career, and cognition (chapters 3 & 4) were investigated in a relatively large population of healthy children. Factors such as environment, occupational achievement of the caregiver, age, attention capacity, and behavior of the child, were studied in more detail in relation to normal but also abnormal educational achievement, sleep, and cognitive performance (chapters 2, 3, 4, & 6). This last chapter of the thesis provides an overview of the main results of the thesis, limitations of the presently available knowledge concerning 'normal and sub-clinical development' and 'ADHD', and the implications for research and clinical practice.

Concluding remarks regarding the assessment of changes in development

With regard to normal development, the value of the research presented in this thesis lies in a number of aspects. Firstly, a test called the Finger Precueing Test (FPT), originally designed for the adult population, was evaluated. Based upon its sensitivity in detecting differences between children with ADHD and controls, as described in chapter 6, it can be concluded that this measure can also be used in clinical studies of children. The FPT makes it possible to study the nature of automatic and controlled response preparation processes that occur during the precue or preparation interval (i.e., the time interval between preparation of the cue and the target signal). This is a relevant aspect of information processing that has received only scant attention in the literature. Based on the data presented in chapter 6, it can be concluded that children aged 9 are able to use a relatively simple, unimanual cue to their advantage, but they are unable to use the more complex, bimanual cues. These results are in contrast to the FPT performance of

young and middle-aged adults, who are able to profit from either unimanual or bimanual cues. Interestingly, like children, elderly individuals (with an age-range of 70-73 years) also show great difficulty in using these bimanual cues (such as the finger- and neither-cued condition), with hand-cued preparation still being intact (Adam et al., 1998). Furthermore, in 9-year-old children, FPT performance was adversely affected when the interval during which the child could anticipate a future action was prolonged. With 100-ms, children seemed to react fairly automatically to cued stimuli, whereas with 1000-ms children acted more “consciously”, that is, they had more time to bring “controlled” processing resources to bear on the cues.

Secondly, the verbal fluency test, a task often used in clinical and experimental settings was re-analyzed, using a novel approach. Verbal fluency is often operationalized as the number of words produced, usually within a restricted category and over a limited period of time (usually 60 seconds) (Lezak, 1995). Two frequently used categories of verbal fluency tasks are *semantic category fluency* (e.g., recitation of examples of a given category) and *initial letter fluency* (e.g., generating words beginning with a given initial letter) (Monsch et al., 1994). In most published articles, the outcome variable is the total number of words generated over 60 seconds. Troyer (2000) stated, however, that evaluation of performance over 60 seconds is a crude measure and does not provide information about the mechanisms underlying (diminished) test performance. In contrast, analysis of word production over time is believed to provide additional information. Word production in the first 15 seconds of either type of fluency task is taken as a measure of automatic information processing whereas production from 15 seconds through 1 minute is taken as a measure of controlled processing. In the studies described in chapters 4 and 5, performance on either type of fluency task was measured both in the traditional way (as with total scores) and as a function of time. With this relatively new method of analyzing performance on the verbal fluency task, knowledge was obtained about information processing in children.

Thirdly, in the studies described in the chapters 2, 3, and 4, the long-term impact of environment, sex, and age on cognitive performance, scholarly functioning, and sleep problems of children was studied further. These effects were examined with a longitudinal, prospective study design, a relatively new approach. Certain behavioral characteristics measured at preschool age proved to be predictive of successful development, from a cognitive and biological perspective. The results of the studies presented in chapters 2 and 3, in which the relevance of attention problems as measured at preschool age as a predictive factor for sleeping problems and a deviant school performance later was determined, have implications for early intervention strategies and emphasize the importance of earlier detection of children with, for instance, ADHD.

Finally, based on the data presented in chapter 3, it can be concluded that problematic sleep measured at preschool age still has an influence 3 years later. This

finding emphasizes the relevance of teaching parents in an early stage about good sleep hygiene for their child: this may prevent more serious or chronic sleep-related problems, which in themselves can have a profound influence on cognitive performance, especially executive functioning.

Value of the ADHD research described in the thesis

The research presented in this thesis adds to current knowledge of ADHD. For instance, as mentioned above, the FPT was adapted for use in children. This made it possible to study the automatic and controlled visuomotor preparation in children suffering from ADHD. This is relevant because ADHD research suggests that there is an output-related deficit, and that faulty or sub-optimal execution of tasks may be the result of faulty or incomplete preparation. Analysis of the FPT results indicated, as described in chapter 6, that ADHD may be associated with an impaired ability to engage in effortful, controlled visuomotor preparation activities. Furthermore, children classified as having ADHD tended to show significantly more variability in speed over all preparation conditions and intervals compared to control children. This finding is in line with earlier conducted studies in which RT paradigms were used (Douglas, 1999). A plausible explanation is that this increase in variability is a manifestation of regulatory problems involving the inconsistent allocation of effort (Douglas, 1999). Analysis of FPR false responses did not reveal significant group effects. This finding was in line with the work of Borger & Van der Meere (2000). In contrast, several authors found contradictory results, stating that ADHD children make more mistakes than controls (Perchet, Revol, Fournieret, Mauguière, & Garcia-Larrea, 2001).

A relatively new strategy for analyzing the data of verbal fluency tasks was described and subsequently applied to the data for children with ADHD. Analysis of fluency task data, as presented in chapter 5, revealed that children with ADHD can not be differentiated from controls in terms of the total number of words produced in 60 seconds in either fluency task (semantic category fluency as well as initial letter fluency). The data presented in this chapter are in line with a large number of other studies that found no differences between ADHD children and controls (Barkley, Grodzinsky, & DuPaul, 1992; Fischer, Barkley, Edelbrock, & Smallish, 1990; Grodzinsky & Diamond, 1992; Kusche, Cook, & Greenberg, 1993; Loge, Station, & Beatty, 1990; Pineda, Ardila, & Rosselli, 1999; Reader, Harris, Schuerholz, & Denckla, 1994; Weyandt & Willis, 1994). In contrast, a number of studies found significant differences between children with ADHD and controls on either semantic category fluency or initial letter fluency (Grodzinsky & Barkley, 1999; Grodzinsky & Diamond, 1992; Klorman et al., 1999; Koziol & Stout, 1992; Loge et al., 1990; Pineda et al., 1999; Schuerholz, Singer, & Denckla, 1998). In these last-mentioned studies, children with ADHD performed significantly worse than control children, although initial letter flu-

ency tended to discriminate somewhat better between ADHD and controls than the semantic category fluency (Sergeant, Geurts, & Oosterlaan, 2002).

The study presented in chapter 5 revealed that ADHD children tend to have more problems finding words than control children in the first 15 seconds of the initial letter fluency task, and as compared with their performance on the semantic category fluency. Two explanations can be proposed on the basis of these findings. First, children who show behavior related to ADHD at an early age, in a phase during which brain maturation occurs, may show a defective performance on tests measuring recently acquired automatic processes at a later age when compared with control children and children with one or more psychiatric problems. This idea of impaired automation of skills in ADHD is consistent with the research of Dykman et al. (in Ackerman, Anhalt, Holcomb, & Dykman [1986]). Secondly, the results emphasize the importance of 'testing the limits' when clinically assessing a child with a long history of ADHD characteristics. From the present results, it can be concluded that children classified as having ADHD are able to achieve a similar level of performance as controls if they are given sufficient time to do a task. Thus, not only motivational aspects but also the total time on a task is relevant, in that children with ADHD need enough time to 'start the engine'. These conclusions have implications for behavioral therapy and classroom management. For example, teachers and clinicians should be aware that children with ADHD might have a delayed development of automating skills, which may affect the learning and acquisition of academic skills, such as reading, writing, and mathematics. More instruction, guidelines, and time may help these children to overcome their deficit in verbal automating skills and to function at an equal level as their classmates.

Furthermore, relatively few studies have tested the development of children suffering from ADHD in a longitudinal design. In the studies described in this thesis, children with ADHD were followed up over 3 years. Both children with ADHD and controls were subjected to two neuropsychological evaluations (i.e., neuropsychological evaluation I when the children were approximately 6 years old and neuropsychological evaluation II at 9 years of age). Three cognitive tasks were included in the design as within-subjects variables, measuring either working memory, or visuomotor integration capabilities. The data showed a tendency for all children, regardless of group membership (ADHD or controls) and type of cognitive test included, to have a better overall performance at neuropsychological evaluation II than at neuropsychological evaluation I. Based on these results, it can be concluded that although the level of cognitive functioning at baseline may be different, all groups (whether ADHD, pathological or healthy controls) tend to improve parallel to each other as a function of time. This finding is in accordance with the results of earlier cross-sectional studies (Grodzinsky & Diamond, 1992; Seidman, Biederman, Faraone, Weber, & Ouellette, 1997). Secondly, when measured at the 3-year follow-up, the differences in working mem-

ory as observed at preschool age were still present, but the difference in performance of the visuomotor integration task seen at preschool age was no longer present. It may well be that the ADHD children tended to have an improved ability to transfer information across different modalities, whereas the deficiencies in working memory remained. These neuropsychological findings reflect an underlying brain dysfunction that endures through at least several important stages of the child's development. This is in line with the results of longitudinal studies of behavioral symptomatology in ADHD. In terms of behavioral symptoms, it has been found that a high proportion of patients do not outgrow the problems related to ADHD while passing from childhood to adolescence and adulthood (Hechtman, Weiss, Perlman, & Amsel, 1984; Weiss & Trokenberg Hechtman, 1993).

Also, as mentioned in the introduction, comorbidity has been found to be an important aspect to consider when dealing with children, adolescents, or adults suffering from the syndrome ADHD. In 50 - 80% of the cases, ADHD occurs simultaneously with other psychiatric or developmental problems (reviewed by Biederman, Newcorn, & Sprich [1991] and Jensen, Martin, & Cantwell [1997]). Seidman et al. (1995) suggested that it is crucial to distinguish between the neuropsychological performance of children with ADHD and co-occurring disorders (such as Learning Disabilities) and that of children with ADHD without these co-occurring disorders. This would make it possible to draw conclusions about whether a cognitive profile of weaknesses and strengths is specific for ADHD or whether it can be attributed to a comorbid disorder. The concept of specificity of the results for ADHD has been recognized by many, although relatively little research has been performed in this field. Therefore, the cognitive performance of children suffering from ADHD was compared to that of both healthy controls and pathological control groups (including both behavioral and/or learning abnormalities). Based on the findings described here, it can be concluded that certain cognitive weaknesses are specific for ADHD and not so much for psychopathology in general.

Finally, the general cognitive abilities of the child and its environment have rarely been included as confounding factor in research studying the cognitive profiles of children suffering from ADHD, whereas it would clearly make a stronger case if deficits in specific information processes were still to exist after controlling for variables such as differences in IQ between groups. In some studies described in this thesis, the cognitive performance of children with ADHD was analyzed with and without controlling for their general ability and reading skills and the occupational achievement of the caregiver (LOA). The reason for preferring this two-step way of measuring the effect of covariates on outcome (instead of including all covariates in one step in the analyses) is two-fold. First, some authors claim that between 3% and 10% of the variance in IQ may be a function of symptoms of ADHD (hyperactive-impulsive behavior), and hypothesized that when a difference between ADHD and control groups in IQ is found, it

should probably not be statistically controlled out in the analyses as this may remove some of the variation in the measures under study that is due to ADHD itself (Barkley, 1998). Second, relatively few studies investigating cognitive impairment in children with ADHD have included a measure of socio-economic status (SES). Therefore, little is known about the relation between SES and ADHD (Stevens, Quittner, Zuckerman, & Moore, 2002). However, the results of the studies presented in chapters 5, 6, 7, 8, & 9 were essentially the same with or without controlling for the factors IQ, reading skills, and LOA. After correction for reading scores and an estimate of general abilities, the results did not change significantly. Thus it can be concluded with more certainty that the results found are indeed caused by specific deficits in information processing and not so much by differences in the general abilities of the child or its environment.

In conclusion, the results presented add to current knowledge concerning ADHD. However, additional research is still needed. Some ideas for future studies are mentioned below.

Implications for the clinical and research practice of ‘ADHD’

In both clinical and research settings, there has been an explosion of media and public interest in ADHD; however, many questions remain unanswered, as indicated below.

A. The entity of the diagnosis ‘ADHD’

A high prevalence of co-occurring syndromes has been observed in clinical and epidemiological samples of ADHD children (Biederman et al., 1991). As mentioned above, the inclusion of a pathological control group enables the specificity of, for instance, cognitive deficits for ADHD to be studied (as described in the studies of Kalff et al. (in press, submitted), Kalff et al. (2002), and Kroes et al. (2002) and in the chapters 5, 6, 7, 8, & 9 of this thesis). Results suggest that certain well-defined deficits are specific to ADHD. Additional research is, however, still warranted in this area of comorbid syndromes. For instance, it would be interesting to study the interaction of ADHD, specific comorbid disorders, and performance on specific cognitive tasks, by including both a group of children with ADHD and comorbid disorders and a group of children with pure ADHD (without comorbid disorders) in the study design.

However, even a ‘pure ADHD’ group (without comorbidity) is heterogeneous, because it can be subdivided into the, DSM-IV defined, subtypes of ADHD (ADHD-predominant inattentive type, the ADHD-predominantly hyperactive/impulsive type, and the comorbid type). It is thus highly likely that the cognitive profile of children suffering from the predominant inattentive type of ADHD is different from that of children with the predominant hyperactivity/impulsivity type or the combined type. For instance, Hynd, Lorys et al. (1991) and Morgan, Hynd, Riccio, & Hall (1996) found greater academic underachievement in chil-

dren with ADHD of the predominant inattentive type than in the children with the predominant hyperactive/impulsive type. Unfortunately, these studies often had methodological limitations (e.g., small sample sizes).

Finally, genetic factors have been suggested to play an etiological role in ADHD. However, not all biological (non-adopted) children of parents with ADHD will develop ADHD (Faraone & Biederman, 1994). This diversity in symptomatology, etiology, and comorbidity raises the possibility that familial ADHD is solely a subtype of ADHD. This should be investigated further because the familial form may have stronger biological roots and thereby exhibit a different behavioral and cognitive pattern than other forms of this disorder (Seidman et al., 1997).

In conclusion, more research of the subtypes, subgroups, or comorbidity within the total ADHD group is needed. During the next years, interest should be focused on the following questions: Is the diagnostic label correct? Is it indeed best to use only one term for referring to this diverse group of children or is it better to define subtypes with each a different label that include more specified guidelines for treatment?

B. The contribution of brain research in understanding the phenomenon 'ADHD'

Scientists and clinicians have long been intrigued by children described as being hyperactive, unable to concentrate, often aggressive, defiant, resistant to discipline and excessively emotional. Many terms have been used over the years to describe this pattern of behavior, including the 'brain injured child', 'minimal brain dysfunction', and most recently 'ADHD', and many refer to a possible underlying deficit, namely, dysfunctioning of the brain. As early as 1902 (Still, 1902), an underlying brain abnormality or dysfunction was inferred even though there was no neurological evidence for this. Today, as mentioned in chapter 1, imaging studies point to there being localized abnormalities in diverse brain regions. For example, several authors reported a smaller right prefrontal cortex in ADHD (Filipek et al., 1997; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopoulos, 1990); differences in volume of the caudate nucleus with a corresponding loss of or reversal of the asymmetry found in normal controls (Castellanos et al., 1994; Castellanos et al., 1996; Filipek et al., 1997; Hynd et al., 1993); a smaller globus pallidus (Aylward et al., 1996; Singer et al., 1993), and decreased volume of the corpus callosum (including the posterior "splenium" region and the genu, rostrum, and rostral body in the anterior region) (Baumgardner et al., 1996; Castellanos et al., 1996; Hynd, Semrud-Clikeman et al., 1991). Finally, a smaller total cerebral volume and smaller cerebellum have been reported (Castellanos et al., 1996). Also, the behavior of these children provides strong indications for there being underlying brain deviations. For instance, cognitive deficits are hypothesized to be a core part of ADHD at school-age and are thought to play a major role in the difficult adaptation of children suffering from this disorder

(Seidman et al., 1997). As a group, these children have a sub-average or relatively poor performance on various tasks measuring both input-and output-related information processing. The results of research in neuroimaging, neurology, and neuropsychology are, however, often inconsistent (e.g., the inconsistencies in outcome on the fluency tests or executive functioning as discussed in chapter 5 & 7). Several methodological differences may explain the discrepancies found, including small and mixed-sex samples, variations in diagnosis or diagnostic procedures, and a limited set of outcome measures (Barkley et al., 1992; Sergeant et al., 2002).

In conclusion, it may be that there is an underlying abnormality or dysfunction of brain regions in children with ADHD. More research is needed in which methodological shortcomings are controlled for and research questions answered. Examples of new studies are the long-term influence of ADHD treatment (Ritalin) on the brain as, for instance, measured with SPECT, the relation between ADHD and biological markers, such as sleep or stress-related cortisol levels, and testing of performance on cognitive tests measuring aspects of real-life situations that can occur at home and at school, to increase the generalizability of findings.

C. The diagnosis 'ADHD' and the role of neuropsychology in clinical practice

The diagnosis of 'ADHD' can be both liberating and restricting for a child, its caregivers, and the social environment. Therefore, clinicians should be cautious in making this diagnosis, and it should only be made as a guide for interventional strategies. Caution is also recommended because the sensitivity and specificity of single tests or test batteries is presently insufficient to support a diagnosis of ADHD with a 100% certainty, even though a number of new tests claiming to provide a reliable and valid prediction of ADHD are available. Thorough diagnostics and substantial experience are therefore required to screen for ADHD, and to assess the level of disabilities, possible comorbidity, and the influence of the diagnosis on the school situation, home, and social functioning. Unfortunately, it takes time and experience to diagnose ADHD, and the diagnosis is still uncertain. In table 1, an example is given of the diagnostic data that are minimally needed for the diagnosis and classification of a child with possible ADHD. ADHD is included in the DSM classification system. From this perspective, it seems logical that the psychiatrist guides the diagnostic processes and the subsequent treatment of ADHD. However, as mentioned on various occasions throughout this thesis, increasing evidence supports an underlying brain dysfunction in ADHD, on the basis of which it can be concluded that ADHD is more a neurodevelopmental disorder than a psychiatric syndrome. From this perspective, multidisciplinary ADHD teams should be established, in which a significant role is given to the neuropsychologist in addition to neurologist, neuropsychiatrist, and social pediatrician.

When considering the role of neuropsychology in the diagnosis of ADHD, sev-

eral comments can be made. Firstly, with respect to the cognitive profile and the possible underachievement of children suffering of ADHD, it would be useful for clinical practice if the diagnostic abilities of specific cognitive tests and test batteries were to be re-evaluated in the context of ADHD. For instance, intellectual functioning such as that measured by IQ tests is dependent upon various cognitive functions (such as working memory, verbal skills, and various non-verbal abilities). As shown in this thesis, children with ADHD have several cognitive deficits. Therefore, it may well be that their total IQ scores substantially underestimate their actual level of information processing and cognitive abilities. A second point relates to the relevance of a process analysis in addition to overall test performance. The tendency to focus on test outcome scores should be re-evaluated. As shown in chapters 4 and 5, the most frequently used outcome measure – the total scores on the fluency task – provides only a fraction of the information that is available after the test is completed. Both clinicians and scientists should focus on the underlying processes and qualitative observations instead of solely interpreting outcome scores. Numerous tasks should be re-evaluated for clinical and experimental use. Thirdly, with respect to the specificity of the cognitive profile for ADHD, ADHD often co-occurs with other syndromes (e.g., Conduct Disorder or Oppositional Defiant Behavior) and disabilities (e.g., Learning Disorders), as reviewed by August & Garfinkel (1990), Biederman et al. (1991), Dykman & Ackerman (1991), Jensen et al., (1997), and Semrud-Clikeman et al. (1992). From the literature, it is known that these co-occurring syndromes or disabilities can affect the cognitive abilities of children. For instance, studies have reported that children with learning disabilities score less well on tests measuring higher-order cognitive functions than healthy control subjects (Pennington & Ozonoff, 1996; Seidman et al., 1995). It may be that these comorbid disorders are the main cause of specific deficits in cognitive functioning, and not so much the fact that the child has ADHD. Therefore, the third implication for clinical practice is to increase knowledge concerning the specificity of the cognitive profile of children with ADHD in comparison to other syndromes, as mentioned earlier.

D. Diagnosis of Adult ADHD

Finally, a field open for further investigation is the syndrome of ADHD as expressed during adolescence and adulthood. As mentioned earlier, follow-up studies have consistently documented that the behavioral symptoms of ADHD tend to persist into adolescence and young adulthood (Hechtman et al., 1984; Weiss & Trokenberg Hechtman, 1993). Although relatively little is known about the outcome of ADHD children as young adults, the information that does exist suggests that at least 60% will continue to have symptoms of ADHD (Barkley, 1996). For instance, interpersonal problems continue to plague as many as 75%, and depression and low self-esteem are also common. Therefore, the problems that adults

have to face as a result of earlier ADHD symptoms in childhood range from residual ADHD symptoms that impair home or work adjustment to depression, substance abuse, low self-esteem, accident proneness, and anti-social personality (Weiss & Trokenberg Hechtman, 1993; Wender, Reimherr, & Wood, 1981). Unfortunately, relatively many questions concerning the diagnostic criteria, comorbid disorders, underlying brain functioning, and subsequently treatment of ADHD in adulthood remain unanswered. Therefore, in the future, it is expected that a large number of researchers will study the behavioral and cognitive functioning of adolescents and adults suffering from ADHD.

Conclusion

Considerable research over the years has provided insight into the normal and abnormal development of children, but also new theories and concepts that still need to be tested. In the future, in addition to the fundamental research presented in this thesis, applied research should provide more insight into ADHD, with the main goal of improving the health services (in terms of the diagnosing and treating individuals with ADHD) that can be provided to the children, adolescents, and adults suffering from the consequences of this disorder. However, the main objective should be to improve the quality of life of individuals suffering from ADHD and the social structure they live in.

Table 1. An example of relevant ingredients while diagnosing ADHD.

Behavioral component:	1. Extended systematic evaluation of the DSM criteria by including data from both the caregivers as well as the teacher of the child. Multiple informers are required for several reasons. First, caregivers are believed to overestimate externalizing behavior in their children, while teachers are able to compare the behavior of the child with the norm. Secondly, when a child only reveals overactivity, impulsiveness, or attentional problems in one situation, it may be that the behavior can be explained by some other factor than ADHD (e.g., an unstructured, chaotic environment). 2. Testing the pervasiveness of the behavioral characteristics, in which it is claimed that the deviations in behavior are present in more than 1 situation over a period of more than 6 months.

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	3. Evaluation of comorbidity (such as learning disorders, Conduct Disorder, affective disorders, tic disorders). As mentioned earlier, in a high percentage of cases, children with ADHD have co-occurring syndromes or disorders, which could lead to specific characteristics. Comorbidity often has consequences for the diagnostic process and can have an influence on the natural history of the disorder and on the success of treatment programs. Assessment and treatment of comorbid disorders is often equally important as that of ADHD (Prins & Ten Brink, 2000; Tannock, 1998). 4. Collection of developmental and anamnestic data. Because ADHD is a developmental syndrome, it is necessary to obtain information concerning behavior in the past, but also medical data (such as head trauma, diseases), family history of ADHD, etc. In addition, certain disorders or disabilities can cause a behavioral pattern similar to that of ADHD. After treating these disorders the behavior of the child is assumed to change. Therefore, it is necessary to control for these factors when diagnosing ADHD.
Cognitive / Academic component:	1. Assessment of the strengths and weaknesses of the cognitive profile of the child. This is also relevant in relation to the treatment of children diagnosed as having ADHD. Can the strengths of the child help to adjust for the weaknesses in the profile? 2. Assessment of qualitative performance of neuropsychological tests. Relevant questions here are for instance: Is the speech internalized in the child? Can the child sit still during the test?
Social component:	Assessment of social functioning (e.g. has the child friends? What are its hobbies?).
Familial burden of having a child with ADHD:	To what extent is the family affected by ADHD?

References

- Ackerman, P. T., Anhalt, J. M., Holcomb, P. J., & Dykman, R. A. (1986). Presumably innate and acquired automatic processes in children with attention and/or reading disorders. *Journal of Child Psychology and Psychiatry*, 27, 513-529.
- Adam, J. J., Paas, F. G. W. C., Teeken, J. C., Van Loon, E. M., Van Boxtel, M. P. J.,

- Houx, P. J., & Jolles, J. (1998). Effects of age on performance in a finger-precuing task. *Journal of Experimental Psychology: Human Perception and Performance.*, 24(3), 870-883.
- August, G. J., & Garfinkel, B. D. (1990). Comorbidity of ADHD and reading disability among clinic-referred children. *Journal of Abnormal Child Psychology*, 18, 29-45.
- Aylward, E. H., Reiss, A. L., Reader, M. J., Singer, H. S., Brown, J. E., & Denckla, M. B. (1996). Basal ganglia volumes in children with Attention-Deficit Hyperactivity Disorder. *Journal of Child Neurology*, 11, 112-115.
- Barkley, R. A. (1996). Attention Deficit-Hyperactivity Disorder. In E. J. Mash & R. A. Barkley (Eds.), *Child psychopathology* (pp. 63-112). New York: The Guilford press.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Barkley, R. A., Grodzinsky, G., & DuPaul, G. J. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. *Journal of Abnormal Child Psychology*, 20, 163-188.
- Baumgardner, T. L., Singer, H. S., Denckla, M. B., Rubin, M. A., Abrams, M. T., Colli, M. J., & Reiss, A. L. (1996). Corpus callosum morphology in children with Tourette syndrome and attention deficit hyperactivity disorder. *Neurology*, 4, 477-482.
- Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety and other disorders. *American Journal of Psychiatry*, 148, 564-577.
- Borger, N., & Van der Meere, J. (2000). Motor control and state regulation in children with ADHD: A cardiac response study. *Biological Psychology*, 51, 247-267.
- Castellanos, F. X., Giedd, J. N., Eckburg, P., Marsh, W. L., Vaituzis, A. C., Kaysen, D., Hamburger, S. D., & Rapoport, J. L. (1994). Quantitative morphology of the cadate nucleus in Attention Deficit Hyperactivity Disorder. *American Journal of Psychiatry*, 151, 1791-1796.
- Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D., Vaituzis, A. C., Dickstein, D. P., Sarfatti, S. E., Vauss, Y. C., Snell, J. W., Lange, N., Kaysen, D., Krain, A. L., Ritchie, G. F., Rajapakse, J. C., & Rapoport, J. L. (1996). Quantitative brain Magnetic Resonance Imaging in Attention-Deficit Hyperactivity Disorder. *Archives of General Psychiatry*, 53, 607-616.
- Douglas, V. I. (1999). Cognitive control processes in Attention Deficit Hyperactivity Disorder. In H. C. Quay & A. E. Hogan (Eds.), *Handbook of disruptive behavior disorders*. (pp. 105-138). New York: Plenum Press.
- Dykman, R. A., & Ackerman, P. T. (1991). Attention deficit disorder and specific reading disability: Separate but often overlapping disorders. *Journal of Learning Disabilities*, 24, 95-103.
- Faraone, S., & Biederman, J. (1994). Genetics of attention-deficit hyperactivity disorder. *Child and Adolescent Psychiatric Clinics of North America*, 3, 285-302.
- Filipek, P. A., Semrud-Clikeman, M., Steingard, R. J., Renshaw, P. F., Kennedy, D. N., & Biederman, J. (1997). Volumetric MRI analysis comparing subjects having attention-deficit hyperactivity disorder with controls. *Neurology*, 48, 589-601.

- Fischer, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: II. Academic, attentional, and neuropsychological status. *Journal of Consulting and Clinical Psychology, 58*, 580-588.
- Grodzinsky, G. M., & Barkley, R. A. (1999). Predictive power of frontal lobe tests in the diagnosis of Attention Deficit Hyperactivity Disorder. *Clinical Neuropsychologist, 13*, 12-21.
- Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention deficit hyperactivity disorder. *Journal of Clinical Psychology, 45*, 427-446.
- Hechtman, L., Weiss, G., Perlman, T., & Amsel, R. (1984). Hyperactives as young adults: Initial predictors of adult outcome. *Journal of the American Academy of Child Psychiatry, 23*, 250-260.
- Hynd, G. W., Hern, K. L., Novey, E. S., Eliopoulos, D., Marshall, R., Gonzalez, J. J., & Voeller, K. K. (1993). Attention Deficit-Hyperactivity Disorder and asymmetry of the caudate nucleus. *Journal of Child Neurology, 8*(339-347).
- Hynd, G. W., Lorys, A. R., Semrud-Clikeman, M., Nieves, N., Huettner, M. I. S., & Lahey, B. B. (1991). Attention deficit disorder without hyperactivity: A distinct behavioral and neurocognitive syndrome. *Journal of Child Neurology, 6*, S37-S43.
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., & Eliopoulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder with hyperactivity. *Archives of Neurology, 919-926*.
- Hynd, G. W., Semrud-Clikeman, M., Lorys, A. R., Novey, E. S., Eliopoulos, D., & Lyytinen, H. (1991). Corpus callosum morphology in Attention Deficit-Hyperactivity Disorder: Morphometric analysis of MRI. *Journal of Learning Disabilities, 24*, 141-146.
- Jensen, P. S., Martin, B. A., & Cantwell, D. P. (1997). Comorbidity in ADHD: Implications for research, practice, and DSM-IV. *Journal of the American Academy Child and Adolescent Psychiatry, 36*, 1065-1079.
- Kalff, A. C., De Sonneville, L. M. J., Hurks, P. P. M., Hendriksen, J. G. M., Kroes, M., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., Vles, J. S. H., & Jolles, J. (in press). Low- and high-level controlled processing in executive motor control tasks in 5/6-year-old children at risk of ADHD. *Journal of Clinical Psychology and Psychiatry*.
- Kalff, A. C., De Sonneville, L. M. J., Hurks, P. P. M., Hendriksen, J. G. M., Kroes, M., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., Vles, J. S. H., & Jolles, J. (submitted). Speed, speed variability, and accuracy of information processing in 5/6-year-old children at risk of ADHD. *Journal of the American Academy Child and Adolescent Psychiatry*.
- Kalff, A. C., Hendriksen, J. G. M., Kroes, M., Vles, J. S. H., Steyaert, J., Feron, F. J. M., Van Zeben, T. M. C. B., & Jolles, J. (2002). Neurocognitive performance of 5- and 6-year-old children who met criteria for Attention Deficit/Hyperactivity Disorder at 18 months follow-up: Results from a prospective population study. *Journal of Abnormal Child Psychology, 30*(6), 589-598.
- Klorman, R., Hazel-Fernandez, L. A., Shaywitz, S. E., Fletcher, J. M., Marchione, K. E., Holehan, J. M., Stuebing, K. K., & Shaywitz, B. A. (1999). Executive function-

- ing deficits in Attention Deficit/Hyperactivity Disorder are independent of Oppositional Defiant or Reading Disorder. *Journal of the American Academy Child and Adolescent Psychiatry*, 38, 1148-1155.
- Koziol, L. F., & Stout, C. E. (1992). Use of a verbal fluency measure in understanding and evaluation ADHD as an executive function disorder. *Perceptual and Motor Skills*, 75, 1187-1192.
- Kroes, M., Kessels, G. H., Kalff, A. C., Feron, F. J. M., Vissers, Y., Jolles, J., & Vles, J. S. H. (2002). Quality of movement as predictor of ADHD: Results from a prospective population study in 5- and 6-year-old children. *Developmental Medicine and Child Neurology*, 44, 753-760.
- Kusche, C. A., Cook, E. T., & Greenberg, M. T. (1993). Neuropsychological and cognitive functioning in children with anxiety, externalizing, and comorbid psychopathology. *Journal of Clinical Child Psychology*, 22, 172-195.
- Lezak, M. D. (1995). *Neuropsychological assessment* (3 ed.). Oxford: Oxford University Press.
- Loge, D. V., Station, R. D., & Beatty, W. W. (1990). Performance of children with ADHD on tests sensitive to frontal lobe dysfunction. *Journal of the American Academy of Child and Adolescent Psychiatry*, 29, 540-545.
- Monsch, A. U., Bondi, M. W., Butters, N., Paulsen, J. S., Salmon, D. P., Brugger, P., & Swenson, M. R. (1994). A comparison of category and letter fluency in Alzheimer's disease and Huntington's disease. *Neuropsychology*, 8, 25-30.
- Morgan, A. E., Hynd, G. W., Riccio, C. A., & Hall, J. (1996). Validity of DSM-IV ADHD Predominantly Inattentive and Combined Types: Relationship to previous DSM diagnoses/syndrome differences. *Journal of the American Academy Child and Adolescent Psychiatry*, 35, 325-333.
- Pennington, B. E., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, 37, 51-87.
- Perchet, C., Revol, O., Fournier, P., Mauguère, F., & Garcia-Larrea, L. (2001). Attention shifts and anticipatory mechanisms in hyperactive children: An ERP study using the Posner paradigm. *Biological Psychiatry*, 50, 44-57.
- Pineda, D., Ardila, A., & Rosselli, M. (1999). Neuropsychological and behavioural assessment of ADHD in 7- to 12-year-old children: A discriminant analysis. *Journal of Learning Disabilities*, 32(2), 159-173.
- Prins, P., & Ten Brink, E. (2000). Richtlijnen voor een multimodale behandeling van ADHD. In P. Prins & N. Pameijer (Eds.), *Protocolen in de jeugdzorg: Richtlijnen voor diagnostiek, indicatiestelling en interventie*. Lisse: Swets & Zeitlinger.
- Reader, M. J., Harris, E. L., Schuerholz, L. J., & Denckla, M. B. (1994). Attention Deficit Hyperactivity Disorder and executive dysfunction. *Developmental Neuropsychology*, 10, 493-512.
- Schuerholz, L. J., Singer, H. S., & Denckla, M. B. (1998). Gender study of neuropsychological and neuromotor function in children with Tourette syndrome with and without Attention-Deficit Hyperactivity Disorder. *Journal of Child Neurology*, 13, 277-282.
- Seidman, L. J., Benedict, K., Biederman, J., Bernstein, J., Seiverd, K., Milberger, S., Norman, D., Mick, E., & Faraone, S. (1995). Performance of ADHD children on

- the Rey-Osterrieth complex figure: A pilot neuropsychological study. *Journal of Child Psychology and Psychiatry*, 36, 1459-1473.
- Seidman, L. J., Biederman, J., Faraone, S. v., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of Attention Deficit-Hyperactivity Disorder: Performance of children and adolescents from a large clinically referred sample. *Journal of Consulting and Clinical psychology*, 65(1), 150-160.
- Seidman, L. J., Biederman, J., Faraone, S. V., Milberger, S., Norman, D., Seiverd, K., Benedict, K., Guite, J., Mick, E., & Kiely, K. (1995). Effects of family history and comorbidity on the neuropsychological performance of children with ADHD: Preliminary findings. *Journal of the American Academy Child and Adolescent Psychiatry*, 34, 1015-1024.
- Semrud-Clikeman, M., Biederman, J., Sprich-Buckminster, S., Lehman, B. K., Faraone, S. V., & Norman, D. (1992). Comorbidity between ADDH and learning disability: A review and report in a clinically referred sample. *Journal of the American Academy Child and Adolescent Psychiatry*, 31, 439-448.
- Sergeant, J. A., Geurts, H., & Oosterlaan, J. (2002). How specific is a deficit of executive function for Attention-Deficit/Hyperactivity Disorder? *Behavioural Brain Research*, 130, 3-28.
- Singer, H. S., Reiss, A. L., Brown, J. E., Aylward, E. H., Shih, B., Chee, E., Harris, E. L., Reader, M. J., Chase, G. A., Bryan, R. N., & Denckla, M. B. (1993). Volumetric MRI changes in basal ganglia of children with Tourette's syndrome. *Neurology*, 43, 950-956.
- Stevens, J., Quittner, A. L., Zuckerman, J. B., & Moore, S. (2002). Behavioral inhibition, self-regulation of motivation, and working memory in children with Attention Deficit Hyperactivity Disorder. *Developmental Neuropsychology*, 21(2), 117-139.
- Still, G. F. (1902). Some abnormal psychical conditions in children. *The Lancet*, 1, 1008-1012, 1077-1082, 1163-1168.
- Tannock, R. (1998). Attention Deficit Hyperactivity Disorder: Advances in cognitive, neurobiological and genetic research. *Journal of Child Psychology and Psychiatry*, 39, 65-99.
- Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology*, 22(3), 370-378.
- Verhulst, F. C. (1999). *De ontwikkeling van het kind* (5th ed.). Assen: Van Gorcum.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children, adolescents and adults*. (2 ed.). New York: The Guilford Press.
- Wender, P. H., Reimherr, F. W., & Wood, D. R. (1981). Attention deficit disorder ('minimal brain dysfunction') in adults. A replication study of diagnosis and drug treatment. *Archives of General Psychiatry*, 38(4), 449-456.
- Weyandt, L. L., & Willis, W. G. (1994). Executive functions in school-aged children: Potential efficacy of tasks in discriminating clinical groups. *Developmental Neuropsychology*, 10(1), 27-38.

Over the last decades, many articles have been written about the processes underlying childhood development. Additional research in this field is, however, still needed and should focus specifically on certain domains, as stated earlier by several authors (e.g., Verhulst (1999)). First, it is important to understand the processes underlying normal development and to examine the factors that influence these processes. Secondly, more needs to be known of the etiology, course, prevalence, and treatment of abnormal functioning. In this thesis, childhood development was investigated by studying healthy children as well as children in whom development was deviant. An overview of this thesis is given below.

ADHD is one of the most frequently monitored developmental disorders worldwide and is known to occur in different cultures. Prevalence estimates fluctuate between 1% and 20% (with an average of 3 - 5% for the general population [Barkley, 1998; Kroes et al., 2001]), depending on the strictness with which criteria are applied, cultural differences, and the degree of consensus between caregivers, teachers, and physicians (Dinklage & Barkley, 1997). According to the latest edition of the DSM (American Psychiatric Association, 1994), the syndrome can be defined best with comprehensive terms such as attention deficits, impulsive behavior, and hyperactivity. However, because almost all children will show some of the predefined characteristics at some stage, one can only speak of ADHD under strict conditions, including preset definitions related to the duration of symptomatology (over at least 6 months), its severity (at least in two domains e.g. at home and at school) and concordance between relatives of the child (e.g. teacher and parent). Over the years, many researchers have studied the etiology of ADHD. Although information is at times inconsistent, much has been learned in the past decades. Preliminary results lead to the conclusion that no single etiological factor can explain all cases of the clinical syndrome 'ADHD', and that more likely an interaction between both psychosocial and biological factors leads to a final common pathway of the syndrome. However, ADHD is often related to localized hemispheric structural abnormalities and/or dysfunctions in, for instance, the frontal-striatal areas and connections, the cerebellum, and the basal ganglia. Also, the behavior of these children reflects these underlying brain deviations. For instance, cognitive deficits are hypothesized to be a core part of ADHD in school-aged children and are thought to play a major role in the difficult adaptation of children suffering from this disorder (Seidman, Biederman, Faraone, Weber, & Ouellette, 1997). As a group, these children exhibit sub-average or relatively weak performance on various tasks measuring both input- and output-related information processing (Barkley, 1998; Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). In contrast to what was thought earlier, follow-up studies have consistently documented that ADHD symptoms tend to persist into adolescence and young adulthood (Barkley, 1996; Hechtman, Weiss, Perlman, & Amsel, 1984; Weiss & Trokenberg Hechtman, 1993). Although relatively little is known about the long-term outcome of ADHD, available data sug-

gest that the problems that adults have to face as a result of earlier ADHD symptoms in childhood range from residual ADHD symptoms that impair home or work adjustment to depression, substance abuse, low self-esteem, accident proneness, and anti-social personality (Weiss & Trokenberg Hechtman, 1993; Wender, Reimherr, & Wood, 1981). In summary, ADHD is a prevalent and serious disorder affecting the entire life span of the affected individual as well as that person's social environment, and thus it is important to learn more about the etiology, developmental profile, diagnostic trademarks, and treatment of this disorder. Unfortunately, even though an explosion of media and scientific attention has served to increase our awareness and knowledge of ADHD, there is still confusion or misunderstanding about the disorder. In **chapter 1** of the thesis, an outline is presented of current knowledge of ADHD in terms of history, prevalence rates, sex differences, etiology, and outcome. The limitations of presently available data are discussed and a link is made to new research that increases knowledge about the etiology and developmental profile of children suffering of ADHD. In order to learn more about ADHD, it is essential to increase simultaneously our understanding of the executive control functions in healthy development, from a neurocognitive and behavioral point of view. Knowledge of healthy cognitive development and of the influence of behavioral, biological, and contextual characteristics of the child is important to future research of ADHD.

The present thesis consists of two parts. In the part I (chapters 2 – 4), several aspects of behavior (e.g., sleep, externalizing and internalizing behavior) and cognition (e.g., verbal fluency, visuomotor preparation) were investigated in a general population of 5- to 9-year-old Dutch children. Secondly, because another main goal of the thesis was to increase knowledge of the cognitive development of children with ADHD, the data collected in the first part and of studies conducted by other researchers were used to generate a number of new research questions. These research questions were discussed more thoroughly in the second part of the thesis, namely, in chapters 5 to 9.

PART I

The term 'development' can be defined as 'a long-term, irreversible process, leading to an organization on a higher and integrated level' (Mönks & Knoers, 1978). Human development can be seen in this perspective as a dynamic-interactive process, in which both genetically determined autonomic factors and external factors (e.g., experience, and environment) are important. Many clinicians and researchers have studied the concept of 'development' from diverse perspectives (for instance, a biological, social, medical, or cognitive perspective). Below, the focus is on specific aspects of development (in terms of cognition and behavior).

The goal of the study presented in **chapter 2** was to elucidate risk factors relevant for identifying children at risk of failure at school (academic delay or transfer to special education) in a general population. Data related to the biological and contextual characteristics and the behavior of the child were collected for 1317 preschool-aged children living in the Limburg area in the Netherlands. After deletion of missing data on the continuous and non-continuous predictors, data from 1235 children were available for analysis. Subsequently, 3 years later, the school career of these children was mapped. Based on these data, three mutually exclusive categories were created: (I) Children who had passed through school successfully ($n = 924$); (II) Children who had stayed down at least one class (before or after inclusion in the study at kindergarten) but who were still learning within the normal school environment ($n = 277$); (III) Children who were transferred, after inclusion in the study at preschool age, from a normal school to a school for children with special needs ($n = 34$). The approach used in this study was new with regard to (a) the longitudinal component of the study, (b) the earlier mentioned benefit of the inclusion of a general population sample, and (c) that the children were assessed in early childhood, at the time when they had just entered the first classes of a normal school. Data analysis revealed that a model predictive for school outcome consisted of biological, contextual, and behavioral factors. Behavioral variables registered at kindergarten that appeared to be predictive for later school career were scores on the Child Behavior Checklist (CBCL) attention problems scale and the CBCL delinquency scale. In addition, the level of occupational achievement, sex of the child, age of mother at birth, number of children in the family, living area, and family status appeared to be a predictor of school career.

The first aim of the study presented in **chapter 3** was to study the association between contextual, biological, and behavioral characteristics of a child on the one hand and sleep on the other. For this purpose, several aspects related to sleep (e.g., presence of nightmares, amount of sleep, sleep problems in general) were examined in a non-clinical population of 5- to 6-year-old Dutch preschool-aged children ($n = 1258$). The results of this first experiment showed that sleep problems were commonly observed in preschool-aged children. Rates of parental reports of sleep problems, as observed in their child at least sometimes, ranged from 3.9% for an increased amount of sleep to 17.9% for nightmares, with general sleep problems (11.8%), sleep walking/talking (14.9%), and a decreased amount of sleep (11.4%) being intermediate. In addition, it was found that certain behavioral (e.g., physical complaints, thought problems, aggressive behavior, and anxiety/depression) and contextual (e.g., the level of occupational achievement of the caregiver, the number of children in the family, family status, and the age of the mother at birth) characteristics of preschool-aged children were correlated highly with specific parent-reported sleep problems. The second research ques-

tion addressed the stability of sleep as a function of time. A sample of the children screened at preschool age (286 of the 1258 children) was screened again 3 years later by means of the CBCL. Data obtained were compatible with the notion that problematic sleep and specific behavioral aspects (such as having attention problems) measured at preschool age were predictive of sleep problems 3 years later. This finding emphasizes the relevance of teaching parents about good sleep hygiene for their child in the hope of preventing more serious or chronic sleep-related problems.

The study presented in **chapter 4** evaluated the performance on Semantic Category Fluency (SCF) versus Initial Letter Fluency (ILF) tasks of 91 healthy children aged 8.4 - 9.7 years. Verbal fluency was operationalized as the number of words produced in a restricted category in 60 seconds. In addition, word production in the first 15 seconds of either type of fluency task was taken as a measure of automatic information processing, whereas production from 15 seconds through 1 minute was taken as a measure of controlled information processing. Data revealed that in 60 seconds children produced significantly more words on the SCF tasks than on the ILF tasks, a pattern that differed from that known for adults. Furthermore, word production decreased significantly as a function of time on both SCF and ILF tasks. Data for performance over time suggested that children tended (equally for both types of fluency) to produce more correct answers over the first 15 seconds of a specific test compared to later time intervals (with equal duration). Also, word production on both types of fluency tasks was not identical across time intervals, suggesting that production is a function of both type of task and time samples. Finally, no sex or age differences were found for all measures of performance on either type of fluency tasks. In contrast, the level of occupational achievement of the caregiver (LOA) appeared to be a significant determinant of the child's performance on either type of fluency, indicating that LOA affected higher-order processes, such as the automation of newly learned verbal skills and effortful processing.

PART II

Over the past decades, ADHD has received increased attention from both clinicians and researchers. Although there has been a virtual explosion of media and public interest in the subject, there is still confusion and misunderstanding about the disorder. Therefore, there is a continuing need for discussion about ADHD. From this perspective, the primary goal of the earlier studies of this thesis was to examine risk factors and cognitive developmental profiles of children suffering from ADHD and to measure the specificity of these profiles by comparing the profiles of ADHD children with those of pathological controls and healthy individuals.

The performance of ADHD children on SCF versus ILF tasks was examined in **chapter 5**. For each participant, word production was recorded for each 15-s time slice on each task. Performance on both fluency tasks was compared to test the hypothesis that children with ADHD are characterized by a performance deficit on the ILF task because performance on this task is less automated than performance on the SCF. Children classified with ADHD (N = 20) were compared to children with other psychopathology (N = 118) and healthy controls (N = 130). Results indicated that the groups could not be differentiated by the total number of words produced in 60 seconds in either fluency task. As hypothesized, a significant interaction of group by productivity over time by type of fluency task was found: ADHD children had more problems finding words in the first 15 seconds of the IFL than did children in the other two groups, and as compared with their performance on the SCF. Results were taken to indicate that children with ADHD symptoms show a delay in the development of automating skills for processing abstract verbal information.

As far as we know, there have been no published investigations of visuomotor preparation in ADHD. This is unfortunate because ADHD research suggests that an output-related deficit and faulty or sub-optimal execution of tasks can be the result of faulty or incomplete preparation. Therefore, the main goal, as stated in **chapter 6**, was to study (automatic and controlled) visuomotor preparation in ADHD, as measured with the Finger Precuing Test (FPT). Two independent variables were manipulated, namely, *preparation condition* and *preparation interval*. The first variable reflects the type of cue given before the reaction stimulus was displayed (three cued conditions (hand-, finger-, neither-cued) vs. one uncued condition). The second variable reflects the time span between cue onset and reaction stimulus onset (100 ms (as a measure of automatic processing) vs. 1000 ms (effortful processing)). The data revealed that, for all cued conditions, healthy children and children with psychopathology other than ADHD were able to profit only from the unimanual hand-cued condition, both automatically and effortful. In contrast, ADHD children were able to benefit from a cue involving two fingers on one hand with a 100-ms preparation interval, but not with a 1000-ms preparation interval. This dissociation suggests that fast, automatic response preparation is not affected by ADHD, whereas attention-demanding or controlled response preparation is. Additionally, children with ADHD showed more variability in overall test performance than children in the other groups. No group differences were found in the accuracy of responses. In conclusion, ADHD seems to be associated with an impaired ability to engage in effortful, controlled visuomotor preparation activities.

Although many theories have been proposed to explain ADHD symptomatology, one of the main theories is that prefrontal circuits are dysfunctional in children

suffering from ADHD. Research results provide evidence of a deficit in some aspects of executive functioning in ADHD children. Unfortunately, these results are not always consistent within the ADHD sample, possibly reflecting sample differences within the ADHD spectrum or differences in the definition of ADHD used between studies. To further our insight into this topic, an extensive study described in **chapter 7** was performed according to a design in which several confounders were taken into consideration, to test executive functioning in ADHD and the specificity of a possible deficit. Children classified with ADHD were compared to children with Conduct Disorder or Oppositional Defiant Disorder (CD/ODD), children with pathology other than ADHD, CD, or ODD (Pathological controls), and normal controls. Five tests were administered to test diverse aspects of executive functioning, that is, the Stroop test, a concept shifting task, verbal fluency tasks, and working memory tasks. To reduce the numerous executive functioning measures to their principal dimensions, a principal components factor analysis was conducted. Five factors were identified, accounting for 74.1% of the variance, namely, attention capacity, Stroop inhibition, simple motor performance, cognitive flexibility, and working memory. In contrast to our expectations, some aspects of executive functioning (e.g., inhibition, working memory, and simple motor performance) did not differentiate between groups (ADHD, CD/ODD, pathological controls, and normal controls). In contrast, aspects of executive functioning that did differentiate between groups were attention capacity and cognitive flexibility. However, significant interactions of sex by group membership were found for these last-mentioned functions. Post-hoc analyses indicated that attention deficits were more prevalent in girls with ADHD, whereas boys with ADHD tended to perform significantly worse on tasks measuring cognitive flexibility and concept shifting. Furthermore, the deficits found in ADHD on tasks measuring executive functioning were specific for ADHD and not for childhood psychopathology in general and were not influenced by general ability and reading skills.

Although the additive value of neuropsychological tests for diagnosing ADHD is increasingly acknowledged, more research into the cognitive functioning of these children is still needed. Therefore, the first objective of the study presented in **chapter 8** was to test the value of cognitive tests in differentiating ADHD children from control children. The second objective was related to comorbidity in ADHD. From the literature it is known that ADHD often co-occurs with other disabilities (such as learning disabilities) and that these co-occurring disabilities by themselves can affect the cognitive abilities of a child. Distinguishing between the neuropsychological performance of children with ADHD and learning disabilities (LD) on the one hand and children with ADHD without LD on the other is therefore crucial. By studying this distinction, it can be concluded with more certainty whether a certain cognitive profile is specific for ADHD. Therefore, the

second aim of the study presented in this chapter was to study the specificity of a certain profile of cognitive functioning for ADHD. To fulfill these aims, three groups were included in the analyses, namely (i) a group of children with ADHD (aged 8.9 ± 1.9 years), (ii) a group of children with ADHD and co-occurring learning disabilities in either mathematics or reading (ADHD/LD; aged 9.3 ± 1.5 years), and (iii) a group of control children (aged 9.1 ± 1.8 years). As a main outcome variable, information processing as measured by the Kaufman Achievement Battery of Children (K-ABC) was chosen. Results indicated that children with ADHD (with or without Learning Disabilities) performed significantly worse on the Mental Processing scale of the K-ABC (as a measure of general abilities) than the controls. Additional analyses revealed that, while controlling for sex, age, and type of school the child attended, the groups did not differ in performance on tasks measuring perceptual abilities, reasoning, and visual-constructive abilities. In contrast, children with ADHD and with ADHD/LD scored significantly less well than the controls on tests measuring (verbal) working memory and temporal processing skills. With respect to the second objective of the study, no significant differences were found between children with ADHD and children with ADHD/LD. Based on this last result, it can be concluded with more certainty that the cognitive deficits in working memory and temporal processing skills seen in children with ADHD are caused primarily by ADHD and that learning disabilities have only a minor role.

An aspect of research that has received limited coverage is the cognitive development of children with ADHD. It is still unclear whether the neuropsychological abnormalities found in relation to ADHD reflect an underlying brain dysfunction that endures over a longer period in the life of the individual, or whether, in contrast, it is possible that a child suffering from ADHD outgrows the neuropsychological abnormalities. The aim of **chapter 9** was, therefore, to study the cognitive performance of children suffering from ADHD in a longitudinal design. In total, three groups were selected, namely (a) a group of children classified as having ADHD, (b) a group of children classified with psychopathology other than ADHD, and (c) a group of healthy control children. All groups were subjected to two neuropsychological evaluations (evaluation I when the children were approximately 5/6 years old and evaluation II at 9/10 years of age). Three cognitive tasks were included in the design as within-subjects variables, measuring either working memory or visual motor integration capabilities. Within-group analyses showed that the performance of all groups improved as time passed. Between-group comparisons revealed that children with ADHD performed at neuropsychological evaluation I significantly less well than children in both control groups on tasks measuring working memory and/or visual-motor integration. Three years later (at evaluation II) this trend was only still observable for tasks measuring working memory. No differences in test performance at follow-up

were found on the task measuring visual motor integration. In summary, it can be concluded that while children with ADHD outgrow certain deficits (e.g., cross-modal transfer of information) as they grow up, other deficits remain.

In the last chapter of the thesis (namely **chapter 10**), an overview is provided of the main results of the thesis, limitations of current data on the subjects' 'normal and subclinical development' and 'ADHD', and the implications of findings for scientific research and their possible clinical application. Emphasis is on the increasingly accepted role of the neuropsychologist, and neuropsychological tools and insights used for cognitive assessment and training. Based on the data presented in this final chapter, it can be concluded that research performed over the years has provided new insights into normal and abnormal development, but also new theories and ideas that still need to be tested. In the future, in addition to the fundamental research presented in this thesis, applied research should provide more insight into ADHD, with the main goal of improving the health services (in terms of the diagnosing and treating individuals) that can be provided to the children, adolescents, and adults suffering from the consequences of attention disorders.

References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1996). Attention Deficit-Hyperactivity Disorder. In R. A. Barkley (Ed.), *Child psychopathology* (pp. 63-112). New York: The Guilford press.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Hechtman, L., Weiss, G., Perlman, T., & Amsel, R. (1984). Hyperactives as young adults: Initial predictors of adult outcome. *Journal of the American Academy of Child Psychiatry*, 23, 250-260.
- Kroes, M., Kalff, A. C., Kessels, A. G. H., Steyaert, J., Feron, F., Van Someren, A. J. W. G. M., Hurks, P. P. M., Hendriksen, J. G. M., Van Zeven, T. M. C. B., Rozendaal, N., Crolla, I. F. A. M., Troost, J., Jolles, J., & Vles, J. S. H. (2001). Child psychiatric diagnoses in a population of Dutch schoolchildren aged 6 to 8 years. *Journal of the American Academy of Child and Adolescent Psychiatry*, 40(12), 1401-1409.
- Mönks, F. J., & Knoers, A. M. P. (1978). *Ontwikkelingspsychologie: Inleiding tot de verschillende deelgebieden* (3th ed.). Nijmegen: Dekker & Van der Vegt.
- Perugini, E. M., Harvey, E. A., Lovejoy, D. W., Sandstrom, K., & Webb, A. H. (2000). The predictive power of combined neuropsychological measures for Attention-Deficit/Hyperactivity Disorder in children. *Child Neuropsychology*, 6(2), 101-114.
- Seidman, L. J., Biederman, J., Faraone, S. v., Weber, W., & Ouellette, C. (1997). Toward defining a neuropsychology of Attention Deficit-Hyperactivity Disorder: Performance of children and adolescents from a large clinically referred sample.

- Journal of Consulting and Clinical psychology*, 65(1), 150-160.
- Verhulst, F. C. (1999). *De ontwikkeling van het kind* (5th ed.). Assen: Van Gorcum.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children , adolescents and adults*. (2 ed.). New York: The Guilford Press.
- Wender, P. H., Reimherr, F. W., & Wood, D. R. (1981). Attention deficit disorder ('minimal brain dysfunction') in adults. A replication study of diagnosis and drug treatment. *Archives of General Psychiatry*, 38(4), 449-456.

Ontwikkeling is inherent aan het leven zelf. Desalniettemin is de groei, zowel op lichamelijk, cognitief, als sociaal niveau, nergens zo uitgesproken als op jonge leeftijd. Verhulst (1999) gaf eerder aan, dat de kennis t.a.v. de ontwikkeling in de kindertijd middels twee typen van onderzoek uitgebreid dient te worden. Ten eerste moet het onderzoek zich richten op het verbreden van de kennis omtrent het begrip 'normale ontwikkeling' en de factoren die daarop van invloed zijn. Ten tweede is het van belang om inzicht te verwerven in het ontstaan, het beloop, de prevalentie en de behandeling van abnormaal functioneren, zoals bijvoorbeeld het geval is wanneer een kind lijdt aan een aandachtsstoornis. In het huidige proefschrift is er voor gekozen om het inzicht t.a.v. ontwikkeling bij kinderen te vergroten door zowel gezonde kinderen als kinderen met een deviante ontwikkeling te onderzoeken. In de volgende paragrafen zal een overzicht gegeven worden van de hoofdstukken, op basis waarvan het proefschrift opgebouwd is.

Een van de meest voorkomende stoornissen gediagnosticeerd op jonge leeftijd is 'ADHD' (of voluit: Attention-Deficit/Hyperactivity Disorder). Volgens het classificatiesysteem DSM-IV (American Psychiatric Association, 1994), is er bij ADHD sprake van een verstoorde aandacht, een hyperactiviteit, een impulsief handelen, of een combinatie van deze kenmerken. Er kan echter enkel gesproken worden van ADHD als het inefficiënte of afwijkende handelen van het kind leidt tot een ernstige verstoring in het sociaal, cognitief of schools functioneren. Daarnaast dient het afwijkende gedrag reeds op jonge leeftijd in twee of meer situaties (bijvoorbeeld op school en thuis) en over een periode langer dan 6 maanden aanwezig te zijn. Lange tijd is er verondersteld dat kinderen met ADHD over hun problemen heen groeien naarmate zij ouder worden. Echter, toenemend blijkt het tegenovergestelde waar te zijn: kinderen met ADHD nemen in veel gevallen hun problemen mee in de adolescentie en de volwassenheid (Barkley, 1996; Hechtman, Weiss, Perlman, & Amsel, 1984; Weiss & Trokenberg Hechtman, 1993). Daarnaast blijkt toenemend dat het gedrag kenmerkend voor ADHD verklaard kan worden door o.a. abnormaliteiten en/of disfunctioneren van specifieke hersenstructuren, zoals bijvoorbeeld de prefrontaal cortex, het cerebellum, en de basale ganglia. Aanwijzingen voor afwijkingen in hersenstructuren en het functioneren ervan worden ook gevonden wanneer men kijkt naar het cognitief functioneren van kinderen met ADHD. Voorbeelden van specifieke cognitieve problemen in ADHD zijn: problemen t.a.v. de volgehouden aandacht (uitgedrukt in een hoge mate van variabiliteit in testprestaties en een afgenomen accuraatheid) en slechtere prestaties op taken die diverse aspecten van executief functioneren meten (zoals het internaliseren van spraak, de zelfregulatie en het werkgeheugen) (Barkley, 1998; Perugini, Harvey, Lovejoy, Sandstrom, & Webb, 2000). Kort samengevat, is ADHD dan ook een complexe stoornis die grote invloed heeft op de ontwikkeling van het kind en zijn omgeving. Het verkrijgen van inzicht in pathogenese en de ontwikkeling van kinderen met ADHD is van groot belang, mede met het oog op de ontwikkeling van optimale diagnostiek en het vroegtijdig

kunnen behandelen van deze doelgroep. Inzicht in de ontwikkeling van het kind met ADHD in de tijd en de specificiteit van deze bevindingen t.a.v. ADHD ontbreken echter nog veelal in de mondiale literatuur. Vanuit deze overwegingen worden er in **hoofdstuk 1** van het proefschrift een aantal aanbevelingen gedaan om dit inzicht te vergroten. Om dit laatste echter te bereiken zal er tegelijkertijd meer inzicht in de ontwikkeling van gezonde kinderen en kinderen met een subklinisch niveau van aandachts- en gedragsproblemen verkregen moeten worden. Derhalve is er voor gekozen om de hoofdstukken 2 t/m 10 van het proefschrift onder te verdelen in enerzijds een gedeelte dat betrekking heeft op de normale en subklinische ontwikkeling en aspecten van het kind en zijn omgeving die deze ontwikkeling kunnen beïnvloeden (deel I: hst. 2 t/m 4) en anderzijds een gedeelte dat betrekking heeft op de pathologische ontwikkeling en meer specifiek de ontwikkeling van kinderen met ADHD (deel II: hst. 5 t/m 10).

DEEL I

De term ‘ontwikkeling’ wordt in de literatuur gedefinieerd als ‘een langdurig, onomkeerbaar proces, dat leidt tot een organisatie op een hoger en geïntegreerd niveau’ (Mönks & Knoers, 1978). De ontwikkeling van de mens kan daarbij gezien worden als een dynamisch-interactief proces, waarbij zowel genetisch vastgelegde, autonome factoren als wel de op de ontwikkeling inwerkende externe factoren, als ervaring, training en omgevingsinvloeden, een belangrijke rol spelen. Vele klinische en wetenschappelijke disciplines hebben vanuit hun eigen invalshoek (o.a. vanuit een medisch, biologisch, sociaal, en cognitief perspectief) gekeken naar het concept ‘ontwikkeling’. In dit eerste gedeelte van het proefschrift wordt slechts een beperkt aantal vragen beantwoord, op basis waarvan geconcludeerd kan worden dat o.a. vroegtijdig gesignaleerde aandachtsproblematiek een grote invloed heeft op de ontwikkeling van kinderen.

Zo is er in **hoofdstuk 2** gepoogd om reeds op jonge leeftijd kinderen te identificeren, die een verhoogd risico hebben op het falen op school. Kan er bijvoorbeeld op basis van kenmerken van het kind of zijn/haar omgeving, zoals gemeten op kleuterleeftijd, voorspeld worden welke kinderen naar verloop van tijd blijven zitten en/of welke kinderen uiteindelijk overgeplaatst worden naar het speciaal basisonderwijs? Om een antwoord te kunnen geven op deze vraag, zijn een groot aantal kinderen geïncludeerd, die alle ten tijde van inclusie in groep 2 van het reguliere basisonderwijs zaten. Van deze groep is data verzameld met betrekking tot de biologische en gedragskarakteristieken van het kind enerzijds en zijn/haar omgeving anderzijds. Drie jaar na inclusie is de school carrière van deze kinderen in kaart gebracht. Op basis van deze data, is vervolgens bepaald welke kinderen nominaal hun schooltijd doorlopen hebben (groep I; n = 924), welke kinderen zijn blijven zitten binnen het reguliere basisonderwijs (groep II; n = 277) en wel-

ke kinderen naar het speciaal basisonderwijs overgeplaatst zijn (groep III; $n = 34$). De data analyse laat zien dat een model aan de hand waarvan het schools functioneren op kleuterleeftijd voorspeld kan worden, moet bestaan uit factoren die betrekking hebben op de omgeving, het gedrag als wel de biologische eigenschappen van een kind. Gedragsvariabelen gemeten op kleuterleeftijd die voorspellend zijn voor school carrière later, zijn onder meer aandacht en delinquent gedrag gemeten m.b.v. de Child Behavior Checklist (CBCL). Daar-naast is aangetoond dat het beroep en de leeftijd van de moeder bij geboorte, het aantal kinderen in het gezin, de familie status, en de omgeving en het geslacht van het kind tevens bepalend zijn voor de school carrière. Een ander aspect dat belangrijk is wanneer men kijkt naar ontwikkeling is slaap. Hoewel slaap problemen vaak gesignaleerd worden bij kinderen, staan er nog altijd relatief veel vragen omtrent dit onderwerp open. Voorbeelden van dergelijke vragen hebben betrekking op (a) de invloed van gedragsmatige, biologische en omgevings-factoren op slaapproblemen bij kinderen en (b) de stabiliteit van slaappgedrag over tijd. Om deze vragen te kunnen beantwoorden, is in **hoofdstuk 3** slaap nader bestudeerd binnen een niet-klinische populatie kinderen. T.b.v. de eerste vraag, zijn diverse aspecten van slaap (o.a. de aanwezigheid van nachtmerries, hoeveelheid slaap en slaapproblemen in het algemeen) onderzocht in een niet-klinische populatie 5/6-jarige kleuters ($n = 1258$). De resultaten van dit eerste experiment lieten zien dat slaapproblemen relatief vaak voorkomen bij kleuters. De rapportage van ouders m.b.t. slaapproblemen bij hun kind, wanneer deze minimaal 'soms' aanwezig zijn, varieerde van 3,9% voor 'een toegenomen mate van slaap' tot 17,9% voor 'nachtmerries', met 'globale slaapproblemen' (11,8%), 'slaap wandelen/praten' (14,9%), en 'een verminderde hoeveelheid slaap' (11,4) daar tussen in. Daarnaast blijken bepaalde gedragingen van het kind (zoals lichamelijke klachten, denkproblemen, agressief gedrag, en angst/depressie gedrag) als wel de omgeving (beroep van de ouders, het aantal kinderen in het gezin, de gezinssituatie, en de leeftijd van de moeder bij geboorte) te correleren met de scores op specifieke slaap parameters gemeten op kleuterleeftijd. Om vervolgens een uitspraak te kunnen doen over de stabiliteit van slaap bij kinderen over de tijd, is een subgroep van de kinderen, die getest zijn op kleuterleeftijd (286 van de 1258 kinderen), drie jaar na inclusie nogmaals onderzocht a.h.v. de Child Behavior Checklist (CBCL). Op basis van deze longitudinale data kan geconcludeerd worden dat verstoorde slaap gemeten op kleuterleeftijd evenals bepaalde aspecten van het gedrag van het kind (zoals aandachtsproblemen) gemeten op kleuterleeftijd voorspellend zijn voor slaap en/of slaapproblemen drie jaar later. Deze bevindingen bevestigen de relevantie van vroegtijdige voorlichting aan ouders omtrent slaap met de hoop om meer serieuze of chronische slaapproblemen te voorkomen.

Verder is binnen een gezonde groep kinderen naar het cognitief functioneren

gekeken. Zo is één aspect van cognitief functioneren, zoals beschreven in **hoofdstuk 4**, gemeten a.h.v. de fluency test: een taak die veelvuldig gebruikt wordt binnen de neuropsychologie om de vloeiendheid van taal te meten. Als algemene instructie wordt de kinderen gevraagd om gedurende een periode van 60 seconden zoveel mogelijk woorden te produceren die behoren tot een bepaalde categorie (bijvoorbeeld dieren en/of eetbare producten). Binnen de fluency tests kan een tweedeling gemaakt worden, resp. (A) de semantische categorie fluency (het kind moet bijvoorbeeld zoveel mogelijk dieren noemen) en (B) de letter fluency (het kind moet zoveel mogelijk woorden opnoemen die met een bepaalde letter beginnen). Relatief nieuw is het idee om de woordproductie als een functie van tijd te meten, waarbij woord productie over de eerste 15 seconde van een 1-minuut-durende test gekozen is als een maat van geautomatiseerde informatie verwerking, terwijl woord productie gedurende de 16 - 60 seconden van de test gekozen is als een maat van gecontroleerde informatieverwerking. A.h.v. deze uitkomstmaten, is de prestatie op beide types fluency tests gemeten bij 91 gezonde kinderen. De resultaten zijn als volgt: Over 60 seconden blijken gezonde kinderen significant meer woorden te kunnen genereren op de semantische categorie fluency taak dan op de letter fluency taak, terwijl volwassenen juist de meeste woorden noemen op de letter fluency taak. Verder blijkt dat de productie van woorden bij kinderen significant afneemt naarmate de 60 seconden verstrijken. Dit laatste geldt zowel voor de semantische categorie als de letter fluency. Additioneel zijn enkele biologische en omgevingsgebonden factoren, zoals leeftijd, geslacht, en het beroep van de ouders, bekeken in relatie tot dit specifieke aspect van cognitief functioneren, terwijl er gecontroleerd wordt voor intermedierende factoren als de verbale intelligentie en het leesniveau van het kind. De resultaten zijn als volgt: geslacht en leeftijd blijken niet te differentiëren op taken die de verbale vloeiendheid meten. Daarentegen blijkt het beroep van de ouders een significante determinant van het presteren van kinderen op beide soorten fluency tests, waarbij meer specifiek blijkt dat het beroep van de ouders van invloed is op de hoger-order processen, zoals het automatiseren van nieuw aangeleerde verbale vaardigheden en de meer gecontroleerde processen.

DEEL II

Een ontwikkelingsstoornis, die toenemende bekendheid krijgt middels de media, gezondheidszorg en wetenschap, is ADHD. De laatste jaren is er een forse toename in artikelen waarin vanuit de cognitieve invalshoef gekeken wordt naar deze stoornis. Toenemend blijkt in dit verband dat de gedragsexpressie van ADHD verklaard kan worden door een anatomische afwijking c.q. een hersendysfunctioneren. Helaas is het nog altijd zo dat er een groot aantal vragen onbeantwoord zijn. Derhalve is in de resterende hoofdstukken van het proefschrift nader gekeken naar de cognitieve ontwikkeling van kinderen met ADHD en de

vraag hoe specifiek deze bevindingen zijn voor de stoornis ‘ADHD’.

Zo is in **hoofdstuk 5** de eerder uitgebreid besproken methode, ten behoeve van het scoren van de fluency tests, getoetst binnen een populatie kinderen met ADHD. In de praktijk wordt de fluency taak vaak geïnterpreteerd als een taak die de taal, aandacht en de executieve vaardigheden van een kind meet. Omdat deze cognitieve functies in kinderen met ADHD veelal aangedaan lijken te zijn, wordt de fluency taak vaker gekozen als instrument ten behoeve van het klinisch en/of wetenschappelijk onderzoek naar ADHD. Echter, de resultaten van de diverse studies zijn niet eenduidig. Verder nemen de wetenschappers vaker enkel, als uitkomstmaat, het totaal aantal woorden gegenereerd over een periode van 60 seconden. Binnen het experiment, beschreven in hoofdstuk 5, wordt dan ook opnieuw de prestatie van ADHD kinderen op zowel de semantische categorie als de letter fluency vergeleken met gezonde kinderen en kinderen met andersoortige pathologie. Als uitkomstmaten zijn meegenomen: de totaal score over 60 seconden en het aantal woorden genoemd als een functie van tijd (in samples van 15 seconden). Kort samengevat, wijzen de resultaten uit dat de groepen (ADHD, pathologische controles, en gezonde controles) niet gedifferentieerd kunnen worden op basis van het totaal aantal woorden geproduceerd over 60 seconden: een bevinding die geldt voor beide typen van de fluency taak (semantische categorie en letter fluency). Daarentegen, wordt er wel een significante interactie van groep met tijd samples en met type fluency taak gevonden. Meer specifiek, vertonen kinderen met ADHD significant meer problemen bij het genereren van woorden beginnend met een specifieke letter gedurende de eerste 15 seconden. Deze bevindingen blijven aanwezig na correctie voor de verbale intelligentie van het kind, het leesvermogen van het kind en het beroep van de ouders. Resultaten worden geïnterpreteerd als dat er bij ADHD een stoornis in de automatische verwerking van abstracte verbale informatie optreedt.

Naast de vloeiendheid van taal zijn er diverse andere aspecten van informatieverwerking (zoals cognitieve processen binnen het domein van waarneming, korte termijn geheugen, motorische uitvoering e.d.) uitvoerig bestudeerd in relatie tot ADHD. Echter, een onontgonnen gebied binnen dit geheel is de visuomotorische preparatie van het handelen, en meer specifiek hoe goed kan een kind met ADHD een hint benutten om zich optimaal voor te bereiden op een motorische actie. Dit is zonde, daar eerder verricht onderzoek pretendeert dat ADHD een output-gerelateerde stoornis is en een foutieve of suboptimale uitvoering het resultaat kan zijn van een foute of incomplete preparatie. Derhalve is het doel van de studie beschreven in **hoofdstuk 6** om de (geautomatiseerde en gecontroleerde) visuo-motorische preparatie in ADHD te meten. Om dit zo optimaal mogelijk te kunnen meten is de Finger Precuing Test (FPT) als uitkomst maat in deze studie gekozen. Twee onafhankelijke variabelen kunnen binnen deze taak systematisch

gemanipuleerd worden, namelijk de *preparatie conditie* en het *preparatie interval*. De eerste variabelennaam verwijst naar het soort hints dat gegeven wordt voordat het kind de reactie stimulus aangeboden krijgt (het, d.m.v. een hint, kunnen prepareren van twee vingers van slechts één hand (hand cue) of het kunnen prepareren twee vingers van twee handen (vinger cue & neither cue) vs. het krijgen van geen hint (geen cue)). De tweede variabele weerspiegelt de tijdspanne tussen het geven van de hint en de doelstimulus, waarbij een preparatie interval van 100-ms gezien wordt als een maat voor automatische verwerking en een preparatie interval van 1000-ms, als een maat voor gecontroleerde verwerking. De data laten zien dat, gezonde, negenjarige kinderen niet kunnen profiteren van de cues die wijzen naar vingers van de twee handen. Wanneer de kinderen meer tijd hebben om de cue te verwerken (1000-ms) worden ze zelfs door deze twee-handen-bevattende cues in verwarring gebracht. Negen jaar oude gezonde kinderen en kinderen met een pathologie kunnen wel effectief gebruik maken van de hand cue, over beide preparatie-intervallen (100- en 1000-ms) heen. Kinderen met ADHD laten daarentegen een ander patroon zien: Zij kunnen gemiddeld even goed als de controles gebruik maken van de hand-cue onder de 100-ms-conditie, maar maken geen gebruik van deze cue onder de 1000-ms-conditie. De resultaten suggereren dat de snelle, automatische respons preparatie niet beïnvloed wordt door ADHD, maar de gecontroleerde preparatie wel. Daarnaast vertoont de ADHD groep, over alle tests genomen, relatief meer variabiliteit in hun responsen dan de andere groepen. Geen verschillen in accuraatheid worden gevonden. ADHD kinderen lijken dan ook primair een probleem in de bewuste allocatie van aandacht en effort te vertonen.

In de literatuur worden tekorten in executief functioneren vaker genoemd in relatie tot ADHD. Echter, wanneer deze studies nader bestudeerd worden, blijken er een aantal limitaties verbonden te zijn aan de onderzoeksdesigns gebruikt in deze studies. Zo worden er in de literatuur diverse aspecten van executief functioneren in relatie tot ADHD bekeken, waarbij de conclusies niet altijd eenduidig zijn. Daarnaast worden vaker slechts relatief kleine groepen met een relatief grote leeftijdsrange bestudeerd. Tenslotte blijft de vraag veelal onbeantwoord of een eventueel tekort in executief functioneren specifiek is voor kinderen met ADHD en/of dat kinderen met een andersoortige stoornis (zoals Conduct Disorder) een soortgelijk tekort laten zien. Vrijwel nergens wordt een pathologische controle groep in het design van de studie opgenomen. Hierdoor is het niet mogelijk om een uitspraak te doen over of het tekort daadwerkelijk door het hebben van ADHD verklaard kan worden of door het hebben van een co-morbide stoornis als Conduct Disorder of een leerprobleem. Derhalve is er in **hoofdstuk 7** voor gekozen om opnieuw naar deze specifieke tak van cognitief functioneren te kijken. Meer specifiek zijn aspecten van het executief functioneren (cognitive flexibiliteit, aandacht, werkgeheugen, Stroop inhibitie) gemeten in kinderen met ADHD,

kinderen met Conduct Disorder dan wel Oppositioneel Opstandig Gedag, kinderen met een andersoortige pathologie en gezonde controle kinderen. Vijf tests zijn binnen dit onderzoek afgenomen om diverse aspecten van executief functioneren te meten, namelijk de Stroop test, een Concept Shifting taak, een verbale vloeiendheid taak, en een tweetal taken die het werkgeheugen meten. Om het vele aantal maten van executief functioneren te verminderen tot hun principale dimensies, is een principale componenten factor analyse uitgevoerd. Vijf factoren zijn uit deze analyse gegenereerd, die tezamen 74,1% van de variantie verklaren: aandacht, stroop inhibitie, simpele motorische vaardigheden, cognitieve flexibiliteit, en werkgeheugen. De volgende resultaten zijn hierbij gevonden: Ten eerste, in tegenstelling tot eerdere verwachtingen, zijn er geen groepsverschillen gevonden t.a.v. sommige aspecten van executief functioneren (zoals inhibitie gemeten a.h.v. de Stroop Kleur Woord Taak en het werkgeheugen). Daarentegen, wordt in de huidige studie een interactie van geslacht en pathologie gevonden, t.a.v. de prestaties op de manifeste variabelen 'cognitieve flexibiliteit' en 'aandacht'. Zo blijken aandachtstekorten meer specifiek een rol te spelen bij meisjes met ADHD, terwijl jongens met ADHD meer een probleem met concept shifting blijken te hebben. Binnen deze vergelijkingen blijkt dat deze verminderde prestatie op de cognitieve tests specifiek is voor ADHD en niet zo zeer voor pathologie in het algemeen. Daarnaast blijken de afwijkende prestaties onafhankelijk te zijn van omgeving, intelligentie en leesvaardigheden.

Zoals eerder gemeld, lijken, binnen de groep van schoolgaande kinderen, m.n. cognitieve tekorten een kern probleem in ADHD te vormen. Helaas zijn de resultaten t.a.v. het verband tussen gedragkenmerken en aspecten van cognitief functioneren niet altijd eenduidig. Daarnaast ontbreekt vaker de motivatie voor het kiezen van specifieke taken die deze functies meten. Om deze redenen wordt in **hoofdstuk 8** dieper ingegaan op de relatie tussen informatieverwerking en ADHD. Verder is het helaas zo dat kinderen met ADHD relatief vaak een leerstoornis hebben naast de ADHD-problematiek. Om te corrigeren voor het feit dat leerstoornissen tevens van invloed zijn op het niveau van informatieverwerking, is er binnen de studie een onderscheid gemaakt tussen kinderen met ADHD zonder leerproblematiek en kinderen met ADHD met leerproblematiek. Binnen de klinische setting zijn derhalve drie groepen kinderen geselecteerd, respectievelijk (A) een groep kinderen met ADHD zonder leerproblemen (gemiddeld leeftijd is $8,9 \pm 1,9$ jaar), (B) een groep kinderen met ADHD en leerproblemen (ADHD/LD; gemiddeld $9,3 \pm 1,5$ jaar), en (C) een gezonde controle groep (gemiddeld $9,1 \pm 1,8$ jaar). Bij al deze kinderen is de Kaufman Achiement Battery voor Kinderen (K-ABC) afgenomen. Twee typen uitkomstmaten zijn op basis van de Kaufman ABC berekend: (1) het niveau van informatie verwerking (algemeen, simultaan en sequentieel) en (2) de prestatie op diverse taken representatief t.a.v. specifieke cognitieve functies. Resultaten laten zien dat kinderen met

ADHD (met of zonder leerproblemen) significant lager presteren op de Mentale Verwerkingschaal van de K-ABC (als een schatter van het algemene niveau van informatie verwerking) dan de gezonde controles. Additionele analyses van de subtaken van de K-ABC laten zien dat de groepen (ADHD, ADHD/LD, en controles) op 9-jarige leeftijd niet verschillen in hun prestaties op taken die de perceptuele vaardigheden, het redeneren, en de visuoconstructieve vaardigheden meten. Daarentegen behalen kinderen met ADHD en ADHD/LD significant lagere prestaties in vergelijking tot hun controles op taken die het verbale werkgeheugen en het temporeel verwerken van informatie meten. Geen verschillen in testprestaties zijn er gevonden tussen kinderen met ADHD en kinderen met ADHD/LD. De bevindingen ondersteunen derhalve de hypothese dat ADHD kinderen een tekort in specifieke cognitieve functies vertonen.

In de eerdere hoofdstukken van dit proefschrift zijn zowel aspecten van normale ontwikkeling als het functioneren van kinderen met een afwijkende ontwikkeling (meer specifiek ADHD) besproken. Vooral het cognitief functioneren van kinderen stond hierbij centraal. Echter, dit cognitief functioneren wordt in de meeste studies slechts op 1 moment in de ontwikkeling gemeten, iets dat tevens in de literatuur vaker gesignaleerd wordt. Relatief weinig is er nog altijd gekeken naar de prestaties van de kinderen op cognitieve tests gemeten op een aantal meetmomenten over de tijd heen. Derhalve wordt in **hoofdstuk 9** het cognitief functioneren van gezonde kinderen, kinderen met ADHD, en kinderen met een andersoortige pathologie gemeten als een functie van tijd. De kinderen, geïncludeerd in deze studie, zijn hierbij onderworpen aan een tweetal neuropsychologische onderzoeken (dat is, meetmoment I toen het kind in groep 2 van het reguliere onderwijs zat en ca. 5/6 jaar oud was en meetmoment II op 9/10 jarige leeftijd). Drie cognitieve taken zijn op beide meetmomenten afgenomen, die een beroep doen op het auditieve werkgeheugen enerzijds en de visuo-motorische integratie anderzijds. De resultaten tonen aan dat gemiddeld alle groepen (onafhankelijk van groepsindeling) groeien in hun functioneren als een functie van tijd. Tussengroepanalyses tonen verder aan dat kinderen met ADHD significant slechter presteren op meetmoment 1 in vergelijking tot beide controle groepen op taken die zowel het werkgeheugen als de visuo-motorische integratie meten. Drie jaar later (op meetmoment II) is deze trend alleen nog waarneembaar op taken die het werkgeheugen meten. Geen verschillen worden er dan ook tijdens de follow-up gevonden op de taak die de visuo-motorische integratie meet. Samenvattend kan geconcludeerd worden dat cognitieve groei voorkomt in alle groepen, maar dat specifieke tekorten gedurende de ontwikkeling aanwezig blijven in het cognitieve profiel van kinderen met ADHD, andere tekorten pas waarneembaar worden op latere leeftijd (bijvoorbeeld, het automatiseren van taalsevaardigheden) en andere tekorten (zoals de overdracht van informatie over diverse modaliteiten) met de tijd verdwijnen.

In het laatste hoofdstuk van het proefschrift (nl. **hoofdstuk 10**) wordt een overzicht gegeven van de bevindingen van de studies beschreven in het proefschrift, de implicaties hiervan en de nut hiervan voor de kliniek. Op basis van dit overzicht kan gesteld worden dat er veel onderzoek gedaan is, dat kan fungeren als basis voor toekomstig onderzoek. Echter, het doel voor de toekomst moet zijn: het verbeteren van de gezondheidszorg gegeven aan kinderen, adolescenten en volwassenen (in termen van diagnostiek, behandeling als wel de kwaliteit van leven).

References

- American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: American Psychiatric Association.
- Barkley, R. A. (1996). Attention Deficit-Hyperactivity Disorder. In R. A. Barkley (Ed.), *Child psychopathology* (pp. 63-112). New York: The Guilford press.
- Barkley, R. A. (1998). *Attention-Deficit/ Hyperactivity Disorder: A Handbook for Diagnosis and Treatment*. (2 ed.). New York: The Guilford Press.
- Hechtman, L., Weiss, G., Perlman, T., & Amsel, R. (1984). Hyperactives as young adults: Initial predictors of adult outcome. *Journal of the American Academy of Child Psychiatry*, 23, 250-260.
- Mönks, F. J., & Knoers, A. M. P. (1978). *Ontwikkelingspsychologie: Inleiding tot de verschillende deelgebieden* (3th ed.). Nijmegen: Dekker & Van der Vegt.
- Perugini, E. M., Harvey, E. A., Lovejoy, D. W., Sandstrom, K., & Webb, A. H. (2000). The predictive power of combined neuropsychological measures for Attention-Deficit/Hyperactivity Disorder in children. *Child Neuropsychology*, 6(2), 101-114.
- Verhulst, F. C. (1999). *De ontwikkeling van het kind* (5th ed.). Assen: Van Gorcum.
- Weiss, G., & Trokenberg Hechtman, L. (1993). *Hyperactive children grow up: ADHD in children, adolescents and adults*. (2 ed.). New York: The Guilford Press.

Al vroeg in mijn carrière als onderzoeker heb ik geleerd, dat het soms niet erg is om de woorden van een ander te gebruiken. Dat heet met een mooi woord 'citeren' en zolang je correct naar de bron verwijst, lijkt dit ten aller tijden geoorloofd (zonder dat er sprake is van plagiaat). Derhalve wil ik graag in de eerste zinnen van mijn dankwoord de beroemde uitspraak van Dr. J. Schmitt (2001) citeren, namelijk 'AIO zijn is de puberteit van de wetenschap'. Uit eigen ervaring weet ik echter, dat ook deze vorm van 'puberen' (evenals andere fases in de ontwikkeling van 'n mens) niet zonder slag of stoot voorbij gaat en dat de 'ik-vorm' in het verhaal zich niet zonder 'systeem' of omgeving optimaal kan ontplooiën. Het systeem is daarbij symbolisch samengesteld uit diverse elementen (zoals een huis opgebouwd wordt uit stenen en cement), die samen er voor zorgen dat de ontwikkeling zo perfect mogelijk kan geschieden. Ieder steentje op zichzelf danken voor zijn bijdrage en onder woorden brengen hoe belangrijk één steen is geweest voor het geheel, is naderhand een onmogelijke taak (vooral als hiervoor slechts een beperkt aantal woorden beschikbaar is). In de hier opvolgende pagina's wil ik het desondanks toch proberen...

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Tja, en nu wordt het moeilijk. Tot op dit moment was de logica in het dankwoord goed te vinden. Maar nu... Er zijn in de 4;04 jaar dat ik AIO was, zo ongelofelijk veel mensen langsgekomen, gebleven en soms ook weer gegaan. Het is onmogelijk om hen allen te bedanken. Derhalve zal ik slechts een paar mensen noemen die om een of andere reden voor mij extra speciaal geweest zijn... Ten eerste mijn (ex-)kamergenootjes Jeroen Schmitt, Karin Weirauch, Inge Crolla en Jos Hendriksen: Omdat de laatste twee genoemden reeds aan bot gekomen zijn, wil ik met name hier plaats vrijmaken voor Karin en Jeroen. Karin: dank voor alle, uitgebreide gesprekken over persoonlijke zaken, de ideale liefde en het werk. Hopelijk volgen er nog vele van deze en sluiten we binnenkort weer eens een leuke weddenschap voor bonbons af. Jeroen: Wie had dat toch gedacht dat ik zou beginnen met een citaat van jou. Dank voor alle mega-mokken thee die je voor me gehaald hebt, onze wetenschappelijke discussies over data-analyses, covariaten, maar ook snaar theorieën e.d. Maar bovenal wil ik je zeggen dat ik genoten heb van alle andere gesprekken, etentjes en lunches. Voor jou geldt datgene dat uiteraard voor al mijn UM-kamergenootjes opgaat: het was een eer om jullie kamergenoot te zijn!

Lydia Krabbendam en Jurgen Cornelis: Wat kan wetenschap onder het genot van een hapje en een drankje toch geweldig zijn! Dank voor alle gezellige en mooie

momenten. Hopelijk komen er nog vele... Jos Adam: Beste Jos, dank voor al je medewerking, de snelle reacties op mijn vragen, en het uitvoerige commentaar op mijn stukken. Het is altijd fijn om met mensen samen te werken die deskundig zijn en die je kunnen helpen om de bevindingen in een juist perspectief te plaatsen. Het eindresultaat van ons gezamenlijke project is mooi geworden. Hopelijk komt het in de toekomst nog eens tot een samenwerking. Mariska den Hartog: Dag dame, dank voor de verhelderende, openhartige en vooral ook zeer gezellige gesprekken en momenten. Ik weet dat privé en zaken een gescheiden goed zouden moeten zijn, maar ik ben zeer blij dat er altijd weer een uitzondering op de regel is... Marjolein de Vugt: Lieve Marjolein, dank voor je vriendschap, vele gezellige ATWT-avondjes (ook al val ik standaard aan het einde in slaap) en je luisterende oor... Ik ben blij dat er nog iemand zo gek is om tussen Eindhoven en Maastricht op en neer te reizen, dat maakt het allemaal net iets aangener maar vooral ook gezelliger (vooral als de NS weer eens vertraging heeft). Hopelijk liggen er nog vele treinreisjes, filmpjes, etentjes en pyjama partijtjes in het verschiet. Susanne Valentijn: Lieve Suus, vanaf 1994 zijn onze wegen op zowel vriendschappelijk, sportief, als wetenschappelijk gebied verbonden geweest. Van 1994 - 1998 als collega student aan de Universiteit te Nijmegen. Vanaf 2000 als collega AIO. Dank voor je vriendschap, voor je enorme gastvrijheid als ik weer eens een slaapplek nodig had, maar vooral ook voor alle andere momenten... Echter, het meest wil ik je bedanken vanwege het feit dat je op die ene belangrijke dag als mijn paranimf achter me wilde staan. Nu mag jij je boekje afronden; zullen we daaropvolgend maar een nieuwe universiteit in Eindhoven of Den Bosch oprichten?

Zoals iedere onderzoeker (i.o.) zal beamen is het onmogelijk onderzoek te doen, zonder een netwerk van mensen die je op e.e.a. manier kunnen ondersteunen. Onder dit kopje wil ik een aantal mensen noemen van het beheer van Neuropsychologie, het secretariaat, ex-stagiaires, statistische hulp, mede-wetenschappers, maar ook mensen die met je mee naar het café gaan te ontladen. Mensen die me niet alleen op het werkvlak dierbaar zijn, maar ook op het persoonlijke vlak. Mede door de belangstelling die ze de afgelopen jaren in mij, m'n onderzoek of het wel en wee van mijn favoriete voetbalclubje getoond hebben en de hulp die ze me gegeven hebben. Een aantal belangrijke namen in dit verband zijn dan ook: Elke Bollen, Dymphie in de Braek, Carla Brands, Liesbeth Bruckers, Nettie Buys, Wendy Candel, Corine Classen, Kees Commissaris, Patricia Hameleers, Marco van Hertrooij, Ankie Hochstenbach, Susan van Hooren, Lisa Jonkman, Brenda Jorissen, Fons Kessels, Ria Kleijnen, Edwin Klinkenberg, Laurent Louwies, Natalie Marchetta, Elsa Misdorn, Wim Riedel, Nico Rozendaal, Rosi Rubsaet, Josien Schneiders, Tamara Smeets, Frouke Sondeijker, Sven Stapert, Amanda van Bergeijk, Annemiek Vermeeren, en Mea Wuisman. Jullie zijn goud waard!

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Tenslotte nog een speciaal woordje gericht aan mijn directe familie... Marja Hurks: Dag lieve Koala, waar moet ik beginnen... Jou danken voor alles wat we samen meegemaakt hebben, kan niet in 5 zinnen. Daarom wil ik je slechts voor een specifiek iets bedanken, namelijk voor de momenten van ontlading. Lekker samen ontsnappen uit de sleur van het dagelijks leven tijdens een filmpje bijv. Dank dat je altijd voor me was en bent. Ik ben blij dat ik jou mijn zusje mag noemen! Lieve papa en mama, dank voor alle steun en liefde die jullie me alle jaren gegeven hebben. Jullie zijn de eerste steen van het huis... En nu is het huis af en wordt het tijd om er op zondagochtend eens een keer goed hard muziek in te draaien. En je moet toch toegeven, paps, dat de kans nu toch wel erg groot wordt dat de Doctorandus eindelijk toch een Doctor gaat worden... Of betekent Dr. 'zij die geen arts kon worden', want die uitdaging ga ik dan voor de verandering toch maar niet aan... Ik hou van jullie.

Hora est.

Petra

Petra Petronnella Maria Hurks is geboren op 11 maart 1974 te Veldhoven. Op het Van Maerlantlyceum te Eindhoven voltooide zij zowel de HAVO (diploma: 1991) als het VWO (1993). De voorliefde voor de exacte wetenschappen leidde er in september 1993 toe, dat Petra wiskunde aan de Technische Universiteit van Eindhoven (TUE) ging studeren. Circa 11 maanden na de 'kick-off' besloot zij de exacte wetenschap in te ruilen voor de opleiding 'Psychologie' gedoceerd aan de Katholieke Universiteit Nijmegen. Na het doorlopen van twee algemenere jaren, koos zij uiteindelijk voor de specialisatie tot Neuro- en Revalidatiepsycholoog. De werking van het brein trok sterk haar interesse. Na een diversiteit aan te volgen vakken, een klinische stage in het Psychiatrisch streekziekenhuis Duin & Bosch en een wetenschappelijke stage in het Epilepsiecentrum Kempenhaeghe, behaalde zij in 1998 haar diploma. Daaropvolgend accepteerde zij in september '98 een functie als 'Assistent in Opleiding (AIO)' aan de Universiteit Maastricht. Gedurende deze aanstelling heeft zij enerzijds uitgebreid mogen experimenteren in de keuken der wetenschap en anderzijds zich mogen specialiseren als neuropsycholoog op het gebied van de cognitieve ontwikkeling. Momenteel is zij als Universitair Docent verbonden aan de faculteiten Psychologie en Geneeskunde van de Universiteit Maastricht.