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Differential Effects of Methylphenidate on Problem Solving in Adults With ADHD

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Abstract

Objective: Two studies were performed to assess both divergent and convergent thinking in adults with ADHD. **Method:** The first study compared the problem-solving abilities of healthy participants (*N* = 144) and unmedicated adults with ADHD (*N* = 144). In the second study, problem-solving abilities of adults with diagnosed ADHD (*N* = 22) were examined twice, that is, on and off methylphenidate (MPH), and compared with the performance of a healthy control group (*N* = 22). Convergent thinking was measured using a Tower of London task, whereas divergent thinking was assessed using verbal fluency tasks. **Results:** Adults with ADHD off MPH displayed marked deficits of both divergent and convergent thinking. MPH treatment resulted in a marked improvement of convergent thinking, while no effect of medication was found regarding divergent thinking. **Conclusion:** Pharmacological treatment of adults with ADHD revealed a differential effect of MPH on problem solving abilities. (*J. of Att. Dis. 2011; 15(2) 161-173*)

Keywords

ADHD, adulthood, problem solving, Tower of London, verbal fluency, methylphenidate

Neuropsychological assessment of children and adults with ADHD has demonstrated that the behavioral problems displayed by patients with ADHD are similar to the problems of patients with acquired lesions of the frontal lobes (Benson, 1991; Boucugnani & Jones, 1989). Therefore, the concept of executive dysfunctioning as the underlying deficit of the cognitive and behavioral disturbances associated with ADHD has received particular attention in recent years (Williams, Wright, & Partridge, 1999). The assumption of an executive function deficit in ADHD was supported by the findings of neuroimaging studies. These studies revealed that anomalies of prefrontal cortical regions and the basal ganglia represent neuroanatomical substrates of ADHD (Casey et al., 1997; Castellanos et al., 1996; Filipek et al., 1997; Hynd et al., 1993; Lou, Henriksen, & Bruhn, 1984; Vaidya et al., 1998). However, alterations of other brain regions including cerebellar, subcortical, and cortical areas were also reported (Castellanos et al., 1996; Filipek et al., 1997; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Singer et al., 1993; Zametkin et al., 1990, 1993). Furthermore, the findings of genetic research (Cook et al., 1995; LaHoste et al., 1996) and neurochemical studies (Barkley, 1998; DuPaul, Barkley, & Connor, 1998; Mercugliano, 1995) indicating anomalies of the dopaminergic, noradrenergic, and frontostriatal system were also in accord with the assumption of an executive function deficit in ADHD. Psychometric assessments have demonstrated that, in comparison to healthy adults, adult patients with ADHD display deficiencies of various functions which have been associated with the frontal lobes. These include attention, working memory, concept formation, impulsivity, and shifting (Arcia & Gualtieri, 1994; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Corbett & Stanczak, 1999; Dinn, Robbins, & Harris, 2001; Epstein, Johnson, Varia, & Conners, 2001; Holdnack, Moberg, Arnold, Gur, & Gur, 1995; Hollingsworth, McAuliffe, & Knowlton, 2001; Hopkins, Perlman, Hechtman, & Weiss, 1979; Horton, 1996; Johnson et al., 2001; Klee, Garfinkel, & Beauchesne, 1986; Kovner et al., 1998; Lovejoy et al., 1999; Silverstein, Como, Palumbo, West, & Osborn, 1995; Tucha et al., 2006; Walker, Shores, Trollor, Lee, & Sachdev, 2000). However, problem-solving abilities of adults with ADHD have not been examined in detail.

The limited number of studies examining problem solving abilities in adults with ADHD unfortunately focused only on single aspects of problem solving, such as verbal

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fluency functions (Dinn et al., 2001; Jenkins et al., 1998; Johnson et al., 2001; Lovejoy et al., 1999; Riccio, Wolfe, Romine, Davis, & Sullivan, 2004; Tucha et al., 2005; Walker et al., 2000; Weyandt, Rice, Linterman, Mitzlaff, & Emert, 1998). Furthermore, these studies have failed to describe the basis and classification of the measures used and their relationship to models of problem solving. This is surprising considering that tests of problem solving have been shown to be particularly sensitive measures for the detection of cognitive impairments of patients suffering from alterations of central dopaminergic neurotransmission such as Parkinson's disease (Berg et al., 1999; Hanes, Andrewes, Smith, & Pantelis, 1996; Hodgson, Tiesman, Owen, & Kennard, 2002; Lange et al., 1992, 2003; Lange, Paul, Naumann, & Gsell, 1995; Morris et al., 1988; Owen et al., 1992, 1995; Pantelis et al., 1997; Robbins et al., 1994; Ruprecht-Dorfler et al., 2003).

Cognitive models describe problem solving as a process to attain a goal. However, there is no immediately apparent approach to solve the problem. In order to attain the goal, obstacles have to be surmounted (Smith & Kosslyn, 2007). Problem solving is a purposeful process that requires a number of interrelated skills including the identification of the problem definition, the ability to break a problem into components, the generation of proper solution strategies, the selection of an appropriate strategy, the consistent execution of the selected strategy, the monitoring of one's behavior in relation to the desired goal, the evaluation of one's final performance and, provided it is necessary, the modification of the solution process (Ben-Yishay & Diller, 1983; Cramon & Matthes-von Cramon, 1993; Goel, Grafman, Tajik, Gana, & Danto, 1997; Lezak, Howieson, & Loring, 2004; Lüer & Spada, 1992; Luria, 1973; Rowe, 1985; Smith & Kosslyn, 2007; Sternberg, 1985; Sternberg, Conway, Ketron, & Bernstein, 1981).

In principle, open problems and closed problems can be distinguished. An open problem is a problem in which neither the goal state nor the solution approach are clearly defined (Krampen, 1993). The solution of such tasks requires *divergent thinking*, that is, a fluent and original process of problem solving aiming for the production of as many appropriate solutions as possible (König, 1986). In the neuropsychological assessment of divergent thinking, verbal fluency tasks (known also as generative naming tasks) are usually used (Lezak et al., 2004). Verbal fluency tasks can be divided into phonemic and semantic tasks as well as single and alternate tasks.

Closed problems are problems in which both the initial state and the goal state are clearly defined. The goal state can only be achieved by a certain solution (Krampen, 1993). The necessary actions and constraining rules are known. The solution of closed problems requires an unimpaired *convergent thinking*, that is, concluding thinking (König, 1986). While divergent thinking is characterized by heuristic approaches (i.e., single and efficient rules that were derived from experience and which have no guarantee of appropriateness), convergent thinking is characterized by algorithmic approaches (i.e., a step-by-step procedure that guarantees a solution of a problem under the condition that the algorithm is appropriate and executed properly; Amabile, 1983). In the neuropsychological assessment of convergent thinking, tasks were adopted that were designed by cognitive psychologists to examine artificial intelligence (Grafman, 1999; Robbins et al., 1998; Shallice, 1982; Stuss & Benson, 1986) including transformation tasks such as the Tower of Hanoi (Simon, 1975) or the Tower of London tasks (Shallice, 1982).

On the basis of these theoretical considerations, the present study examines both divergent and convergent thinking in adults with ADHD. In adults with ADHD, beneficial effects of methylphenidate (MPH) have been shown on cognitive functioning including attentional functions (Tucha et al., 2006), inhibition (Aron, Dowson, Sahakian, & Robbins, 2003), distractibility (Riordan et al., 1999) and working memory (Mehta, Calloway, & Sahakian, 2000; Schweitzer et al., 2004; Turner, Blackwell, Dowson, McLean, & Sahakian, 2005). However, the effect of stimulant drug treatment on problem-solving abilities has not yet been examined in detail. The present study has therefore assessed problem solving in adults with ADHD and the effect of individually tailored doses of stimulant drug treatment on these functions.

Study 1

Method

Participants. A total of 144 adult patients with ADHD participated in the present study. One hundred and eighteen patients were self-referred and 26 patients were referred from local psychiatrists or neurologists to the Department of Psychiatry, University of Regensburg, Germany. All patients met the *Diagnostic and Statistical Manual of Mental Disorders* (4th ed., *DSM-IV*) criteria for ADHD devised by Barkley and Murphy (1998) which includes the retrospective diagnosis of an ADHD in childhood (*DSM-IV* criteria) and current symptoms. Patients were selected according to age, diagnosis, intellectual functions (IQ), and willingness to participate in the study. Patients who were younger than 18 years of age, who had intelligence quotient (IQ) values below 85 and participants with another Axis I diagnosis were excluded from the study. None of the patients had previously been diagnosed with ADHD or received stimulant therapy at any time in the past. All patients were unmedicated at the time of participation. Forty-eight patients met *DSM-IV* criteria for ADHD—predominantly inattentive

Table 1. Characteristics (*M* ± SEM) of Adult Patients With ADHD and Healthy Participants (Study I)

	Healthy Participants[a]	Patients With ADHD[a]
Sex (female / male)	60 / 84	60 / 84
Age (in years)	36.0 ± 1.1	33.8 ± 0.9
Education (in years)	10.7 ± 0.2	10.4 ± 0.2
Intellectual functions (IQ)[b]	112.8 ± 1.2	111.9 ± 1.2
Processing speed (in s)[c]	26.9 ± 0.8	27.8 ± 0.8
Arousal (in ms)[d]	236.5 ± 3.5	244.7 ± 4.4

a. *N* = 144.
b. Multiple choice vocabulary test (Lehrl, Triebig, & Fischer, 1995).
c. Trail making test—Part A (Reitan, 1958).
d. Alertness task (Zimmermann & Fimm, 1993).

type, 15 patients met criteria for ADHD—predominantly hyperactive-impulsive type and 81 patients met criteria for ADHD—combined type.

Furthermore, 144 healthy adult participants were assessed. None of the healthy participants had a history of neurological or psychiatric disease. Healthy participants were recruited from the local community. At the time of the study no participant was taking any medication known to affect the central nervous system. Demographic characteristics of groups are presented in Table 1. The groups did not differ in sex, age (Mann-Whitney *U* test: $Z = -0.97$, $p = .332$), education level ($Z = -1.17$, $p = .241$), intellectual functions ($Z = -0.30$, $p = .768$), processing speed ($Z = -1.20$, $p = .232$), and simple reaction time ($Z = -1.62$, $p = .105$). Intellectual functions were measured using the Multiple Choice Vocabulary Test (Lehrl, Triebig, & Fischer, 1995). This test consists of 37 lines, each comprising of one authentic word and four fictitious words. The participant is required to find the authentic word by underlying it. The Multiple Choice Vocabulary Test is a valid and short test procedure which provides a measure for intellectual functioning. Processing speed was assessed using Part A of the Trail making test (Reitan, 1958; Spreen & Strauss, 1991) which requires participants to connect a series of digits placed in random order on a sheet of paper in ascending order. In the simple reaction time task, participants were asked to respond by pressing a button when a visual stimulus (a cross of about 1.2 by 1.8 cm) appeared on a computer screen. A total of 20 trials were undertaken. A measure of arousal (tonic alertness) was calculated on the basis of the participant's simple reaction time (Zimmermann & Fimm, 1993, 2002). Prior to neuropsychological assessment all participants gave informed consent to participate in the study.

Methods and Procedure. All participants underwent neuropsychological assessment of divergent and convergent thinking. For the assessment of divergent thinking (solving of open problems) four tests of verbal fluency were performed, including a single and an alternate phonemic verbal fluency task as well as a single and an alternate semantic verbal fluency task (Aschenbrenner, Tucha, & Lange, 2000). Convergent thinking (solving of closed problems) was measured by using a Tower of London task (TOL; Tucha & Lange, 2004). Functions and neuropsychological test measures are presented in Table 2.

Table 2. Neuropsychological Test Battery (Study I and Study II)

Function	Measure	
Intellectual functions	Multiple choice vocabulary test	Lehrl, Triebig, and Fischer (1995)
Processing speed	Trail making test—Part A	Reitan (1958)
Arousal	Alertness task	Zimmermann and Fimm (1993)
Divergent thinking		
Single phonemic verbal fluency	S-word test	Aschenbrenner, Tucha, and Lange (2000)
Alternate phonemic verbal fluency	H/T-word test	Aschenbrenner et al. (2000)
Single semantic verbal fluency	Animal test	Aschenbrenner et al. (2000)
Alternate semantic verbal fluency	Sport/fruit test	Aschenbrenner et al. (2000)
Convergent thinking	Tower of London task	Tucha and Lange (2004)

Divergent thinking. On the single phonemic verbal fluency task (S-Word Test), which is similar to the Controlled Oral Word Association Test (Benton, Hamsher, & Sivan, 1989), the participants were asked to produce, within 2 minutes, as many different words as possible beginning with the letter "S". Names (e.g., "Steve, Stockholm, Sweden"), words beginning with another letter, nonexistent or foreign-language expressions, words with the same stem (e.g., "sport, sport ground, sport badge") and perseverations of words already given as a response were regarded as rule violations (Aschenbrenner et al., 2000).

The single semantic verbal fluency task (Animal Test) required participants to name as many animals as possible within 2 minutes. Words which were not identifiable as animal names and perseverations of words were considered as rule violations (Aschenbrenner et al., 2000).

The alternate phonemic fluency task (H/T-Word Test) required participants to alternate between words beginning with the letter "H" and words beginning with the letter "T". Names, words beginning with another letter, nonexistent or foreign-language expressions, words with the same stem, perseverations of words already given as a response and perseverations of words beginning with the same letter (e.g., two subsequent words beginning with the letter "H") were considered as rule violations (Aschenbrenner et al., 2000).

On the alternate semantic fluency task (Sport/Fruit Test) participants were asked to alternate between sports and fruits. Words which were not identifiable as sport or fruit names, perseverations of words already given as a response and perseverations of words belonging to the same semantic category (e.g., two subsequent words denoting fruits) were considered as rule violations (Aschenbrenner et al., 2000).

All fluency tasks were performed for 2 minutes. All words named by the participant were recorded by the examiner.

Convergent thinking. In the TOL (Tucha & Lange, 2004), three differently colored balls are arranged on a board with three vertical pegs of different lengths. The task requires the subject to move the balls from a start position to a target position which is presented as a drawing. The participants were requested to change the start position to the target position using the minimal number of moves which is specified by the examiner. The task used in the present study consisted of 20 problems with a level of difficulty ranging from three to six moves. Each level of difficulty had five problems. Only one ball could be moved at a time and once a ball had been taken off a peg, it had to be placed on another peg. Participants were encouraged not to make the first move until they were confident that they could execute the entire sequence needed to solve the problem. The number of problems solved using the minimal number of moves and the initial planning time were recorded.

Data Analysis. Statistical analysis was performed using the Mann-Whitney *U* test. An alpha level of .05 was applied for statistical analysis. All statistical analyses were carried out using SPSS 14.0. Furthermore, effect sizes for group differences were computed. While the significance criterion represents the standard measure for analyzing whether a phenomenon exists, the effect size refers to the magnitude or the importance of effects. Following Cohen's (1988) guidelines for interpreting effect sizes, negligible effects ($d < 0.2$), small effects ($d \geq 0.2$), medium effects ($d \geq 0.5$) and large effects ($d \geq 0.8$) were distinguished (Bezeau & Graves, 2001; Zakzanis, 2001).

Table 3. Neuropsychological Test Results ($M \pm$ SEM) of Healthy Participants and Patients With ADHD (Study I)

	Healthy Participants[a]	Patients With ADHD[a]	Effect Size (*d*)
Divergent thinking			
Single phonemic verbal fluency (S-word test)			
Correct answers	25.4 ± 0.5	20.8 ± 0.6*	0.8
Rule violations	0.9 ± 0.1	1.4 ± 0.2**	0.4
Alternate phonemic verbal fluency (H/T-word test)			
Correct answers	23.7 ± 0.5	18.7 ± 0.5*	0.9
Rule violations	1.0 ± 0.1	1.4 ± 0.2	0.3
Single semantic verbal fluency (animal test)			
Correct answers	38.9 ± 0.7	34.5 ± 0.7*	0.5
Rule violations	0.4 ± 0.1	0.4 ± 0.1	0.1
Alternate semantic verbal fluency (sport/fruit test)			
Correct answers	24.1 ± 0.3	21.8 ± 0.4*	0.6
Rule violations	0.4 ± 0.1	0.5 ± 0.1	0.1
Convergent thinking (Tower of London task)			
Overall performance			
Correct solutions	16.4 ± 0.2	14.9 ± 0.2*	0.6
Planning time (in s)	9.0 ± 0.5	8.0 ± 0.4	0.2
3-move problems			
Correct solutions	4.9 ± 0.0	4.8 ± 0.0	0.2
Planning time (in s)	3.7 ± 0.2	3.8 ± 0.2	0.1
4-move problems			
Correct solutions	4.1 ± 0.1	3.8 ± 0.1**	0.3
Planning time (in s)	6.8 ± 0.4	6.3 ± 0.3	0.1
5-move problems			
Correct solutions	3.7 ± 0.1	3.3 ± 0.1*	0.4
Planning time (in s)	10.6 ± 0.6	10.2 ± 0.7	0.1
6-move problems			
Correct solutions	3.4 ± 0.1	2.9 ± 0.1*	0.5
Planning time (in s)	17.1 ± 1.2	14.8 ± 1.0	0.2

a. $N = 144$.
*$p \leq .01$. **$p \leq .05$.

Results

In all verbal fluency tasks performed, adults with ADHD generated fewer correct answers than healthy participants (single phonemic verbal fluency task: $Z = -5.48$, $p < .001$; alternate phonemic verbal fluency task: $Z = -6.62$, $p < .001$; single semantic verbal fluency task: $Z = -3.90$, $p < .001$; alternate semantic verbal fluency task: $Z = -4.29$, $p < .001$). According to Cohen (1988), these differences represent medium to large effects. Neuropsychological test performance and effect sizes for group differences are presented in Table 3. The analysis of rule violations (alternate phonemic verbal fluency task: $Z = -1.05$, $p = .292$; single semantic verbal fluency task: $Z = -0.93$, $p = .354$; alternate semantic verbal fluency task: $Z = -1.06$, $p = .288$) showed no statistically significant differences between groups with the exception of a significant difference in the single phonemic verbal fluency task ($Z = -2.21$, $p = .027$). In the latter task, adults with ADHD displayed an increased number of rule violations. However, the analysis of effect sizes revealed only small to negligible differences. Furthermore, in the (TOL) ADHD patients solved significantly fewer problems in the minimal number of moves than healthy participants. While no difference between groups was found in the 3-move problems ($Z = -1.44$, $p = .151$), significant differences were observed regarding the 4-move problems ($Z = -2.06$, $p = .039$), 5-move problems ($Z = -3.92$, $p < .001$), and 6-move problems ($Z = -3.46$, $p = .001$) as well as the overall performance ($Z = -4.51$, $p < .001$). The underlying effect sizes were small to medium. No differences and only negligible to small effect sizes were found with regard to the initial planning time (3-move problems: $Z = -1.21$, $p = .226$; 4-move problems: $Z = -0.20$, $p = .840$; 5-move problems: $Z = -0.71$, $p = .477$; 6-move problems: $Z = -1.51$, $p = .131$; overall performance: $Z = -1.36$, $p = .174$).

Study II

Method

Participants. Patients with ADHD and healthy participants met the same inclusion and exclusion criteria as described in Study I. Twenty-two adult patients with ADHD and 22 healthy adults participated in the study. The study used a cross-over design in which patients with ADHD were assessed both on and off MPH treatment. In the first test session, 14 patients were tested off stimulant medication and 8 patients on stimulant medication. Adults with ADHD received individually tailored and clinically appropriate doses of MPH with a mean total dose of 24 mg per day, with individual total doses ranging from 10 to 45 mg. None of the patients was taking concurrent psychotropic medications (e.g., antidepressants) at the time of the study. In the medication condition, neuropsychological assessment was performed approximately one hour after administration of the medication. When patients were tested off stimulant medication, the time to the last medication was at least 18 hours. The time period between testing and retesting was on average 20.8 weeks (*SEM* = 4.4 weeks). One patient met criteria for ADHD—predominantly hyperactive-impulsive type, 9 patients met *DSM-IV* criteria for ADHD—predominantly inattentive type and 12 patients met criteria for ADHD—combined type. According to self-reports and psychometric assessments of vigilance (data not shown), patients were responding favorably to the medication. Demographic characteristics of groups are presented in Table 4. Patients did not differ from healthy participants in sex, age ($Z = -0.42$, $p = .672$), education level ($Z = -0.27$, $p = .790$) and intellectual functions ($Z = -0.57$, $p = .571$). In addition, the groups did not differ regarding processing speed (ADHD patients *off MPH* versus healthy participants: $Z = -0.33$, $p = .742$; ADHD patients *on MPH* versus healthy participants: $Z = -0.64$, $p = .525$) and simple reaction time (ADHD patients *off MPH* versus healthy participants: $Z = -0.86$, $p = .392$; ADHD patients *on MPH* versus healthy participants: $Z = -0.01$, $p = .991$). Prior to neuropsychological assessment all participants gave written consent to the study.

Methods and Procedure. All participants were tested with the test battery described in Study I (Table 2).

Data Analysis. Statistical comparisons between healthy participants and patients with ADHD were performed using the Mann-Whitney *U* test. Comparisons between patients' test performance while on and off medication were performed using the Wilcoxon's test. Furthermore, effect sizes for differences between paired observations were computed. For statistical analysis an alpha level of .05 was applied. All statistical analyses were carried out using SPSS 14.0.

Table 4. Characteristics ($M \pm$ SEM) of Healthy Participants and Adults With ADHD (Study II)

	Healthy Participants[a]	Patients With ADHD[a]	
Sex (female / male)	7 / 15	7 / 15	
Age (in years)	35.1 ± 2.9	32.4 ± 1.7	
Education (in years)	10.7 ± 0.4	10.6 ± 0.4	
Intellectual functions (IQ)[b]	110.8 ± 2.8	112.5 ± 3.0	
		off MPH	on MPH
Processing speed (in s)[c]	25.9 ± 2.0	26.1 ± 1.9	23.1 ± 1.7
Arousal (in ms)[d]	225.6 ± 6.1	240.8 ± 11.6	229.1 ± 9.1

a. *N* = 22.
b. Multiple choice vocabulary test (Lehrl, Triebig, & Fischer, 1995).
c. Trail making test—Part A (Reitan, 1958).
d. Alertness task (Zimmermann & Fimm, 1993).

Results

Comparisons between adults with ADHD off MPH treatment and healthy participants. The results of the present study (Table 5) confirm the findings of Study I. Patients with ADHD produced significantly fewer correct answers in all four verbal fluency tasks than healthy participants (single phonemic verbal fluency task: $Z = -3.26$, $p = .001$; alternate phonemic verbal fluency task: $Z = -3.10$, $p = .002$; single semantic verbal fluency task: $Z = -2.49$, $p = .013$; alternate semantic verbal fluency task: $Z = -2.12$, $p = .034$). These differences represent medium to large effects (Table 6). With regard to the number of rule violations, no significant differences were found between groups (single phonemic verbal fluency task: $Z = -1.06$, $p = .290$; alternate phonemic verbal fluency task: $Z = -1.64$, $p = .100$; single semantic verbal fluency task: $Z = -0.93$; $p = .353$; alternate semantic verbal fluency task: $Z = -1.68$, $p = .094$). The analysis of effect sizes revealed primarily medium to large differences indicating that ADHD patients made more rule violations than healthy participants. Furthermore, ADHD patients off MPH differed significantly from healthy participants with regard to their performance in the Tower of London task. Patients with ADHD solved significantly fewer 5-move problems ($Z = -3.91$, $p = .001$) and 6-move problems ($Z = -2.66$, $p = .008$) than healthy participants. Their overall performance regarding the number of problems solved in the minimal number of moves was also significantly reduced ($Z = -3.05$, $p = .002$). These differences were of large size. No group differences were found in the number of correct solutions of 3-move problems ($Z = -0.83$, $p = .408$) and 4-move problems ($Z = -1.66$,

Table 5. Neuropsychological Test Results ($M \pm SEM$) of Healthy Participants and Patients With ADHD (Study II)

	Healthy Participants[a]	Patients With ADHD[a]	
		Off MPH	On MPH
Divergent thinking			
Single phonemic verbal fluency (S-word test)			
Correct answers	26.9 ± 1.5	19.5 ± 1.2*	21.6 ± 1.7**
Rule violations	0.6 ± 0.2	1.3 ± 0.4	1.2 ± 0.3
Alternate phonemic verbal fluency (H/T-word test)			
Correct answers	25.3 ± 1.3	18.3 ± 1.6*	18.9 ± 1.5*
Rule violations	0.9 ± 0.2	1.6 ± 0.3	0.9 ± 0.2
Single semantic verbal fluency (animal test)			
Correct answers	39.8 ± 1.4	34.4 ± 1.5**	33.4 ± 1.5**
Rule violations	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1
Alternate semantic verbal fluency (sport/fruit test)			
Correct answers	25.6 ± 1.1	22.3 ± 1.1**	22.5 ± 0.9**
Rule violations	0.2 ± 0.1	0.5 ± 0.1	0.5 ± 0.2
Convergent thinking (Tower of London task)			
Overall performance			
Correct solutions	17.0 ± 0.6	14.8 ± 0.4*	16.7 ± 0.3***
Planning time (in s)	8.5 ± 0.9	7.1 ± 0.8	8.0 ± 0.7
3-move problems			
Correct solutions	4.9 ± 0.1	4.8 ± 0.1	4.9 ± 0.1
Planning time (in s)	3.5 ± 0.4	2.9 ± 0.2	3.8 ± 0.3***
4-move problems			
Correct solutions	4.3 ± 0.2	4.0 ± 1.5	4.5 ± 0.1†
Planning time (in s)	6.1 ± 0.7	5.6 ± 0.7	6.5 ± 0.5
5-move problems			
Correct solutions	4.1 ± 0.2	3.1 ± 0.2*	3.9 ± 0.3†
Planning time (in s)	9.7 ± 1.5	8.4 ± 1.1	9.5 ± 1.0
6-move problems			
Correct solutions	3.9 ± 0.2	2.9 ± 0.2*	3.4 ± 0.2†
Planning time (in s)	16.5 ± 2.0	13.9 ± 2.1	14.6 ± 1.8

a. $N = 22$.
*$p \leq .01$. **$p \leq .05$ compared with healthy participants; ***$p \leq .01$. †$p \leq .05$; compared with ADHD patients off MPH.

$p = .096$). The underlying effect sizes were small. No differences and only small effect sizes were found with regard to the initial planning time (3-move problems: $Z = –0.65$, $p = .518$; 4-move problems: $Z = –0.68$, $p = .496$; 5-move problems: $Z = –0.65$, $p = .518$; 6-move problems: $Z = –1.22$, $p = .222$; overall performance: $Z = –1.46$, $p =.146$).

Comparisons between adults with ADHD off and on MPH treatment. MPH treatment of adults with ADHD had no significant effect on both the number of correct answers (single phonemic verbal fluency task: $Z = –1.43$, $p = .152$; alternate phonemic verbal fluency task: $Z = –1.73$, $p = .083$; single semantic verbal fluency task: $Z = –0.38$, $p = .705$; alternate semantic verbal fluency task: $Z = –1.56$, $p = .875$) and the number of rule violations (single phonemic verbal fluency task: $Z = 0.00$, $p = 1.000$; alternate phonemic verbal fluency task: $Z = –0.07$, $p = .948$; single semantic verbal fluency task: $Z = –0.47$, $p = .638$; alternate semantic verbal fluency task: $Z = –0.52$, $p = .600$) in the verbal fluency tasks. The differences between conditions regarding the number of correct answers represented negligible effects, while negligible to medium effects were found in the number of rule violations. However, MPH treatment of ADHD patients resulted in significant improvements of the patients' performance in the TOL as indicated by both a decrease in planning time during the 3-move problems ($Z = –2.66$, $p = .008$) and an increase in the number of problems solved in the minimal number of moves (4-move problems: $Z = –2.06$, $p = .040$; 5-move problems: $Z = –2.04$, $p = .042$; 6-move problems: $Z = –2.17$, $p = .030$; overall performance: $Z = –3.06$, $p =.002$). These differences represented medium to large effects. No differences and only negligible to small effect sizes were found in the number of 3-move problems solved ($Z = –1.13$, $p = .257$) and in the remaining measures of initial planning time (4-move problems: $Z = –1.06$, $p = .291$;

Table 6. Effect Sizes (d) for Group Differences (Study II)

	Healthy Participants Versus Patients With ADHD off MPH	Patients With ADHD off MPH Versus Patients With ADHD on MPH	Healthy participants Versus Patients With ADHD on MPH
Divergent thinking			
Single phonemic verbal fluency (S-word test)			
Correct answers	1.1	0.1	0.8
Rule violations	1.0	0.3	0.8
Alternate phonemic verbal fluency (H/T-word test)			
Correct answers	1.2	0.1	1.1
Rule violations	0.6	0.6	0.1
Single semantic verbal fluency (animal test)			
Correct answers	0.7	0.1	1.0
Rule violations	0.1	0.1	0.1
Alternate semantic verbal fluency (sport/fruit test)			
Correct answers	0.6	0.0	0.6
Rule violations	0.6	0.0	0.6
Convergent thinking (Tower of London task)			
Overall performance			
Correct solutions	0.9	0.8	0.2
Planning time	0.3	0.3	0.1
3-move problems			
Correct solutions	0.2	0.3	0.1
Planning time	0.3	0.5	0.1
4-move problems			
Correct solutions	0.3	0.5	0.2
Planning time	0.2	0.3	0.1
5-move problems			
Correct solutions	1.0	0.9	0.3
Planning time	0.2	0.2	0.0
6-move problems			
Correct solutions	0.9	0.7	0.4
Planning time	0.3	0.1	0.2

5-move problems: Z = –1.22, p = .223; 6-move problems: Z = –0.47, p = .638; overall performance: Z = –1.32, p =.189).

Comparisons between adults with ADHD on MPH treatment and healthy participants. On MPH, adults with ADHD generated significantly fewer correct answers in the verbal fluency tasks than healthy participants (single phonemic verbal fluency task: Z = –2.36, p = .018; alternate phonemic verbal fluency task: Z = –2.87, p = .004; single semantic verbal fluency task: Z = –2.54; p = .011; alternate semantic verbal fluency task: Z = –2.04, p = .042). The underlying differences were of medium to large size. No differences were found between groups in the number of rule violations (single phonemic verbal fluency task: Z = –1.54, p = .124; alternate phonemic verbal fluency task: Z = –0.37, p = .715; single semantic verbal fluency task: Z = –0.60; p = .547; alternate semantic verbal fluency task: Z = –1.44, p = .149). However, both a large effect in the number of rule violations in the single phonemic verbal fluency task, and a medium effect concerning the number of rule violations in the alternate semantic verbal fluency task, indicated that patients with ADHD experienced difficulties in divergent thinking. The remaining differences were of negligible size. With regard to the Tower of London task, there was neither a significant difference between groups in the number of correct solutions (3-move problems: Z = –0.47, p = .962; 4-move problems: Z = –0.67, p = .503; 5-move problems: Z = –0.46, p = .647; 6-move problems: Z = –1.49, p = .137; overall performance: Z = –1.06, p = .289) nor in the initial planning time (3-move problems: Z = –1.27, p = .204; 4-move problems: Z = –1.09, p = .275; 5-move problems: Z = –0.88, p = .379; 6-move problems: Z = –0.94, p = .348; overall performance: Z = –0.16, p = .869). The effects between patients and healthy participants represented only negligible to small differences.

Discussion

The present studies revealed that adult patients with ADHD off MPH displayed marked deficits of both divergent and convergent thinking indicating a considerable impairment of problem-solving abilities. The findings concerning divergent thinking confirm the literature stating that adults with ADHD off stimulant medication generate fewer answers on verbal fluency tasks than healthy participants (Boonstra et al., 2005; Dinn et al., 2001; Jenkins et al., 1998; Lovejoy et al., 1999; Tucha et al., 2005; Walker et al., 2000). Furthermore, previous studies also found that the number of rule violations on fluency tasks is a less sensitive measure for the differentiation of ADHD adults and healthy participants than the number of correct answers or the total output (Jenkins et al., 1998; Tucha et al., 2005). The small to large effects and in a particular test even a statistically significant difference concerning the number of rule violations, as observed in the present studies, should not be overinterpreted. Although patients generally tended to produce more rule violations than healthy participants, rule violations were found to be only a rare phenomenon in both groups. Since the reliability of examinations based on the observation of short test scales and rare events is usually very small (Kline, 2000), the value of the observed differences in the number of rule violations is very limited. The small number of rule violations indicates that the patients' disturbances on the verbal fluency tasks may probably result from a reduced productivity rather than a deficient processing. A reduction of productivity due to a general slowing in adults with ADHD could be excluded, since no differences in reaction time and processing speed were found to exist between groups. Furthermore, any influence of sex, age, education, and intellectual functions on fluency performance as described in previous research (Bolla, Lindgren, Bonaccorsy, & Bleecker, 1990; DesRosiers & Kavanagh, 1987; Lindenberger, Mayr, & Kliegl, 1993; Parkin & Lawrence, 1994; Salthouse, 1993; Troyer, 2000; Wiederholt et al., 1993) could be excluded since the groups did not differ in these variables.

The analysis of effect sizes for group differences (ADHD patients off medication vs. healthy participants) showed that the differences between groups in the phonemic verbal fluency tasks are more pronounced than the group differences in the semantic verbal fluency tasks. While in both studies of the present examination the differences between groups in the number of correct answers in the S-Word Test and H/T-Word Test were found to be large (0.8 to 1.1 and 0.9 to 1.2, respectively), the differences in the Animal Test and Sport/Fruit Test were medium (0.5 to 0.7 and 0.6, respectively). Previous research demonstrated that there is a difference in difficulty between phonemic and semantic fluency tasks (Gurd & Ward, 1989; Lezak et al., 2004; Martin, Wiggs, Lalonde, & Mack, 1994; Pasquier, Lebert, Grymonprez, & Petit, 1995). In comparison to their performance on phonemic verbal fluency tasks, healthy participants usually perform better on semantic verbal fluency tasks. This difference in performance may partially be explained by different strategies that can effectively be applied to the tasks, such as the generation of words within phonemic and semantic subcategories (clustering) and the flexible switching to new subcategories when a subcategory is exhausted (Troyer, 2000). Former studies indicate that performance on phonemic fluency tasks is closely related to switching but not to clustering, while performance on semantic fluency tasks seems to be influenced by both clustering and switching (Troyer, Moscovitch, & Winocur, 1997).

The present results also indicate that adult patients with ADHD off MPH differed significantly from healthy participants with regard to convergent thinking. Patients with ADHD off MPH solved significantly fewer problems in the TOL than healthy participants. In particular, patients displayed more severe difficulties in problems with a higher level of difficulty as defined by the number of moves required to solve a problem (5-move problems and 6-move problems). The analysis of effect sizes revealed small differences between groups in the initial planning time pointing to a reduced planning time in ADHD patients; however these differences did not reach significance. To date, the examination of Riccio and colleagues (2004) is the only available study in which convergent thinking of adults with ADHD off stimulant medication was assessed using a tower task. The authors used a computerized version of the (TOL) as devised by Culbertson and Zillmer (1998) but found no significant differences between their patients with ADHD and both a healthy and a clinical control group. Those results do not contradict the present results since a nonrejection of the null hypothesis does not indicate that no differences exist in the population (Cohen, 1988; Pedhazur & Schmelkin, 1991). Reasons why the study of Riccio and colleagues (2004) failed to find differences may include that the authors examined a smaller (N = 34) and younger (mean age = 22.1 years of age) sample of adults with ADHD that they applied different diagnostic and recruitment criteria and that they used a different variant of the (TOL). In the TOL, various measures were registered including the number of total moves and time measures such as the initiation and the execution time. However, the number of problems solved in the minimum number of moves was not recorded.

Treatment of adults with ADHD using individually tailored doses of MPH revealed a differential effect of MPH on problem-solving abilities. In comparison to their test performance while off MPH, adults with ADHD on MPH showed a marked improvement of convergent thinking. These MPH-induced improvements were not only significant but also of medium to large size. Consequently, following MPH treatment adults with ADHD reached an undisturbed level of functioning with regard to convergent thinking. However, no effect of medication was found on divergent thinking. Therefore, adults with ADHD still showed a considerable impairment of divergent thinking while on MPH treatment. While the effect of MPH on convergent thinking of adults with ADHD has not been examined yet, there is only one study examining the effect of MPH on divergent thinking. This study reported a significant improvement of verbal fluency performance in eight patients with ADHD following MPH treatment (Kuperman et al., 2001). However, the value of this finding is very limited, not only because of the small sample size but also because of other methodological weaknesses, such as the lack of a healthy control group and the total lack of a description of the verbal fluency task used in the study.

The present results must be viewed in the context of some limitations. First, the sample sizes assessed in Study II were small (22 adults with a diagnosed ADHD and 22 healthy control participants). A second restriction of the study is that only laboratory measures were performed. Since laboratory measures are usually designed to prove theoretical predictions under strict control of situational variables, concerns regarding their ecological validity have been raised (Barkley, 1991). The ecological validity of a psychometric test represents the functional and predictive relationship between participants' performance in a task and their normal behavior. Therefore, the results of adults with ADHD in laboratory measures may not accurately represent symptoms and problems associated with ADHD as they occur in natural settings such as the workplace.

In conclusion, although stimulant medication has been shown to be effective in the treatment of cognitive disturbances of adults with ADHD (Aron et al., 2003; Mehta et al., 2000; Riordan et al., 1999; Schweitzer et al., 2004; Tucha et al., 2006; Turner et al., 2005), the strengths of psychoeducational intervention or executive training programmes such as those developed for adults with acquired deficits of problem solving secondary to brain injury should also be considered as additional treatment options (Sohlberg & Mateer, 2001; Wasserstein & Lynn, 2001). In this respect it has to be considered that most of the everyday problems are open problems in which neither the final state (goal or target state) nor the solution approach are clearly defined, such as dealing with money, planning a career or establishing a relationship. Indeed, former studies have reported that adults with ADHD suffer from impaired social and sexual relationships, impaired integration in working life, occupational problems, impaired leisure functioning, and problems in financial matters (Barkley, 2006; Faraone et al., 2000; McCann & Roy-Byrne, 2000; Wender, 1995; Wilens & Dodson, 2004). More recently, Biederman et al. (2006) found that adults with ADHD and deficits of executive functioning display a lower academic and occupational outcome and a lower socioeconomic status than adults suffering from ADHD without deficits of executive functioning.

References

Amabile, T. M. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*, 357-376.

Arcia, E., & Gualtieri, C. T. (1994). Neurobehavioural performance of adults with closed-head injury, adults with attention deficit, and controls. *Brain Injury, 8*, 395-404.

Aron, A. R., Dowson, J. H., Sahakian, B. J., & Robbins, T. W. (2003). Methylphenidate improves response inhibition in adults with attention deficit/hyperactivity disorder. *Biological Psychiatry, 54*, 1465-1468.

Aschenbrenner, S., Tucha, O., & Lange, K. W. (2000). *Der Regensburger Wortflüssigkeitstest* [Regensburg Word Fluency Test]. Göttingen: Hogrefe Verlag.

Barkley, R. A. (1991). The ecological validity of laboratory and analogue assessment methods of ADHD symptoms. *Journal of Abnormal Child Psychology, 19*, 149-178.

Barkley, R. A. (1998). Etiologies. In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment* (2nd ed., pp. 164-185). New York: Guilford.

Barkley, R. A. (2006). ADHD in adults: developmental course and outcome of children with ADHD, and ADHD in clinic referred adults. In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder* (pp. 248-296). New York: Guilford.

Barkley, R. A., & Murphy, K. R. (1998). *Attention-deficit hyperactivity disorder: a clinical workbook* (2nd ed.) New York: Guilford.

Benson, D. F. (1991). The role of frontal dysfunction in attention deficit hyperactivity disorder. *Journal of Child Neurology, 6*, S9-12.

Benton, A. L., Hamsher, K. d., & Sivan, A. B. (1989). *Multilingual Aphasia examination*. (3rd ed.). Iowa City, IA: AJA Associates.

Ben-Yishay, Y., & Diller, L. (1983). Cognitive remediation. In M. Rosenthal, E. Griffith, M. Bond, & J. Miller (Eds.), *Rehabilitation of the head injured adult* (pp. 367-380). Philadelphia, PA: Davis.

Berg, D., Becker, G., Zeiler, B., Tucha, O., Hofmann, E., Preier, M., et al. (1999). Vulnerability of the nigrostriatal system as detected by transcranial ultrasound. *Neurology, 53*, 1026-1031.

Bezeau, S., & Graves, R. (2001). Statistical power and effect sizes of clinical neuropsychology research. *Journal of Clinical and Experimental Neuropsychology, 23*, 399-406.

Biederman, J., Petty, S., Fried, R., Fontanella, J., Doyle, A. E., Seidman, L. J., et al. (2006). Impact of psychometrically defined deficits of executive functioning in adults with attention deficit hyperactivity disorder. *American Journal of Psychiatry, 163*, 1730-1738.

Bolla, K. I., Lindgren, K. N., Bonaccorsy, C., & Bleecker, M. L. (1990). Predictors of verbal fluency (FAS) in the healthy elderly. *Journal of Clinical Psychology, 46*, 623-628.

Boonstra, A. M., Oosterlaan, J., Sergeant, J. A., & Buitelaar, J. K. (2005). Executive functioning in adult ADHD: A meta-analytic review. *Psychological Medicine, 35*, 1097-1108.

Boucugnani, L. L., & Jones, R. W. (1989). Behaviors analogous to frontal lobe dysfunction in children with attention deficit hyperactivity disorder. *Archives of Clinical Neuropsychology, 4*, 161-173.

Casey, B. J., Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D., Schubert, A. B., et al. (1997). Implication of right frontostriatal circuitry in response inhibition and attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*, 374-383.

Castellanos, F. X., Giedd, J. N., Marsh, W. L., Hamburger, S. D., Vaituzis, A. C., Dickstein, D. P., et al. (1996). Quantitative brain magnetic resonance imaging in attention-deficit hyperactivity disorder. *Archives of General Psychiatry, 53*, 607-616.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cook, E. H., Stein, M. A., Krasowski, M. D., Cox, N. J., Olkon, D. M., Kieffer, J. E., et al. (1995). Association of attention-deficit disorder and the dopamine transporter gene. *American Journal of Human Genetics, 56*, 993-998.

Corbett, B., & Stanczak, D. E. (1999). Neuropsychological performance of adults evidencing attention-deficit hyperactivity disorder. *Archives of Clinical Neuropsychology, 14*, 373-387.

Cramon, D. Y. V., & Matthes-von Cramon, G. (1993). Problemlösendes Denken. In D. Y. V. Cramon, N. Mai, & W. Ziegler (Eds.), *Neuropsychologische Diagnostik* (pp. 123-152). Weinheim: VCH.

Culbertson, W. C., & Zillmer, E. A. (1998). The construct validity of the Tower of London as a measure of the executive functioning of ADHD children. *Assessment, 5*, 215-226.

DesRosiers, G., & Kavanagh, D. (1987). Cognitive assessment in closed head injury: Stability, validity and parallel forms for two neuropsychological measures of recovery. *International Journal of Clinical Neuropsychology, 9*, 162-173.

Dinn, W. M., Robbins, N. C., & Harris, C. L. (2001). Adult attention-deficit/hyperactivity disorder: Neuropsychological correlates and clinical presentation. *Brain and Cognition, 46*, 114-121.

DuPaul, G. J., Barkley, R. A., & Connor, D. F. (1998). Stimulants. In R. A. Barkley (Ed.), *Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment* (2nd ed., pp. 510-551). New York: Guilford.

Epstein, J. N., Johnson, D. E., Varia, I. M., & Conners, C. K. (2001). Neuropsychological assessment of response inhibition in adults with ADHD. *Journal of Clinical and Experimental Neuropsychology, 23*, 362-371.

Faraone, S. V., Biederman, J., Spencer, T., Wilens, T., Seidman, L. J., Mick, E., et al. (2000). Attention-deficit/hyperactivity disorder in adults: an overview. *Biological Psychiatry, 48*, 9-20.

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 normal controls. *Neurology, 48*, 589-601.

Goel, V., Grafman, J., Tajik, J., Gana, S., & Danto, D. (1997). A study of the performance of patients with frontal lobe lesions in a financial planning task. *Brain, 120*, 1805-1822.

Grafman, J. (1999). Experimental assessment of adult frontal lobe function. In B. L. Miller & J. L. Cummings (Eds.), *The human frontal lobes* (pp. 321-344). New York: Guilford.

Gurd, J. M., & Ward, C. D. (1989). Retrieval from semantic and letter-initial categories in patients with Parkinson's disease. *Neuropsychologia, 27*, 743-746.

Hanes, K. R., Andrewes, D. G., Smith, D. J., & Pantelis, C. (1996). A brief assessment of executive control dysfunction: Discriminant validity and homogeneity of planning, set shift, and fluency measures. *Archives of Clinical Neuropsychology, 11*, 185-191.

Hodgson, T. L., Tiesman, B., Owen, A. M., & Kennard, C. (2002). Abnormal gaze strategies during problem solving in Parkinson's disease. *Neuropsychologia, 40*, 411-422.

Holdnack, J. A., Moberg, P. J., Arnold, S. E., Gur, R. C., & Gur, R. E. (1995). Speed of processing and verbal learning deficits in adults diagnosed with attention deficit disorder. *Neuropsychiatry, Neuropsychology and Behavioral Neurology, 8*, 282-292.

Hollingsworth, D. E., McAuliffe, S. P., & Knowlton, B. J. (2001). Temporal allocation of visual attention in adult attention deficit hyperactivity disorder. *Journal of Cognitive Neuroscience, 13*, 298-305.

Hopkins, J., Perlman, T., Hechtman, L., & Weiss, G. (1979). Cognitive style in adults originally diagnosed as hyperactives. *Journal of Child Psychology and Psychiatry, 20*, 209-216.

Horton, A. M. (1996). Neuropsychological findings in adult attention deficit disorder: A pilot study. *Applied Neuropsychology, 3*, 181-185.

Hynd, G. W., Hern, K. L., Novey, E. S., Eliopulos, D., Marshall, R., Gonzalez, J. J., et al. (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., & Eliopulos, D. (1990). Brain morphology in developmental dyslexia and attention deficit disorder/hyperactivity. *Archives of Neurology, 47*, 919-926.

Jenkins, M., Cohen, R., Malloy, P., Salloway, S., Johnson, E. G., Penn, J., et al. (1998). Neuropsychological measures which discriminate among adults with residual symptoms of attention deficit disorder and other attentional complaints. *Clinical Neuropsychologist, 12,* 74-83.

Johnson, D. E., Epstein, J. N., Waid, L. R., Latham, P. K., Voronin, K. E., & Anton, R. F. (2001). Neuropsychological performance deficits in adults with attention deficit/hyperactivity disorder. *Archives of Clinical Neuropsychology, 16*, 587-604.

Klee, S. H., Garfinkel, B. D., & Beauchesne, H. (1986). Attention deficits in adults. *Psychiatric Annals, 16*, 52-56.

Kline, P. (2000). *Handbook of psychological testing* (2nd ed.). London: Routledge.

König, F. (1986). Kreativitätsdiagnostik als essentieller Bestandteil der Intelligenzdiagnostik. [Assessment of creativity in the assessment of intelligence]. *Diagnostica, 4*, 345-357.

Kovner, R., Budman, C., Frank, Y., Sison, C., Lesser, M., & Halperin, J. (1998). Neuropsychological testing in adult attention deficit hyperactivity disorder: A pilot study. *International Journal of Neurosciene, 96*, 225-235.

Krampen, G. (1993). Diagnostik der Kreativität. In G. Trost, K. H. Ingenkamp, & R. Jäger (Eds.), *Test and trends 10* (pp. 11-39). Weinheim: Beltz Psychologie Verlags Union.

Kuperman, S., Perry, P. J., Gaffney, G. R., Lund, B. C., Bever-Stille, K. A., Arndt, S., et al. (2001). Bupropion SR vs. methylphenidate vs. placebo for attention deficit hyperactivity disorder in adults. *Annals of Clinical Psychiatry, 13*, 129-134.

LaHoste, G. J., Swanson, J. M., Wigal, S. B., Glabe, C., Wigal, T., King, N., et al. (1996). Dopamine D4 receptor gene polymorphism is associated with attention deficit hyperactivity disorder. *Molecular Psychiatry, 1*, 121-124.

Lange, K. W., Paul, G. M., Naumann, M., & Gsell, W. (1995). Dopaminergic effects on cognitive performance in patients with Parkinson's disease. *Journal of Neural Transmission* (*Suppl*), *46*, 423-432.

Lange, K. W., Robbins, T. W., Marsden, C. D., James, M., Owen, A. M., & Paul, G. M. (1992). L-dopa withdrawal in Parkinson's disease selectively impairs cognitive performance in tests sensitive to frontal lobe dysfunction. *Psychopharmacology, 107*, 394-404.

Lange, K. W., Tucha, O., Alders, G. L., Preier, M., Csoti, I., Merz, B., et al. (2003). Differentiation of parkinsonian syndromes according to differences in executive functions. *Journal of Neural Transmission, 110*, 983-995.

Lehrl, S., Triebig, G., & Fischer, B. (1995). Multiple choice vocabulary test MWT as a valid and short test to estimate premorbid intelligence. *Acta Neurologica Scandinavica, 91*, 335-345.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Lindenberger, U., Mayr, U., & Kliegl, R. (1993). Speed and intelligence in old age. *Psychology and Aging, 8*, 207-220.

Lou, H. C., Henriksen, L., & Bruhn, P. (1984). Focal cerebral hypoperfusion in children with dysphasia and/or attention deficit disorder. *Archives of Neurology, 41*, 825-829.

Lovejoy, D. W., Ball, J. D., Keats, M., Stutts, M. L., Spain, E. H., Janda, L., et al. (1999). Neuropsychological performance of adults with attention deficit hyperactivity disorder (ADHD): Diagnostic classification estimates for measures of frontal lobe/executive functioning. *Journal of the International Neuropsychological Society, 5*, 222-233.

Lüer, G., & Spada, H. (1992). *Denken und Problemlösen*. In H. Spada (Ed.), *Allgemeine Psychologie* (2 ed., pp. 189-280). Bern: Huber.

Luria, A. R. (1973). *The working brain*. New York: Basic Books.

Martin, A., Wiggs, C. L., Lalonde, F., & Mack, C. (1994). Word retrieval to letter and semantic cues: A double dissociation in normal subjects using interference tasks. *Neuropsychologia, 32*, 1487-1494.

McCann, B. S., & Roy-Byrne, P. (2000). Attention-deficit/hyperactivity disorder and learning disabilities in adults. *Seminars in Clinical Neuropsychiatry, 5*, 191-197.

Mehta, M. A., Calloway, P., & Sahakian, B. J. (2000). Amelioration of specific working memory deficits by methylphenidate in a case of adult attention deficit/hyperactivity disorder. *Journal of Psychopharmacology, 14*, 302.

Mercugliano, M. (1995). Neurotransmitter alterations in attention-deficit/hyperactivity disorder. *Mental Retardation and Developmental Disabilities Research Reviews, 1*, 220-226.

Morris, R. G., Downes, J. J., Sahakian, B. J., Evenden, J. L., Heald, A., & Robbins, T. W. (1988). Planning and spatial working memory in Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry, 51*, 757-766.

Owen, A. M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., Quinn, N. P., et al. (1992). Fronto-striatal cognitive deficits at different stages of Parkinson's disease. *Brain, 115*, 1727-1751.

Owen, A. M., Sahakian, B. J., Hodges, J. R., Summers, B. A., Polkey, C. E., & Robbins, T. W. (1995). Dopamine-dependent frontostriatal planning deficits in early Parkinson's disease. *Neuropsychology, 9*, 126-140.

Pantelis, C., Barnes, T. R., Nelson, H. E., Tanner, S., Weatherley, L., Owen, A. M., et al. (1997). Frontal-striatal cognitive deficits in patients with chronic schizophrenia. *Brain, 120*, 1823-1843.

Parkin, A. J., & Lawrence, A. (1994). A dissociation in the relation between memory tasks and frontal lobe tests in the normal elderly. *Neuropsychologia, 32*, 1523-1532.

Pasquier, F., Lebert, F., Grymonprez, L., & Petit, H. (1995). Verbal fluency in dementia of frontal lobe type and dementia of Alzheimer type. *Journal of Neurology, Neurosurgery and Psychiatry, 58*, 81-84.

Pedhazur, E. J., & Schmelkin, L. (1991). *Measurement, design, and analysis: An integrated approach*. Hillsdale, NJ: Lawrence Erlbaum.

Reitan, R. M. (1958). Validity of the Trailmaking Test as an indication of organic brain damage. *Perceptual and Motor Skills, 8*, 271-276.

Riccio, C. A., Wolfe, M. E., Romine, C., Davis, B., & Sullivan, J. R. (2004). The Tower of London and neuropsychological assessment of ADHD in adults. *Archives of Clinical Neuropsychology, 19*, 661-671.

Riordan, H. J., Flashman, L. A., Saykin, A. J., Frutiger, S. A., Carroll, K. E., & Huey, L. (1999). Neuropsychological correlates of methylphenidate treatment in adult ADHD with and without depression. *Archives of Clinical Neuropsychology, 14*, 217-233.

Robbins, T. W., James, M., Owen, A. M., Lange, K. W., Lees, A. J., Leigh, P. N., et al. (1994). Cognitive deficits in progressive supranuclear palsy, Parkinson's disease, and multiple system atrophy in tests sensitive to frontal lobe dysfunction. *Journal of Neurology, Neurosurgery and Psychiatry, 57*, 79-88.

Robbins, T. W., James, M., Owen, A. M., Sahakian, B. J., Lawrence, A. D., McInnes, L., et al. (1998). A study of performance on tests from the CANTAB battery sensitive to frontal lobe dysfunction in a large sample of normal volunteers: Implications for theories of executive functioning and cognitive aging. Cambridge Neuropsychological Test Automated Battery. *Journal of the International Neuropsychological Society, 4*, 474-490.

Rowe, H. A. H. (1985). *Problem solving and intelligence*. Hillsdale, NJ: Lawrence Erlbaum.

Ruprecht-Dorfler, P., Berg, D., Tucha, O., Benz, P., Meier-Meitinger, M., Alders, G. L., et al. (2003). Echogenicity of the substantia nigra in relatives of patients with sporadic Parkinson's disease. *Neuroimage, 18*, 416-422.

Salthouse, T. A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. *Journal of Gerontology, 48*, 29-36.

Schweitzer, J. B., Lee, D. O., Hanford, R. B., Zink, C. F., Ely, T. D., Tagamets, M. A., et al. (2004). Effect of methylphenidate on executive functioning in adults with attention-deficit/hyperactivity disorder: Normalization of behaviour but not related brain activity. *Biological Psychiatry, 56*, 597-606.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transactions of the Royal Society of London, Series B, 298*, 199-209.

Silverstein, S. M., Como, P. G., Palumbo, D. R., West, L. L., & Osborn, L. M. (1995). Multiple sources of attentional dysfunction in adults with Tourette's syndrome: Comparison with attention deficit-hyperactivity disorder. *Neuropsychology, 9*, 157-164.

Simon, H. A. (1975). The functional equivalence of problem solving skills. *Cognitive Psychology, 7*, 268-288.

Singer, H. S., Reiss, A. L., Brown, J. E., Aylward, E. H., Shih, B., Chee, E., et al. (1993). Volumetric MRI changes in basal ganglia of children with Tourette's syndrome. *Neurology, 43*, 950-956.

Smith, E. E., & Kosslyn, S. M. (2007). *Cognitive psychology: mind and brain*. Upper Saddle River, NJ: Pearson Education.

Sohlberg, M. M., & Mateer, C. A. (2001). Improving attention and managing attentional problems: Adapting rehabilitation techniques to adults with ADD. In J. Wasserstein, L. E. Wolf, & F. F. Lefever (Eds.), *Adult attention deficit disorder: Brain mechanisms and life outcomes* (pp. 359-375). New York: New York Academy of Sciences.

Spreen, O., & Strauss, E. (1991). *A compendium of neuropsychological tests: Administration, norms, and commentary* (2nd ed.). New York: Oxford University Press.

Sternberg, R. J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. Cambridge, UK: Cambridge University Press.

Sternberg, R. J., Conway, B. E., Ketron, J. L., & Bernstein, M. (1981). People's conceptions of intelligence. *Journal of Personality and Social Psychology, 41*, 37-55.

Stuss, D. T., & Benson, D. F. (1986). *The frontal lobes*. New York: Raven Press.

Troyer, A. K. (2000). Normative data for clustering and switching on verbal fluency tasks. *Journal of Clinical and Experimental Neuropsychology, 22*, 370-378.

Troyer, A. K., Moscovitch, M., & Winocur, G. (1997). Clustering and switching as two components of verbal fluency: Evidence from younger and older healthy adults. *Neuropsychology, 11*, 138-146.

Tucha, O., & Lange, K. W. (2004). *Tower of London* [German Version]. Göttingen: Hogrefe Verlag.

Tucha, O., Mecklinger, L., Laufkötter, R., Kaunzinger, I., Paul, G. M., Klein, H. E., et al. (2005). Clustering and switching on verbal and figural fluency functions in adults with attention deficit hyperactivity disorder. *Cognitive Neuropsychiatry, 10*, 231-248.

Tucha, O., Mecklinger, L., Laufkötter, R., Klein, H. E., Walitza, S., & Lange, K. W. (2006). Methylphenidate-induced improvements of various measures of attention in adults with attention deficit hyperactivity disorder. *Journal of Neural Transmission, 113*, 1575-1592.

Turner, D. C., Blackwell, A. D., Dowson, J. H., McLean, A., & Sahakian, B. J. (2005). Neurocognitive effects of methylphenidate in adult attention-deficit/hyperactivity disorder. *Psychopharmacology, 178*, 286-295.

Vaidya, C. J., Austin, G., Kirkorian, G., Ridlehuber, H. W., Desmond, J. E., Glover, G. H., et al. (1998). Selective effects of methylphenidate in attention deficit hyperactivity disorder: A functional magnetic resonance study. *Proceedings of the National Academy of Sciences, 95*, 14494-14499.

Walker, A. J., Shores, E. A., Trollor, J. N., Lee, T., & Sachdev, P. S. (2000). Neuropsychological functioning of adults with attention deficit hyperactivity disorder. *Journal of Clinical and Experimental Neuropsychology, 22*, 115-124.

Wasserstein, J., & Lynn, A. (2001). Metacognitive remediation in adult ADHD. Treating executive function deficits via executive functions. *Annals of the New York Academy of Sciences, 931*, 376-384.

Wender, P. H. (1995). *Attention-deficit hyperactivity disorder in adults*. New York: Oxford University Press.

Weyandt, L. L., Rice, J. A., Linterman, I., Mitzlaff, L., & Emert, E. (1998). Neuropsychological performance of a sample of adults with ADHD, developmental reading disorder, and controls. *Developmental Neuropsychology, 14*, 643-656.

Wiederholt, W. C., Cahn, D., Butters, N. M., Salmon, D. P., Kritz, S. D., & Barrett, C. E. (1993). Effects of age, gender and education on selected neuropsychological tests in an elderly community cohort. *Journal of the American Geriatrics Society, 41*, 639-647.

Wilens, T. E., & Dodson, W. (2004). A clinical perspective of attention-deficit/hyperactivity disorder. *Journal of Clinical Psychiatry, 65*, 1301-1313.

Williams, C., Wright, B., & Partridge, I. (1999). Attention deficit hyperactivity disorder—A review. *British Journal of General Practice, 49*, 563-571.

Zakzanis, K. K. (2001). Statistics to tell the truth, the whole truth, and nothing but the truth: formulae, illustrative numerical examples, and heuristic interpretation of effect size analyses for neuropsychological researchers. *Archives of Clinical Neuropsychology, 16*, 653-667.

Zametkin, A. J., Liebenauer, L. L., Fitzgerald, G. A., King, A. C., Minkunas, D. V., Herscovitch, P., et al. (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., King, A. C., Semple, W. E., Rumsey, J., et al. (1990). Cerebral glucose metabolism in adults with hyperactivity of childhood onset. *New England Journal of Medicine, 323*, 1361-1366.

Zimmermann, P., & Fimm, B. (1993). *A computerized neuropsychological assessment of attention deficits* (Manual). Herzogenrath, Germany: PsyTest.

Zimmermann, P., & Fimm, B. (2002). A test battery for attentional performance. In M. Leclercq & P. Zimmermann (Eds.), *Applied neuropsychology of attention: Theory, diagnosis and rehabilitation* (pp. 110-151). New York: Psychology Press.

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