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Cognitive Impairment in Adult ADHD—Perspective Matters!

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Objective: The assessment of cognitive functions of adults with attention deficit hyperactivity disorder (ADHD) comprises self-ratings of cognitive functioning (subjective assessment) as well as psychometric testing (objective neuropsychological assessment). The aim of the present study was to explore the utility of these assessment strategies in predicting neuropsychological impairments of adults with ADHD as determined by both approaches. **Method:** Fifty-five adults with ADHD and 66 healthy participants were assessed with regard to cognitive functioning in several domains by employing subjective and objective measurement tools. Significance and effect sizes for differences between groups as well as the proportion of patients with impairments were analyzed. Furthermore, logistic regression analyses were carried out in order to explore the validity of subjective and objective cognitive measures in predicting cognitive impairments. **Results:** Both subjective and objective assessment tools revealed significant cognitive dysfunctions in adults with ADHD. The majority of patients displayed considerable impairments in all cognitive domains assessed. A comparison of effect sizes, however, showed larger dysfunctions in the subjective assessment than in the objective assessment. Furthermore, logistic regression models indicated that subjective cognitive complaints could not be predicted by objective measures of cognition and vice versa. **Conclusions:** Subjective and objective assessment tools were found to be sensitive in revealing cognitive dysfunctions of adults with ADHD. Because of the weak association between subjective and objective measurements, it was concluded that subjective and objective measurements are both important for clinical practice but may provide distinct types of information and capture different aspects of functioning.

Keywords: adult ADHD, assessment, cognition, complaints, neuropsychological testing

Attention deficit hyperactivity disorder (ADHD) in adulthood is associated with academic failure, social dysfunction, low self-esteem and reduced quality of life (Agarwal, Goldenberg, Perry, & Ishak, 2012; Biederman, 2005; Canu, Newman, Morrow, & Pope, 2008; Canu & Carlson, 2007). The diagnostic assessment of ADHD in adulthood involves a clinical evaluation of symptoms of inattention, hyperactivity and impulsivity, which have been found to be linked directly to impairments such as low academic achieve-

ment (Daley & Birchwood, 2010). Once the diagnosis of ADHD is established in an individual, specific treatments can be initiated in order to reduce symptoms and to improve functioning. Conventional psychological and pharmacological treatment strategies in adults with ADHD include, among others, cognitive-behavioral therapy (CBT) and stimulant drug treatment—for example, with methylphenidate—which both have been shown to be beneficial for adults with ADHD (Vidal-Estrada, Bosch-Munso, Nogueira-

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Morais, Casas-Brugue, & Ramos-Quiroga, 2012; Wigal, 2009; Wilens, Spencer, & Biederman, 2001).

The clinical evaluation of symptoms and impairments of adults with assumed ADHD benefits from an assessment of cognitive functions involving subjective and objective assessment tools. In this respect, the term “subjective” refers to the patients’ self-evaluation of their cognitive abilities and impairments (e.g., in self-report questionnaires), whereas “objective” refers to the measurement of cognitive functions with neuropsychological test procedures. Subjective and objective measurements are frequently applied in both clinical practice and clinical research. In both contexts, the two approaches have been shown to reveal dysfunctions in adults with ADHD in various cognitive domains, such as attention, executive functioning, memory, and learning. (Barkley & Murphy, 2010; Biederman et al., 2008; Fuermaier et al., 2013a, 2013b; Hervey, Epstein, & Curry, 2004; Schoechlin & Engel, 2005; L. Tucha et al., 2011; O. Tucha et al., 2006; O. Tucha et al., 2005). Evaluations of adults with ADHD in clinical settings often comprise several steps. The first step is usually that individuals report cognitive and affective complaints they experience (self-report). An objective assessment of cognitive functions might be indicated as a second step, in particular if subjective reports indicate considerable cognitive impairment. Decisions regarding the choice of potential treatments are largely dependent on a subsequent clinical evaluation of the results obtained in the subjective and objective assessments. It is commonly assumed that subjective and objective assessments represent concordant measures. However, there is currently a lack of empirical evidence that self-reports of cognitive functioning correspond with actual impairments as revealed in objective neuropsychological assessment.

To date, only a few studies have examined the relationship between subjective and objective measures of cognitive functions in adults with ADHD. With regard to the assessment of executive dysfunctions, research found only negligible to small associations between subjective and objective measures in adults with ADHD, challenging the assumption that both assessment strategies measure the same construct (Barkley & Fischer, 2011; Biederman et al., 2008). However, some studies reported relations between self-reported cognitive impairments and objective test data. For example, Stavro, Ettenhofer, and Nigg (2007) found a considerable association of medium size between objective measures of executive functions on the one hand and symptoms of inattention/disorganization obtained by both self- and informant reports on the other hand. A broader context for the examination of the relationship between subjective and objective measures of executive functions has been applied in a review by Toplak, West, and Stanovich (2013). These authors analyzed 20 studies including children and adults in both clinical and nonclinical samples and found a weak association between subjective and objective measures of executive functions, with an overall median correlation of only .19. Moreover, with regard to attention, Young and Gudjonsson (2005) revealed some positive correlation between errors in a measure of sustained attention and self-rated ADHD symptomatology, although correlations were only small (ranging from .25 to .27).

In summary, despite research having been done in this area, a majority of the conducted studies focused on executive functioning and yielded only mixed results (Barkley & Murphy, 2010; Biederman et al., 2008; Stavro et al., 2007). The relationship between subjective and objective measures in adults with ADHD remains

unclear for a broad range of functions. Since subjectively reported complaints as well as objectively determined cognitive impairments guide clinicians in their decisions, it is of utmost importance to better understand the relation between patients’ self-reports and objective assessments of cognition. The aim of the present study was, thus, to explore the concordance between a range of subjective and objective measures of cognition in adults with ADHD and to determine the validity of subjective and objective assessments in predicting cognitive impairments. It was hypothesized that both subjective and objective cognitive measures will reveal impairments of adults with ADHD in various cognitive domains (i.e., attention, memory, and executive functions). Moreover, based on the weak association between subjective and objective executive measures as reported by Toplak and colleagues (2013), it was expected that objectively defined cognitive impairments of adults with ADHD will not be predicted by self-reported cognitive functioning and vice versa. Conclusions were drawn in order to provide implications for the diagnostic process and clinical assessment of adults with ADHD.

Method

Participants

Patients with ADHD. Seventy-four adults with ADHD participated in the study. Patients were self-referred or referred from local psychiatrists or neurologists to the Department of Psychiatry and Psychotherapy, SRH Group, Karlsbad-Langensteinbach, Germany. Diagnostic assessments were performed by experienced clinicians associated with the Department of Psychiatry and Psychotherapy and involved a clinical psychiatric interview according to *DSM-IV* criteria for ADHD as devised by Barkley and Murphy (1998), including the retrospective diagnosis of ADHD in childhood (*DSM-IV* criteria) and current symptoms. Moreover, all participants completed two self-report rating scales designed to quantify current and retrospective ADHD symptoms (Rösler, Retz-Junginger, Retz, & Stieglitz, 2008). Patients were selected according to age, diagnosis, intellectual functions (IQ), and willingness to participate in the study. Patients were excluded (a) if they had clinically significant chronic medical conditions, (b) if they were currently treated with stimulant medication, (c) if there was a history suggestive of “psychosis” (indicating schizophrenia, delusional disorder, depressive disorder with psychotic features or manic episode), (d) if there was a history of neurological disorder including head injury, (e) if there was a history of substance abuse disorder during the previous 6 months, (f) if the initial psychiatric assessment indicated a current major depressive episode, or (g) if estimated verbal IQ was <85. Nineteen of the 74 adults with ADHD were excluded (reasons for exclusion: current treatment with stimulant medication [$n = 18$] and current substance abuse [$n = 1$]), resulting in a sample of 55 adults with ADHD. In the diagnostic assessment of the 55 patients with ADHD, 17 patients met *DSM-IV* criteria for ADHD—predominantly inattentive type (ADHD-I), one patient met criteria for ADHD—hyperactive-impulsive type (ADHD-H) and 37 patients met criteria for ADHD—combined type (ADHD-C). Seventeen of the 55 patients with ADHD were diagnosed with one or more comorbid disorders, including mood disorders ($n = 14$), anxiety disorders ($n = 2$), personality disorders ($n = 3$), eating disorders ($n = 1$), adjustment

disorder ($n = 1$), and substance abuse disorder (with no substance abuse in the previous 6 months; $n = 2$). Fourteen patients were treated with antidepressive medication for a prolonged period of time because of affective disorders. All of the 55 patients with ADHD reported not to have been diagnosed with ADHD in the past and were thus for the first time diagnosed with ADHD in adulthood. Furthermore, these patients were not treated for their ADHD symptoms in the past (neither by pharmacological nor by nonpharmacological treatment). Characteristics of patients with ADHD are presented in Table 1.

Healthy participants. Furthermore, 66 healthy participants were assessed. Healthy participants were recruited via public announcements, word-of-mouth and through contacts of the researchers involved. None of the healthy participants reported to have a history of neurological or psychiatric disease. At the time of the study, no healthy participant was taking any medication known to affect the central nervous system. All healthy participants were recruited from the local community and completed the same self-rated questionnaires for current and retrospective ADHD symptoms prior to the assessment (Rösler et al., 2008). Intellectual functions of all participants were measured using the Multiple Choice Vocabulary Test (Lehrl, 1995). Patients and healthy participants did not differ in age, $t(119) = -1.38, p = .171$, gender ($\chi^2(1) = 0.001; p = .973$) and intellectual functions, $t(119) = -0.36, p = .717$. However, healthy participants had a significantly higher school education than patients with ADHD, $t(119) = 5.67, p < .001$. As expected, healthy participants scored lower on both questionnaires for ADHD symptoms, $t(88) = -19.82, p < .001$ for current symptoms; $t(88) = -18.37, p < .001$ for retrospective symptoms. Characteristics of healthy participants are also presented in Table 1.

Measures

Self-report scales for ADHD symptoms. Childhood ADHD symptoms were self-rated with the short version of the Wender Utah Rating Scale (WURS-K) including 25 items on a 5-point Likert scale (Ward, Wender, & Reimherr, 1993). Severity of current ADHD symptoms was self-rated with the ADHD self-report scale (Rösler et al., 2008) consisting of 18 items on a 4-point Likert scale corresponding to the diagnostic criteria of *DSM-IV* (American Psychiatric Association, 1994; Rösler et al., 2008). A sum score was calculated for each rating scale.

Subjective measures of cognitive functioning.

Questionnaire for experiences of attention deficits (FEDA). The Questionnaire for Experiences of Attention Deficits (German:

FEDA) is a 27-item self-report scale of experienced deficits in attention in everyday situations (Suslow, Arolt, & Junghanns, 1998; Zimmermann, Messner, Poser, & Sedelmeier, 1991). Participants were asked to indicate on a scale from 0 (*never*) to 4 (*very frequently*) how often certain problems of attention occur in their lives. The questionnaire is composed of three subscales, representing items of *distractibility* (e.g., "It is hard to concentrate when something is going on around me"), *fatigue* (e.g., "Even in easy tasks I need to take a break in order to get some rest") and *motivation* (e.g., "It happens that I lose interest even in my hobbies"). Mean scores were calculated for each subscale of the questionnaire.

Memory Self-Efficacy Questionnaire (MSEQ). Memory self-efficacy was assessed using two scales of the Memory Self-Efficacy Questionnaire (MSEQ; West, Bagwell, & Dark-Freudeman, 2005). The MSEQ is a domain-specific measure of memory self-efficacy, assessing five different levels of performance for several memory domains. In the present study, memory self-efficacy for two domains was assessed: self-efficacy for remembering a grocery list and self-efficacy for remembering a short story. For each memory domain (grocery list, short story), the item material was presented in written form on a sheet of paper. Subsequently, the five levels of performance in each domain were defined in the requirement to remember a specified number of items from the same item material (e.g., level 1: Remembering 10 sentences from the story of 10 sentences; level 2: Remembering 8 sentences from the story of 10 sentences). Individuals responded *yes* or *no* to indicate whether they could perform the tasks at each of the described levels. They were then provided with a confidence rating for *yes* responses (*no* response = 0 confidence). Confidence ratings ranged on a scale from 10% to 100% in steps of 10, with lower ratings indicating lower confidence. The mean confidence rating was calculated. The MSEQ measures the self-evaluation of memory performance and requests no actual memory performance such as storage or retrieval of item material.

Comprehensive Assessment of Prospective Memory (CAPM-IADL). The Comprehensive Assessment of Prospective Memory (CAPM) measures the frequency of prospective memory failure in everyday activities (Roche, Fleming, & Shum, 2002). The subscale CAPM-IADL consists of 23 items about specific everyday prospective memory lapses related to Instrumental Activities of Daily Living (activities of household management such as managing finances, shopping). The participants were required to rate how often they experienced memory lapses for each item on a 5-point scale. Higher scores indicated more frequent memory failures, ranging from 1 (*never*) to 5 (*very frequently*). The mean score of responses was calculated.

Dysexecutive Questionnaire (DEX). The Dysexecutive Questionnaire (DEX; Burgess, Alderman, Evans, Emslie, & Wilson, 1998) is a sensitive and ecologically valid instrument which consists of 20 questions covering the most commonly reported symptoms of the dysexecutive syndrome (e.g., planning for the future, making decisions, acting without thinking). Participants were asked to rate on a scale ranging from 0 (*never*) to 4 (*very often*) how often they observed the symptoms described in the DEX. The mean score of responses was calculated.

Questionnaire for Complaints of Cognitive Disturbances (FLei). The Questionnaire for Complaints of Cognitive Disturbances (German: FLei) is a self-report instrument that depicts

Table 1
Characteristics of Participants

	Healthy participants ($n = 66$)	Patients with ADHD ($n = 55$)
Age (in years)	31.9 $\pm$ 10.2	34.6 $\pm$ 10.7
Gender (female/male)	31/35	26/29
Intellectual functions (IQ)	100.4 $\pm$ 8.2	101.1 $\pm$ 11.4
Education (in years)	11.9 $\pm$ 1.6	10.2 $\pm$ 1.6
WURS-K ^a	10.9 $\pm$ 7.7	45.6 $\pm$ 12.7
ADHD-self-report scale	8.2 $\pm$ 5.2	33.4 $\pm$ 8.6

Note. ADHD = attention deficit hyperactivity disorder.

^a Wender Utah Rating Scale-Short version.

items of commonly reported cognitive complaints (Beblo et al., 2010). The questionnaire is composed of three subscales measuring complaints in attention (10 items; e.g., to stay focused for an unbroken period of time), memory (10 items; e.g., memory for names), and executive functioning (10 items; e.g., to plan a party). The questionnaire additionally includes five control items which were not included in the analysis. Participants were asked to indicate on a scale from 0 (*never*) to 4 (*very frequently*) how often the described problems occur. The mean score on each of the three scales was calculated.

Objective measures of cognitive functions.

Selective attention. Selective attention was measured with a computerized test (Visual Scanning) from the Test Battery for Attentional Performance (Zimmermann & Fimm, 2002). In the Visual Scanning test, a series of 5×5 matrices was presented in the center of the computer screen. Each matrix consisted of a regular array of 25 squares each of which had an opening on one of its sides. A square with an opening on the top was defined as critical stimulus. The participants were asked to press the left response button as quickly as possible whenever a matrix contained a critical stimulus or to press the right response button if the critical stimulus was not contained. The reaction time (RT) for correct responses of trials which did not contain a critical stimulus was registered.

Vigilance. Vigilance was measured with a computerized test (Vigilance) from the Test Battery for Attentional Performance (Zimmermann & Fimm, 2002), which required reaction to auditory presented stimuli. In the vigilance test, a sequence of tones was presented to the participant. Two different types of tones could be distinguished, one with a high pitch and the other one with a low pitch. The two types of tones were presented alternately in a constant rhythm (presentation Time 167 ms; stimulus onset asynchrony 1,500 ms). A target event was defined if two tones of the same pitch were directly presented after each other. The participant was requested to press a specified response button as quickly as possible if a target event occurred. The total duration of the vigilance test was 30 minutes in which 1,200 stimuli were presented. The target event rate was about one target event per minute (36 target events in total) whereas the time interval between two consecutive target events was irregular. The number of omissions was registered as a measure of vigilance. The task measured vigilance by requiring the participant to remain alert and ready to react to infrequently occurring target events for a relatively long and unbroken period of time.

Word recognition. A word list paradigm was developed to measure delayed recognition of unrelated words. In the learning phase, 40 unrelated German nouns (two different study lists existed, each containing 40 words, from which one was used) were presented consecutively in random order at the center of a computer screen (Arial, font size 44). Each word appeared for 4 seconds on the screen before the next word was presented. To control for serial position effects (primacy and recency effects), five additional words were placed at the beginning and at the end of the study list. Participants were instructed to focus on the stimulus presentation and to use whatever mnemonics they thought were effective to memorize the words presented on the screen. A recognition test followed after a delay of 40 minutes. The participants were asked to perform neuropsychological tests during the delay. In the recognition test, all words from the study list and 40

additional words which have not been presented before (two different distractor lists existed, each containing 40 words, from which one was used) were presented consecutively in random order at the center of the screen (80 words in total). The choice for the word list used during the learning phase and for the distractor list used in the recognition test was counterbalanced across participants. Words placed to control for primacy and recency effects were not presented in the recognition test. The participants were instructed to indicate with a button press on one of two predefined buttons on the keyboard whether the displayed word has been presented in the study phase or not. The test was self-paced and the next word appeared as soon as the participants gave a response. The number of correctly classified words was registered. A previous study demonstrated that the paradigm was sensitive to detect memory dysfunctions in adults with ADHD (Fuermaier et al., 2013a).

Story recall. Retrospective memory of a coherent story (story recall) was assessed by the Logical Memory II, a subtest of the Wechsler Memory Scale (Wechsler, 1987). Two short stories were read to the participants who had to recall the stories immediately and after a delay of about 20 minutes. The number of correctly recalled items in the delayed recall trial was registered as a measure of story recall.

Delayed task execution. A planning task was applied to assess delayed task execution as a measure of prospective memory. The paradigm has been developed to measure complex prospective memory and was shown to be sensitive in identifying impairments in prospective memory in both children and adults with ADHD (Fuermaier et al., 2013b; Kliegel, Ropeter, & Mackinlay, 2006). In the present task, participants were asked to plan and, after a delay of about 60 minutes, to carry out 10 subtests in a limited period of time (10 minutes) under the consideration of certain rules. During the task, several components of complex prospective memory can be assessed, that is, task planning (plan quality), retention (retrospective memory for plan information), self-initiation (self-initiation of task execution at a predefined event), and plan-fidelity (plan-fidelity in task execution according to initial plan). However, general task performance is indicated by a measure of switching between subtests (task switching). Task switching is calculated by the sum of actually initiated subtests at task execution under consideration of the rules. Task switching is crucial in this paradigm and may indicate general task performance since successful execution of the task requires active switching between subtests. Therefore, the number of initiated subtests at task execution was suggested as the primary measure for prospective memory (for details of the task, see Fuermaier et al., 2013b).

Inhibition. Inhibition was measured with the Stroop Color-Word Interference task (Bäumler, 1985; Stroop, 1935). The Stroop Color-Word Interference task consisted of three conditions. First, in the Color-Word condition, color words (YELLOW, GREEN, BLUE and RED) printed in black ink were presented on a card and the participants were required to read them in clear voice as fast as possible. Second, in the Color Block condition, colored rectangles (rectangles printed in yellow, green, blue, and red) were presented on a card and the participants were required to name the color of the rectangles as fast as possible. Third, in the Color-Word Interference condition, color words (YELLOW, GREEN, BLUE, and RED) were presented and printed in mismatching ink (e.g., RED printed in blue ink). The participants were required to name the color of the

words as fast as possible and to ignore the meaning of the printed word. Each trial consisted of the same number of stimuli. The time in seconds to complete each trial was registered. As dependent variable, a difference score was calculated per participant as a measure of inhibition by subtracting the time needed for completion of the Color Block condition from the Color-Word Interference condition (Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005).

Flexibility. Cognitive flexibility was assessed with the Trail Making Test (Reitan, 1958). The Trail Making Test consisted of two parts. Part A required participants to draw a line, as fast as possible, between numbers in ascending order. Part B consisted of numbers and letters. Participants were required to switch attention between both concepts. They had to draw a line between both types of stimuli in ascending order, alternating between numbers and letters as fast as possible. The time in seconds to complete the test was registered. The target measure of the Trail Making Test for cognitive flexibility was the performance on part B (TMT-B).

Word fluency. In the Regensburg Word Fluency Test (S-Word Test; Aschenbrenner, Tucha, & Lange, 2000), which is similar to the Controlled Oral Word Association Test (Benton, Hamsher, & Sivan, 1989), 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 number of correctly produced words was registered.

Intellectual functions. Intellectual functions (IQ) were measured using the Multiple Choice Vocabulary Test (Lehrl, 1995). This test consists of 37 lines, each comprising of one authentic word and four fictitious words. The participants were required to find the authentic word by underlining it. The Multiple Choice Vocabulary Test is a valid and short test procedure which provides a measure for intellectual functioning.

Procedure

All participants were tested individually. Prior to the assessment, all participants were informed about the aim of the study. It was emphasized that participation was voluntary, not paid, and that all data would be analyzed anonymously. At the beginning of the assessment, participants gave written informed consent to participate in the study. Subsequently, the questionnaires (subjective measure of cognitive functioning) were filled out, which took around 60 minutes. After a break, the neuropsychological assessment (objective measures of cognitive functions) was carried out, which took around 120 minutes. Table 2 presents an overview of all subjective and objective measures applied in the present study. The total duration of the assessment was about 180 minutes.

Ethics Statement

The study was conducted in compliance with the Helsinki Declaration. Ethical approval was obtained by the ethics committee of the medical faculty of the University of Heidelberg, Germany. All par-

Table 2

Subjective Measures (Self-Report Scales) and Objective Measures (Psychometric Neuropsychological Tests) of Neuropsychological Functions

Measure	Authors	Function/Aspect of functioning
Subjective measures of cognitive functioning		
Questionnaire for Experiences of Attention Deficits (FEDA)	Zimmermann, Messner, Poser, & Sedelmeier, 1991	Problems of attention: Distractibility Fatigue Motivation
Memory Self-Efficacy Questionnaire (MSEQ)	West, Bagwell, & Dark-Freudeman, 2005	Functioning of retrospective memory
Comprehensive Assessment of Prospective Memory (CAPM)	Roche, Fleming, & Shum, 2002	Problems of prospective memory: Basic activities of daily living Instrumental activities of daily living
Dysexecutive Questionnaire (DEX)	Burgess, Alderman, Evans, Emslie, & Wilson, 1998	Dysexecutive symptoms
Questionnaire for Complaints of Cognitive Disturbances (FLei)	Beblo et al., 2010	Complaints of the following: Attention Memory Executive functioning
Objective measures of cognitive functions		
Visual Scanning (TAP)	Zimmermann & Fimm, 2002	Selective attention
Vigilance (TAP)	Zimmermann & Fimm, 2002	Vigilance
Word recognition	Fuermaier et al., 2013a	Retrospective memory for words (word recognition)
Logical Memory II (WMS)	Wechsler, 1987	Retrospective memory for stories (story recall)
Delayed task execution	Fuermaier et al., 2013b	Prospective memory
Stroop Color-Word Interference test	Bäumler, 1985; Stroop, 1935	Inhibition
Trail Making test	Reitan, 1958	Flexibility
Regensburg Word Fluency test	Aschenbrenner, Tucha, & Lange, 2000	Divergent thinking (word fluency)

ticipants gave written informed consent prior to the assessment and were debriefed at the end of the assessment.

Statistical Analysis

Self-report scores and objective test scores of neuropsychological functions were compared between healthy participants and patients with ADHD employing multiple analyses of variance (ANOVA). An initial significance level of $\alpha = .05$ was corrected (Bonferroni correction) to control for α -inflation in multiple test procedures. Moreover, effect sizes (Cohen's d) were calculated for all comparisons. Following Cohen's guidelines for interpreting effect sizes, negligible effects ($d < 0.2$), small effects ($0.2 \leq d < 0.5$), medium effects ($0.5 \leq d < 0.8$) and large effects ($d \geq 0.8$) were distinguished (Cohen, 1988). Furthermore, the number of patients with ADHD with subjective and objective impairments in the neuropsychological functions was determined. This was achieved by classifying the participants' self-ratings and objective test scores on the basis of a commonly accepted categorization of ability levels (Lezak, Howieson, & Loring, 2004). Self-ratings and test scores lower than the "low-average" values (i.e., percentile ≤ 10) were individually classified as impaired. The percentiles of patients' self-ratings were calculated on the basis of the self-ratings of a control sample, which was matched to age, gender, and intellectual functions ($n = 105$, including the 66 healthy participants that were described in the participants section; z transformation). The percentiles of patients' objective test scores were calculated on the basis of published normative data (for sustained attention, vigilance, story recall, inhibition, flexibility, and word fluency) or on the basis of test scores of a control sample that was matched with regard to age, gender, and intellectual functions (for delayed task execution and word recognition; $n = 90$; including the 66 healthy participants that were described in the participants section). Moreover, with respect to both self-reports and objective test results, the proportion of patients with ADHD showing impairments in neuropsychological domains (attention, retrospective memory, prospective memory, and executive functions) was determined. Impairment in a particular domain was defined if at least one test/questionnaire score of that particular domain indicated a score of the lowest 10% of scores of healthy participants or normative data, respectively. Furthermore, the relationship between subjective and objective measures was analyzed by calculating binary logistic regression analyses. Logistic regression models were performed in order to (a) determine the validity of subjective self-reports of cognitive functioning (all questionnaire scores) in predicting an objectively defined impairment in a particular neuropsychological domain (based on the test scores of this individual domain) and to (b) determine the validity of objectively defined cognitive impairments (as measured with neuropsychological tests) in predicting a self-reported impairment in a particular neuropsychological domain (based on the questionnaire scores of this individual domain).

Results

Subjective Assessment of Cognitive Functioning

With regard to the subjective assessment of cognitive functioning, analyses of variance (ANOVA) revealed a significant difference between healthy participants and patients with ADHD on all self-report scales. A Bonferroni corrected significance level of $\alpha =$

.007 ($\alpha = .05/7$) was applied to control for inflation of Type I error due to multiple testing. Effect size calculations indicated large dysfunctioning in patients with ADHD on all measures of attention, retrospective memory, prospective memory, and executive functioning. Furthermore, data were z -transformed based on questionnaire scores of control participants (105 control participants matched according to age, gender, and intellectual functions). Data analysis on the frequency with which patients with ADHD reported impaired cognitive functioning showed that the majority of patients (between 60.0% and 85.2%, depending on the function) indicated impairments in each aspect of cognitive functioning (see Table 3).

Objective Assessment of Cognitive Functions

Significant differences (ANOVA) between healthy participants and patients with ADHD were found in all neuropsychological test measures with the exception of the test for divergent thinking (word fluency; see Table 4). A Bonferroni corrected significance level of $\alpha = .006$ ($\alpha = .05/8$) was applied. Effect size calculations indicated cognitive dysfunctions of patients with ADHD ranging from small size ($d = 0.35$ for word fluency) to large size ($d = 1.18$ for delayed task execution; see Table 4). Furthermore, data were z -transformed based on norms as provided by the test authors (for tests of selective attention, vigilance, story recall, inhibition, flexibility and word fluency) or based on results of control participants (for word recognition and delayed task execution; 90 control participants matched according to age, gender, and intellectual functions). Thereby the proportion of patients with ADHD showing impairments in each individual cognitive function was determined (see Table 4). Moreover, the proportion of patients with ADHD showing impairments in the different neuropsychological domains (attention, retrospective memory, prospective memory, executive functions) was calculated. This analysis revealed that around 50% of the patient sample showed impairments per domain (see Table 4).

Predictive Validity of Self-Reports About Cognitive Functioning

Binary logistic regression models were computed in order to determine the validity of self-reports of cognitive functioning (predictors) in predicting objectively assessed impairments (criterion). No significant model was found to predict an impairment in attention, $\chi^2(7, N = 55) = 12.057, p = .099$, on the basis of all applied self-report measures of cognitive functioning. The binary logistic regression model explained 20.0% of the total variance (Cox & Snell R^2) and self-report scores allowed correct classification of 64.8% of patients with ADHD to have an objectively defined impairment in attention. The contributions of single questionnaire scores to the model are presented in Table 5. With regard to impairments in memory, again no model was found to predict either impaired retrospective memory, $\chi^2(7, N = 55) = 6.618, p = .470$, or impaired prospective memory, $\chi^2(7, N = 55) = 7.678, p = .362$. A proportion of 63.0% of patients with ADHD were correctly classified to have an impairment in retrospective memory (Cox & Snell $R^2 = 11.5\%$) and 66.7% to have an impairment in prospective memory (Cox & Snell $R^2 = 13.3\%$). Finally, no significant model was obtained to predict an impairment in executive functions, $\chi^2(7, N = 55) = 6.531, p = .479$.

Table 3

Subjective Assessment of Cognitive Functioning (Self-Report) of Healthy Participants (Control) and Patients With ADHD

Aspect of functioning	Control (<i>n</i> = 66)	ADHD (<i>n</i> = 55)	<i>t</i> (119)	<i>p</i>	ES ^a	% of patients with impairment ^b
Attention						92.3
FEDA ^c (Ranging from 0 [<i>never</i>] to 4 [<i>very frequently</i>])	1.95 ± 0.43	3.27 ± 0.74	12.29	<.001*	2.23	85.0
FLei-A ^d (Ranging from 0 [<i>never</i>] to 4 [<i>very often</i>])	0.87 ± 0.63	2.56 ± 0.66	14.31	<.001*	2.63	85.2
Retrospective memory						81.5
MSEQ ^e Confidence rating [0% to 100%]	80.85 ± 14.76	54.93 ± 16.81	9.20	<.001*	1.65	60.0
FLei-M ^d (Ranging from 0 [<i>never</i>] to 4 [<i>very often</i>])	1.08 ± 0.57	2.41 ± 0.58	12.55	<.001*	2.31	72.2
Prospective memory						63.6
CAPM-IADL ^f (Ranging from 1 [<i>never</i>] to 5 [<i>very frequently</i>])	0.93 ± 0.48	1.90 ± 0.69	9.11	<.001*	1.66	63.6
Executive functioning						87.0
DEX ^g (Ranging from 0 [<i>never</i>] to 4 [<i>very often</i>])	0.88 ± 0.49	2.09 ± 0.64	11.79	<.001*	2.15	72.7
FLei-EF ^d (Ranging from 0 [<i>never</i>] to 4 [<i>very often</i>])	0.69 ± 0.56	2.27 ± 0.75	13.19	<.001*	2.42	81.5

Note. ADHD = attention deficit hyperactivity disorder.

^a Effect size (ES) indicated by Cohen's *d*. ^b Impaired if scored within the lowest 10% of scores of matched control participants (*n* = 105). ^c Questionnaire for Experiences of Attention Deficits. ^d Questionnaire for Complaints of Cognitive disturbances (Complaints in: A = Attention; M = Memory problems; EF = Executive Functioning). ^e Memory Self-Efficacy Questionnaire (Confidence ratings). ^f Comprehensive Assessment of Prospective Memory-Problems in Instrumental Activities of Daily Living. ^g Dysexecutive Questionnaire.

* Significant at *p* < .007.

Questionnaire scores correctly classified 63.0% of patients to have an objectively defined impairment in executive functions, Cox & Snell $R^2 = 11.4\%$.

Predictive Validity of Impairments as Measured With Neuropsychological Tests

Binary logistic regression models were carried out in order to determine the validity of objectively defined impairments as measured with neuropsychological tests (predictors) in predicting subjectively defined impairments as measured with self-reports (criterion). No significant model was found to predict impaired functioning in attention, $\chi^2(8, N = 55) = 7.680, p = .465$, on the basis of cognitive impairments as determined by neuropsychological tests. The binary logistic regression model explained 13.7% of the total variance (Cox & Snell R^2) and the information about objectively defined cognitive impairments allowed correct classification of 92.3% of patients with ADHD to have a subjectively defined impairment in attention. The contributions of single test scores to the model are presented in Table 6. With regard to self-reports of impaired functioning in memory, again no model was found to predict either impaired functioning in retrospective memory, $\chi^2(8, N = 55) = 5.216, p = .734$, or impaired functioning in prospective memory, $\chi^2(8, N = 55) = 9.257, p = .321$. Of patients with ADHD, 81.5% were correctly classified to have an impairment in self-reported functioning of retrospective memory (Cox & Snell $R^2 = 9.2\%$) and 70.9% to have an impairment in self-reported functioning of prospective memory (Cox & Snell $R^2 = 15.5\%$). Finally, no significant model was obtained to predict self-reported executive dysfunctioning, $\chi^2(8, N = 55) = 14.920, p = .061$. Cognitive impairments as defined on test scores cor-

rectly classified 92.6% of patients to have a subjectively defined impairment in executive functioning (Cox & Snell $R^2 = 24.1\%$).

Discussion

Both subjective and objective measures of cognition are of great relevance for the assessment of neuropsychological functioning in neuropsychiatric conditions such as adult ADHD. The present study explored the concordance between results of a subjective and an objective assessment of cognitive functions in adults with ADHD and provided implications for clinical practice.

Identification of Cognitive Impairments With Subjective and Objective Measures

The patients' self-reports revealed large dysfunctioning in adults with ADHD in measures of all neuropsychological domains, including attention, retrospective memory, prospective memory, and executive functioning. Analysis of the frequency of patients reporting impairments in cognitive functioning showed that a majority of patients reported impairments in various neuropsychological domains. More specifically, a larger proportion of patients reported impairments in attention (about 92% of patients) and executive functioning (between about 73% and 82% of patients) than in retrospective memory (between about 60% and 73% of patients) and prospective memory (about 64% of patients). Despite a difference in the proportion of patients reporting impairments of executive functioning between the present study (between 73% and 82% of patients) and a recent study conducted by Biederman and colleagues (2008; 49% of patients), both studies demonstrated

Table 4

Objective Assessment of Cognitive Functions (Standardized Psychometric Testing) of Healthy Participants (Control) and Patients With ADHD

Function	Control (<i>n</i> = 66)	ADHD (<i>n</i> = 55)	<i>t</i> (119)	<i>p</i>	ES ^a	% of patients with impairment ^{b, c}
Attention						47.3
Selective attention ^d (Reaction time in seconds)	4.62 ± 1.49	5.49 ± 1.60	3.06	.003*	0.57	38.2
Vigilance ^e (Number of omissions)	1.12 ± 1.75	2.56 ± 3.67	2.83	.005*	0.52	42.9
Retrospective memory						49.1
Word recognition ^f (Number of words correctly classified)	73.99 ± 12.21	67.30 ± 9.93	3.26	.001*	0.60	35.6
Story recall ^g (Number of items correctly recalled)	28.26 ± 7.06	20.24 ± 7.47	6.06	<.001*	1.11	41.8
Prospective memory						50.9
Delayed task execution ^h (Number of initiated subtests)	12.85 ± 6.71	6.18 ± 4.09	6.44	<.001*	1.18	50.9
Executive functions						56.4
Inhibition ⁱ (Difference score in seconds)	26.79 ± 9.69	37.36 ± 16.08	4.46	<.001*	0.81	12.7
Flexibility ^j (Time to complete in seconds)	57.93 ± 19.47	71.46 ± 22.77	3.52	.001*	0.64	40.0
Word fluency ^k (Number of words produced)	23.92 ± 6.98	21.62 ± 5.96	1.93	.056	0.35	27.3

Note. ADHD = attention deficit hyperactivity disorder.

^a Effect size (ES) indicated by Cohen's *d*. ^b Impaired on a specific test if scored within the lowest 10% of scores of test norms (sustained attention, vigilance, story recall, inhibition, flexibility, word fluency) or of matched control participants (*n* = 90; word recognition, delayed task execution). ^c Impaired on domain if impairment is indicated in at least one test of a particular domain. ^d Visual Scanning task (TAP). ^e Vigilance task (TAP). ^f Word recognition task. ^g Logical Memory II (WMS). ^h Delayed task execution in a paradigm of complex prospective memory (score of *task switching*). ⁱ Stroop Color-Word Interference task (time [in seconds] needed for the Color-Word Interference condition minus time [in seconds] needed for the Color Block condition). ^j Trail-Making Test-B (TMT-B). ^k Regensburg Word Fluency Test.

* Significant at *p* < .006.

that a significant amount of adults with ADHD experience difficulties with planning and organizing in their daily lives. Furthermore, objective neuropsychological assessment also revealed considerable differences between groups. Compared to control participants, adults with ADHD showed a significantly decreased performance in all neuropsychological tests with the exception of the word fluency test, in which a trend for a decreased performance was found in adults with ADHD. The severity of cognitive dysfunctions found in adults with ADHD differed across measures, with the largest effects found on measures of retrospective memory (*d* = 1.11) and prospective memory (*d* = 1.18), whereas considerably smaller effects (of small to large size) were found on the remaining measures (i.e., attention and executive functions). The large effects on retrospective memory (story recall) and prospective memory (delayed task execution) might be explained by the high demands of these tests on a range of executive functions. For example, it has been shown that free recall of information (in comparison to recognition) requires a variety of executive operations associated with encoding and retrieval in which individuals with ADHD were found to be highly susceptible (such as semantic clustering, effortful rehearsal, and strategic use of effective mnemonics as well as careful consideration of response alternatives; Fuermaier et al., 2013a; Pollak, Kahana-Vax, & Hoofien, 2007). For this reason, the more severe dysfunction of patients with ADHD in story recall compared to word recognition appears comprehensible. With regard to prospective memory, we recently demonstrated that prospective memory does not rely on a unified

mental construct, but requires several aspects of executive control (such as planning, inhibition, and monitoring of own behavior; Fuermaier et al., 2013a). In each neuropsychological domain assessed, about 50% of patients with ADHD were classified as being impaired when a commonly accepted categorization system of ability levels was applied (i.e., percentile ≤ 10; Lezak et al., 2004) to the patients' test performances. In conclusion, the subjective and objective neuropsychological assessment revealed impairments of adults with ADHD in various cognitive domains, including attention, memory, and executive functions and hence largely supports findings of previous research (Barkley & Fischer, 2011; Biederman et al., 2008; Boonstra et al., 2005; Schoechlin & Engel, 2005; L. Tucha et al., 2009, 2011; O. Tucha et al., 2006).

Discordance Between Subjective and Objective Measures

Comparison between subjective and objective measures of cognitive functioning in adults with ADHD demonstrated that patients reported more severe cognitive impairments than actually found in the objective assessment. In addition, based on the subjective assessment, more patients were classified as suffering from cognitive impairment than on the basis of the objective test results. These differences are supported by the poor overlap between subjective and objective measures as shown in logistic regression models. A comprehensive subjective assessment of cognitive functioning failed to predict objectively defined impairments of atten-

Table 5
Binary Logistic Regression Models (Forced Entry of Predictor Variables) to Predict an Objectively Defined Impairment of Adults With ADHD as Measured With Neuropsychological Tests

Predictor variables	B	SE B	Wald	p	Odds ratio
Prediction of impairment in attention ^a					
FEDA ^b	0.076	0.853	0.008	.929	1.079
MSEQ ^c	0.047	0.023	4.091	.043	1.049
CAPM-IADL ^d	-0.067	0.533	0.016	.899	0.935
DEX ^e	-0.207	0.793	0.068	.794	0.813
FLei-A ^f	-0.425	0.826	0.265	.606	0.654
FLei-M ^f	1.891	0.898	4.430	.035	6.625
FLei-EF ^f	-1.186	0.684	3.004	.083	0.305
Total R ² = .200 ^g					
Prediction of impairment in retrospective memory ^a					
FEDA ^b	0.262	0.761	0.119	.731	1.299
MSEQ ^c	-0.022	0.021	1.128	.288	0.978
CAPM-IADL ^d	-0.453	0.515	0.776	.378	0.635
DEX ^e	-0.252	0.753	0.112	.738	0.777
FLei-A ^f	0.927	0.830	1.247	.264	2.526
FLei-M ^f	-0.243	0.792	0.094	.759	0.784
FLei-EF ^f	-0.841	0.667	1.590	.207	0.431
Total R ² = .115 ^g					
Prediction of impairment in prospective memory ^a					
FEDA ^b	0.794	0.793	1.003	.317	2.212
MSEQ ^c	-0.013	0.021	0.363	.547	0.987
CAPM-IADL ^d	-1.008	0.536	3.539	.060	0.365
DEX ^e	-0.671	0.788	0.726	.394	0.511
FLei-A ^f	-0.677	0.788	0.737	.391	0.508
FLei-M ^f	0.259	0.819	0.100	.752	1.296
FLei-EF ^f	-0.067	0.617	0.012	.913	0.935
Total R ² = .133 ^g					
Prediction of impairment in executive functions ^a					
FEDA ^b	1.024	0.797	1.648	.199	2.783
MSEQ ^c	0.011	0.021	0.262	.609	1.090
CAPM-IADL ^d	0.086	0.506	0.029	.865	1.090
DEX ^e	0.822	0.764	1.159	.282	2.276
FLei-A ^f	-0.784	0.794	0.975	.324	0.457
FLei-M ^f	0.284	0.793	0.128	.720	1.328
FLei-EF ^f	-0.824	0.628	1.725	.189	0.439
Total R ² = .114 ^g					

Note. ADHD = attention deficit hyperactivity disorder.

^a Impairment in a domain is defined if scored within the lowest 10% of scores in at least one test of a particular domain. ^b Questionnaire for Experiences of Attention Deficits. ^c Memory Self-Efficacy Questionnaire. ^d Comprehensive Assessment of Prospective Memory-Instrumental Activities of Daily Living. ^e Dysexecutive Questionnaire. ^f Questionnaire for complaints of cognitive disturbances (A = Attention; M = Memory; EF = Executive Functioning). ^g Cox and Snell R².

tion, retrospective memory, prospective memory, as well as executive functions. The subjective assessment only explained a small amount of variance of the objective cognitive impairments (ranging from about 11% for executive functions to 20% for attention), which resulted in insufficient classification rates of patients (ranging from 63% for retrospective memory and executive functions to about 67% for prospective memory). Similarly, cognitive impairments as determined by neuropsychological test performance failed to predict self-reported impairments of cognitive functioning. Objectively assessed neuropsychological impairments only explained a small amount of variance of self-reported cognitive impairments (ranging from about 9% for retrospective memory to

about 24% for executive functions) and, therefore, provided only limited value in predicting self-reported impairments of attention, retrospective memory, prospective memory, as well as executive functions. Previous research on various samples including children and adults with ADHD (Barkley & Fischer, 2011; Biederman et al., 2008; Manor et al., 2008; Toplak, Bucciarelli, Jain, & Tannock, 2009), patients with Parkinson's disease (Koerts et al., 2011) or brain tumors (O. Tucha, Smely, Preier, & Lange, 2000), as well as nonclinical samples (Toplak et al., 2013) already demonstrated that the association between subjective and objective measures of cognitive functions is often weak, in particular with regard to executive functions. A study in which executive dysfunctions of

Table 6
Binary Logistic Regression Models (Forced Entry of Predictor Variables) to Predict an Subjectively Defined Impairment of Adults With ADHD as Measured With Self-Report Questionnaires

Predictor variables	B	SE B	Wald	<i>p</i>	Odds ratio
Prediction of impairment in attention ^a					
Selective attention ^b	0.064	1.426	0.002	.964	1.066
Vigilance ^c	−2.715	1.448	3.517	.061	0.066
Word recognition ^d	0.080	1.608	0.002	.961	1.083
Story recall ^e	0.952	1.716	0.308	.579	2.592
Delayed task execution ^f	−1.765	1.569	1.265	.261	0.171
Inhibition ^g	−2.206	2.110	1.093	.296	0.110
Flexibility ^h	0.422	1.308	0.104	.747	1.525
Word fluency ⁱ	−1.536	1.471	1.090	.296	0.215
Total $R^2 = .137^j$					
Prediction of impairment in retrospective memory ^a					
Selective attention ^b	0.316	0.803	0.154	.694	1.371
Vigilance ^c	0.358	1.003	0.128	.721	1.431
Word recognition ^d	−0.650	1.052	0.383	.536	0.522
Story recall ^e	−0.023	0.795	0.001	.977	0.977
Delayed task execution ^f	−0.973	0.796	1.493	.222	0.378
Inhibition ^g	19.906	14867	<0.001	.999	441,746.887
Flexibility ^h	−0.094	0.844	0.012	.912	0.911
Word fluency ⁱ	0.078	0.924	0.007	.933	1.081
Total $R^2 = .092^j$					
Prediction of impairment in prospective memory ^a					
Selective attention ^b	0.038	0.685	0.003	.956	1.038
Vigilance ^c	−0.622	0.791	0.619	.431	0.537
Word recognition ^d	−0.787	0.913	0.743	.389	0.455
Story recall ^e	0.501	0.701	0.512	.474	1.651
Delayed task execution ^f	−1.471	0.655	5.049	.025	0.230
Inhibition ^g	−1.354	0.945	2.052	.152	0.258
Flexibility ^h	0.330	0.709	0.217	.641	1.391
Word fluency ⁱ	0.331	0.756	0.192	.661	1.393
Total $R^2 = .155^j$					
Prediction of impairment in executive functions ^a					
Selective attention ^b	3.294	1.931	2.909	.088	26.946
Vigilance ^c	−2.357	1.264	3.477	.062	0.095
Word recognition ^d	−1.851	1.270	2.123	.145	0.157
Story recall ^e	−1.173	1.249	0.882	.348	0.309
Delayed task execution ^f	−2.127	1.348	2.489	.115	0.119
Inhibition ^g	−0.120	1.485	0.006	.936	0.887
Flexibility ^h	1.210	1.275	0.901	.342	3.354
Word fluency ⁱ	−2.069	1.401	2.180	.140	0.126
Total $R^2 = .241^j$					

Note. ADHD = attention deficit hyperactivity disorder.

^a Impairment in a domain is defined if scored within the lowest 10% of scores in at least one questionnaire of a particular domain. ^b Visual Scanning task (TAP; time in seconds). ^c Vigilance task (TAP; number of omissions). ^d Word recognition task (number of correctly classified words). ^e Logical Memory II (WMS; number of correctly recalled items). ^f Delayed task execution in a paradigm of complex prospective memory (score of *task switching*). ^g Stroop Color-Word Interference task (time [in seconds] needed for the Color-Word Interference condition—time [in seconds] needed for the Color Block condition). ^h Trail-Making Test-B (TMT-B; time in seconds). ⁱ Regensburg Word Fluency Test (number of correctly produced words). ^j Cox and Snell R^2 .

adults with ADHD have been defined on the one hand on the basis of objective test scores and on the other hand on the basis of subjective self-reports revealed distinct characteristics of both approaches (Biederman et al., 2008). While the former was associated with lower IQ and lower academic achievement, the latter was related to higher levels of ADHD symptoms, psychiatric comorbidities and lower socioeconomic status.

Several explanations have been considered for the poor associations between subjective and objective cognitive measures. These explanations address various issues, such as limitations in ecological validity of objective neuropsychological assessment tools, impaired metacognitive abilities of patients with ADHD, and a qualitative distinction between measures of both approaches. Referring to the ecological validity of objective neuropsychological

assessment tools, Koerts and colleagues, for example, concluded on the basis of their study on patients with Parkinson's disease that objective measures do not always reflect the impairments patients actually encounter in daily life (Koerts et al., 2011). Objective tests are usually structured (i.e., rules and goals are set, start and end of behavior is prompted) and are often aimed at measuring a single aspect of cognition, whereas situations in daily life are usually unstructured and require sustained goal-directed collaboration between various cognitive functions. A limited ecological validity of neuropsychological tests with regard to executive functions has also been advocated by Barkley and Fischer (2011), who showed that self-ratings of executive dysfunctioning were better predictors for impairments in major life activities (such as occupational functioning) than objective tests for executive functions. This finding, however, is not confirmed by the results of Stavro and colleagues (2007), who emphasized the importance of neuropsychological test performance in predicting functioning in major life activities. The authors proposed a structural equation model to explore the relationship between symptoms of ADHD, executive functions (as assessed with a neuropsychological test battery), and functioning in major life activities (i.e., social, occupational, and educational functioning). A direct effect was found from executive dysfunctions to ADHD symptoms (i.e., inattentive-disorganized symptoms), which were linked directly to impairments in major life activities. The authors concluded that these relations may represent the behavioral path through which (objectively defined) executive dysfunctions may lead (through ADHD symptoms) to impaired functioning in major life activities.

Another explanation for the discordance between self-evaluations of cognitive functioning and neuropsychological test performance might be deficient metacognitive abilities of patients with ADHD. Metacognition can be described as "cognition about cognition" and refers to self-knowledge about cognitive processes, self-assessment of ongoing processes (self-monitoring), and self-regulation (Nelson & Narens, 1990). One may assume that the poor association between self-evaluation of cognitive functioning and neuropsychological test performance indicates that patients with ADHD have difficulties in the self-evaluation of their own functioning and abilities. This assumption is supported by previous research in which deficiencies of self-evaluation were found for a variety of functions in adults with ADHD, including emotional competence, emotional recognition, and driving competence (Friedman et al., 2003; Knouse, Bagwell, Barkley, & Murphy, 2005; Rapport, Friedman, Tzelepis, & Van Voorhis, 2002). The hypothesis of deficient metacognitive abilities of patients with ADHD is supported by previous research on adults with acquired brain lesions demonstrating an association between impairments of metacognition and frontal lobe brain injury (Shimamura, 1994). Deficient metacognition of adults with ADHD might result from frequently reported structural and functional abnormalities of the frontal lobes and associated executive dysfunctions of patients with ADHD (Castellanos et al., 2002; Cubillo & Rubia, 2010; Durston & Konrad, 2007; Schweitzer et al., 2000; Tannock, 1998).

Moreover, considering the poor association between subjective and objective measures of cognition, it can be concluded that subjective and objective assessment strategies have a distinct role for the clinical assessment of cognitive functions. In this context, it has been argued that the two assessment strategies assess different underlying mental constructs by capturing different levels of

cognition (Toplak et al., 2013). The characteristics of both approaches might be best described by the distinction between *optimal performance*, which is assumed to be measured by psychometric tests, and *typical performance*, which is assumed to be measured by self-ratings (Toplak et al., 2013). Psychometric tests assess cognitive performance in highly structured and externally defined environments in which goals and outcomes of the test session have been set by the task itself or by the examiner (e.g., the clinician). Task settings are highly constrained and participants are instructed to maximize performance for a short and well-defined period of time. It can therefore be concluded that psychometric tests assess the efficiency of cognitive processes (optimal performance). In contrast, participants' responses are not externally constrained by the examiner when they are requested to rate how well they perform in day-to-day situations that are likely to involve cognitive resources. Furthermore, they are not asked to perform to the best of their ability (optimal performance) but to indicate typical performance in daily life. In this respect, task interpretation is to some extent determined by the participants. Hence, self-ratings assess the extent to which individuals achieve their goals in typical day-to-day situations and thereby provide an indication of individuals' goal pursuit (typical performance). Assuming that subjective and objective measures indeed assess different concepts, the weak association of these measures is not surprising. The insufficient predictive validity of self-ratings with regard to objectively defined cognitive impairments as observed in the present study may therefore support the assumption by Toplak and colleagues (2013).

Finally, the weak association between subjective and objective measures of cognitive functions in adults with ADHD might be explained by the fact that most of the commonly applied tests (such as the Test Battery for Attentional Performance) and questionnaires (such as the DEX) have originally been designed to quantify cognitive dysfunctioning in populations with severe brain injuries and not to measure cognitive functioning of adults with ADHD (Wilson, Alderman, Burgess, Emslie, & Evans, 1996; Zimmermann & Fimm, 2002). The tests and questionnaires applied in the present study may consequently not fully capture the disease-specific problems that adults with ADHD experience in daily life. Indeed, studies on patients with severe cognitive impairments as a consequence of acquired brain lesions demonstrated that the association between subjective and objective measures of executive functions is at least of moderate size (Bennett, Ong, & Ponsford, 2005; Odhuba, van den Broek, & Johns, 2005). Consequently, in the context of neuropsychological assessment of adults with ADHD, more specific and sensitive objective as well as subjective measures appear necessary, which are specifically designed to measure functions and impairments that are assumed to cause major problems for patients with ADHD in daily life; for example, distractibility, self-organization, and time-management (Barkley & Murphy, 2010; Biederman, 2005).

Limitations

The present study must be viewed in the context of some limitations. Even though only a weak association was found between subjective measures of cognitive functioning and a range of objective measures of cognition, it must be taken into account that the neuropsychological assessment applied in the present study

only addressed a certain number of cognitive functions as assessed by a selection of neuropsychological tests. In general, a more comprehensive neuropsychological assessment would allow a more precise and complete examination of the relationship between subjective and objective measures. A selection of tests was advisable in order to reduce the testing time and thus the burden on patients with ADHD. Based on results from clinical practice and research, the tests mentioned above have been selected which have been proven sensitive to the impairments of adults with ADHD (Boonstra et al., 2005; Hervey et al., 2004; Schoechlin & Engel, 2005; L. Tucha et al., 2008, 2009; O. Tucha et al., 2006, 2005). The use of a different set of neuropsychological tests, though, might have resulted in stronger associations between subjective and objective measures.

Moreover, even though most tests allow the calculation of several variables (such as RT, number of omissions, or number of commissions), neuropsychological test performance in the present study was evaluated by only taking one specific variable per test into account (such as number of omissions for the vigilance task or mean RT for the test of selective attention). The decision regarding which measure to be considered as the main outcome variable was made in accordance with results of previous research as well as according to recommendations by the test publishers. However, as there might also be a rationale for an examination of other variables per test, we additionally performed exploratory data analysis by considering other test variables (number of omissions for the test of selective attention, mean RT for correct responses for the vigilance test, and the immediate recall trial for the test of story recall). Group comparisons (between patients and healthy participants) as well as logistic regression models revealed very similar effects as the analysis reported (data not shown). It therefore can be concluded that the results presented are not determined by the selection of test variables.

Furthermore, it has to be considered that a subgroup of patients with ADHD ($n = 14$) has been treated with antidepressant medication for a prolonged period of time. Antidepressant medication might have affected cognitive functioning (as assessed with subjective and objective measures) as well as patients' metacognition. For this reason, additional statistical analysis was performed by excluding all patients with antidepressant medication (resulting in $n = 41$ patients with ADHD not treated with medication known to affect the central nervous system). Additional data analysis revealed similar results as obtained on the total patient group ($n = 55$), indicating that antidepressant medication did not affect results markedly (data not shown). In line with this, additional explorative comparisons between patients treated with ($n = 14$) and without ($n = 41$) antidepressant medication revealed no significant difference in the proportion of patients showing cognitive impairments (in both subjective and objective cognitive measures). However, it has to be considered that the issue of medication effects on (meta)cognitive functioning cannot be addressed adequately in the present study because of a small sample size and, therefore, needs to be studied in future research.

Further insight into (meta)cognitive functioning of patients with ADHD might be achieved by comparing adults with different subtypes of ADHD. In order to provide directions for future research, explorative analysis was performed by comparing patients of the combined subtype ($n = 37$) with patients of the inattentive subtype ($n = 17$; data not shown). In all subjective and

objective measures of cognitive functioning only one significant difference was found indicating that a higher proportion of patients of the combined subtype of ADHD reported attention impairments than patients of the inattentive subtype ($p = .038$). Moreover, the validity of subjective and objective cognitive measures in predicting cognitive impairments was weak and nonsignificant for both patients of the combined subtype as well as for patients of the inattentive subtype. A rather similar cognitive profile of patients of different subtypes of ADHD has also been demonstrated in previous research (L. Tucha et al., 2008). However, further research on this issue would be desirable that considers larger patient samples as well as patients of all subtypes of ADHD.

Finally, considering the poor association between subjective and objective measures of cognitive functions of adults with ADHD, further research is needed seeking for more adequate predictors of cognitive impairments of adults with ADHD. For example, explorative data analysis indicated that educational level did not correlate with any cognitive impairment as determined by either subjective or objective measures (data not shown). However, it is reasonable to assume that other measures of real life functioning, such as occupational attainment, might predict the presence of cognitive impairment. Unfortunately, an assessment of occupational attainment has not been included in the present study and can therefore not be examined in this respect.

Conclusions

The present study explored cognitive functioning of adults with ADHD in a comprehensive assessment using subjective and objective measurement tools. Both assessment strategies revealed dysfunctions of adults with ADHD on a broad range of cognitive functions and identified impairments in the majority of patients. Subjective as well as objective measures were sensitive in detecting cognitive dysfunctions of adults with ADHD, even though effects were considerably larger in the subjective assessment than in the objective assessment. However, subjective complaints failed to predict objectively defined impairments and, likewise, objectively defined impairments failed to predict self-reported impairments, indicating a poor association between both approaches. Subjective and objective measures of cognitive functions appear to provide distinct types of information and represent different aspects of functioning and should therefore not be interpreted as equivalent or interchangeable. Objective psychometric tests may provide information about the cognitive efficiency of the individual, whereas subjective self-reports might indicate success in individual goal achievement. For example, a clinical assessment that reveals impairments in neuropsychological tests but shows average performance on self-rated cognitive functioning might indicate a processing weakness in structured and highly controlled settings. In contrast, an individual assessment in which impairments are revealed on the basis of self-reports but that shows no abnormalities in neuropsychological test performance might indicate problems in typical situations in which priorities and goals have to be set by the individual. In this case, a structured environment under well-defined settings might facilitate individual performance.

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