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ORIGINAL ARTICLE

Multitasking in adults with ADHD

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Abstract Adults with ADHD have problems in everyday multitasking situations presumably because of deficits in executive functions. The present study aims to find out (a) whether adults with ADHD show deficient multitasking performance in a standardized task, (b) how they perceive the multitasking situation, and (c) which task structure might be beneficial for them as compared with adults without ADHD. Therefore, we experimentally compared task performance, mood, and motivation in a group of 45 men with ADHD (M-age = 34.47, SD = 9.95) with a comparison group of 42 men without ADHD (M-age = 31.12, SD = 10.59) in three conditions: (a) a multitasking paradigm, (b) an interleaving condition in which tasks had to be performed without planning or monitoring, and (c) a non-interleaving condition. Our results showed no impaired multitasking performance in adults with ADHD. However, they showed better mood and more motivation in the non-interleaving condition.

Keywords ADHD · Multitasking · Executive function · Adults

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Introduction

Patients with ADHD are assumed to be highly impulsive. They have a hard time waiting their turn (e.g., Krause and Krause 2009), inhibiting responses (e.g., Boonstra et al. 2010), and planning actions (e.g., Roberts et al. 2011), and this impulsivity leads to several detrimental effects as for instance, risky behavior (e.g., fast driving; Jerome et al. 2006) and sensation seeking (e.g., Antrop et al. 2000). Importantly, ADHD symptoms change from childhood to adulthood in such a way that hyperactivity and inattention decline, whereas impulsivity persists (Biederman et al. 2000).

Additionally, patients with ADHD do not only demonstrate a deficient inhibitory control in their everyday behavior but also show impaired performance on different executive function tasks measuring for instance inhibitory control, such as Go/NoGo tasks (Boonstra et al. 2010; Hervey et al. 2004; Pennington and Ozonoff 1996; Willcutt et al. 2005). Executive function deficits have been intensively investigated in children with ADHD, whereas there is still comparatively little research on executive function deficits in adults with ADHD (e.g., Roberts et al. 2011).

Executive functions in adults with ADHD

In general, adults with ADHD demonstrate a weakened executive functioning in comparison to adults without

ADHD, and this deficit has an adverse effect on educational and occupational attainment as well as on social functioning (Biederman et al. 2006). Moreover, recent studies reveal that response inhibition deficits are pronounced in adults with ADHD and seem to be a core deficit in adult ADHD (Bekker et al. 2005; Boonstra et al. 2010). Further executive function deficits pertain to problems in working memory, switching, and verbal fluency (Adler et al. 2006; Seidman et al. 1998; Tucha et al. 2005). Moreover, a meta-analysis revealed that the pattern of executive functions in adults with ADHD mirror those found in children with ADHD, including differences between adults with and without ADHD in the following areas: verbal fluency, inhibition, and set-shifting. Specifically, differences are characterized with medium to large-effect sizes (Cohen's $d = .62$ to $d = .89$; Boonstra et al. 2005).

Another important result of this meta-analysis was the similarity of effect sizes found in the executive function area as compared to the non-executive function area (i.e., word reading). Average determinations for both domains yielded a mean effect size of $d = .40$ for the executive function variables and mean effect size of $d = .43$ for the non-executive function variables. Therefore, the authors suggest to "call into question models of ADHD that depend heavily upon executive functions for their explanatory power" (Boonstra et al. 2005, p. 1105). In the same vein, results on executive functions in adults with ADHD are, as in children, heterogeneous (Nigg et al. 2005) and self-rated executive functions predict occupational problems better than objective executive function measures in adults with ADHD (Barkley and Murphy 2010).

Multitasking as an everyday executive function situation

Thus, another perspective might be helpful in explaining cognitive and executive function deficits in adults with ADHD. Instead of trying to identify distinct executive functions (Miyake et al. 2000), Shallice and Burgess (1991) have tried to combine different executive functions in one task with the aim to identify individuals with frontal lobe damage and predict their problems in everyday life. Individuals with frontal lobe problems sometimes demonstrate remarkably intact performance on various neuropsychological and cognitive test batteries, but they fail to meet requirements of their everyday lives (Shallice and Burgess 1991). According to Shallice (1982), this failure is due to a failure of the supervisory attentional system (SAS; Norman and Shallice 1986; Shallice 1982, 1988), which is only activated in novel, problem-solving situations. Shallice and Burgess argued that in the well-defined task setting (i.e., short in length, a single explicit problem, goal provided by the examiner) of traditional neuropsychological tests, the difficulties, which occur in everyday life, are not relevant.

Therefore, multitasking is associated with executive functions and is defined as "the ability to perform concurrent tasks or jobs by interleaving" (Burgess 2000, p. 281). Thus, a number of discrete and different tasks have to be completed: performance on these tasks needs to be dovetailed to be time effective; only one task can be performed at one time; unforeseen interruptions will occur; things will not always go as planned; the time for return to a task is not signaled directly by the situation; subtasks usually differ in terms of priority, difficulty, and the length of time; there is no performance feedback that participants in many laboratory experiments will receive; and typically, failures are not signaled at the time they occur. This implies the ability not only to work on tasks interleavingly but also to plan and monitor this process (Shallice and Burgess 1991). To measure multitasking analogous to open-ended multiple subgoal daily problem-solving situations, the authors developed the six element test (SET; Behavioral Assessment of the Dysexecutive Syndrome; Burgess et al. 1996).

Multitasking in ADHD

Derived from a view of executive function deficits in ADHD, one would assume to find multitasking problems in ADHD. However, there are only a few studies concerning the multitasking performance of participants with ADHD: one study using the SET found a multitasking deficit in adolescents with ADHD (Clark et al. 2000). These deficits were mainly due to the inability of adolescents with ADHD to attempt to perform all tasks, not due to rule breaks (i.e., working on two tasks of the same kind in a row). A further study comparing executive functions, memory, and learning in patients with Tourette syndrome also included the SET as one of the executive function measures, and found that adolescents with a comorbid ADHD showed the worst performance in the SET (Channon et al. 2003). Others used a modified SET to assess the multitasking abilities in children with ADHD and replicated these findings (Chan et al. 2006; Siklos and Kerns 2004). To our knowledge, there are no studies assessing the multitasking performance in adults with ADHD.

Present study

In our study, we measured the performance of men with and without ADHD in a comparable multitasking, interleaving, and non-interleaving condition, to which participants were randomly assigned. Multitasking was operationalized through the standard SET; interleaving was operationalized through the same task, but the instruction was to switch

subtasks every 20 s; non-interleaving was operationalized through the same task, and the instruction to work on each subtask one sixth of the time. We assessed participants' mood and motivation in the three different conditions.

Because adults with ADHD show deficits in executive functions, we hypothesized that adults with ADHD differ concerning their task performance in the three different conditions from adults without ADHD. Mainly in the multitasking condition, adults with ADHD should demonstrate deficits compared to adults without ADHD; however, also in the other conditions, the performance of adults with ADHD should be worse than that of adults without ADHD. Similarly, we assume that adults with ADHD experience a worse mood and less motivation while solving subtasks of the multitasking condition, and that they show their best performance, best mood, and more motivation in the condition, which is structured the most (i.e., non-interleaving condition) compared to the other conditions (i.e., multitasking and interleaving).

Method

Participants

Exclusion criteria for participation in the present study were the use of medication (e.g., methylphenidate) at the day of the experiment or 48 h before and/or history of medication with atomoxetine. Because of the higher prevalence of ADHD in men in adulthood (Barkley 1990; Krause and Krause 2009) and the resulting difficulties in the recruitment of women, we only asked men to participate in our study.

ADHD group

Forty-five men with ADHD (age: $M = 34.47$ years, $SD = 9.95$) were recruited from a neuropsychological outpatient practice in Hamburg/Germany. All of them fulfilled criteria for hyperkinetic disorder F90.0 (ICD-10; World Health Organization 2009) as primary disorder. Participants with ADHD were requested to fulfil a complex diagnostic procedure (separate from the experimental session) in three appointments on several days.

The first appointment consisted of a general exploration and a clinical interview exploring the ICD-10 criteria for ADHD (WHO 2009). At the second appointment, patients conducted neuropsychological tests sensitive for ADHD. They fulfilled the digit span forward and backward (Wechsler 1997), the Trail-Making-Test forms A and B (Lewis and Rennick 1979), the d-2 test (Brickenkamp 2002), and two subtests from the test battery for attentional performance (visual scanning & Go/NoGo; TAP 2.0; Zimmermann and Fimm 2006). Furthermore, patients themselves and a significant other person (i.e., wives and girlfriends in most of the cases) were asked to fill out the following questionnaires: The dysexecutive questionnaire (DEX; Wilson et al. 1996; correlation between the self-rated and significant other-rated DEX, $r(23) = .21$, ns), a questionnaire of experienced deficits in attention (FEDA; Zimmermann et al. 1991; correlation between the self-rated and significant other-rated FEDA, $r(23) = .08$, ns), and a screening questionnaire for psychological disorders of the DSM-IV (SKID; Wittchen et al. 1997). Interestingly, further inspection of the means suggests that patients themselves rated their everyday executive functioning as measured with the DEX as worse ($M = 66.20$, $SD = 10.43$) compared to their significant others ($M = 45.72$, $SD = 15.69$), $t(23) = 6.27$, $P < .001$. At the third appointment, a semi-structured interview was used to exclude other disorders than ADHD, which could account for the symptoms. Furthermore, primary school reports were reviewed to ensure the occurrence of the symptoms before the age of seven.

Most participants had received their diagnosis during adulthood: on average 1.7 years ($SD = 3.11$) before their participation in the study. Twenty-seven (61.4%) of the participants had received their diagnosis during the last year, thirty-two (72.8%) during the last 2 years, and five (4.5%) before the age of 18 years. Comorbidities were only obtained in the ADHD group and not in the control group. Nine participants in the ADHD group exhibited the following comorbid disorders: personality disorders and anxiety ($n = 3$), history of drug abuse ($n = 6$).

Control group

The non-clinical comparison group ($n = 42$, age: $M = 31.12$, $SD = 10.59$) was recruited using various strategies to address a group that is as heterogeneous as possible in age, IQ, and socioeconomic status (SES), to match the ADHD group (Table 1): We posted notices at two big universities in Germany, addressed members of a fitness center (Hamburg/Germany), and students of a vocational school (Frankfurt/Germany). Participants without ADHD only fulfilled a screening version of the diagnostic procedure: the digit span forward and backward (Wechsler 1997), the Go/NoGo task from the TAP (Zimmermann and Fimm 2006), and the DEX (Wilson et al. 1996).

Background variables

Detailed characteristics of the sample (i.e., number of job changes, marital status, and children) are provided in Table 1. It is important to note that we only present instruments and questionnaires used in both the ADHD and control sample in this table.

Table 1 Characteristics of the sample

	Participants				Group difference
	ADHD group ($n = 45$)		Control group ($n = 42$)		
SET score (SD)	5.13	(1.40)	5.21	(1.31)	.874
Go/NoGo reaction time (SD)	452.80	(81.15)	444.20	(88.95)	.909
Digit span forward percentile (SD)	34.88	(30.09)	40.50	(25.79)	.359
Digit span backward percentile (SD)	30.70	(28.62)	49.69	(30.26)	.004
DEX (SD)	57.39	(14.52)	27.96	(7.23)	<.001
Age (SD)	34.46	(9.94)	31.12	(10.59)	.133
Cognitive ability (SD)	102.62	(10.47)	102.86	(9.70)	.914
SES (SD)	2.36	(.92)	2.23	(.84)	.497
Number of jobs (SD)	3.23	(4.15)	1.83	(2.41)	.147
Martial status (%)					
Separated/divorced	15.9%		0%		.010
Children					
Yes	36.4%		12.8%		.013

SES

In a demographic questionnaire, participants had to indicate their educational level (1 = nine years of education, 2 = ten years of education, 3 = twelve to thirteen years of education, and 4 = university degree), working status (1 = unemployed, 2 = low-wage employment, 3 = part-time employment, and 4 = full-time employment), and monthly income (1 = up to approximately \$2,160; 2 = up to approximately \$3,600; 3 = up to approximately \$5,760; and 4 = approximately more than \$5,760). These SES variables correlated significantly with each other, $r(85) = .13$, $P < .001$; $r(85) = .44$, $P < .001$; $r(85) = .38$, $P < .004$. Therefore, we used the mean as an index for SES in the following analysis. Participants with ADHD ($M = 2.36$, SD = .92) and without ADHD ($M = 2.23$, SD = .84) did not differ as regards their SES, $t(85) = .68$, ns.

Cognitive ability screening

The block design test of the WISC was chosen because of its high predictive and diagnostic values (Donders et al. 2001; Sattler 1992). Adults with ADHD ($M = 102.62$, SD = 10.47) and without ADHD ($M = 102.86$, SD = 9.70) did not differ significantly concerning their performance in the block design test, $t(85) = .11$, ns (see Table 1). Both groups, adults with and without ADHD, were average on the block design subtest relative to a norm (Aster et al. 2006).

Design

The study followed a 2-between (group: ADHD vs. no ADHD) × 3-between (condition: multitasking, interleaving, and non-interleaving) design. The dependent variables were performance (i.e., SET score and number of items completed), mood, and motivation (measured in questionnaires).

Procedure

All experiments were conducted by a female experimenter on an appointment separate from the diagnostic appointments and took place in a quiet room. Informed consent was obtained from the participant or, if the participant was younger than 18 years, from the parents after stressing that (a) all data were anonymous and treated with strict confidentiality, (b) the participant was free to withdraw his consent at any time with no unfavorable consequences, and (c) the data would be processed electronically. During the whole session, the participant sat in front of a table with the female experimenter sitting on the other side giving standardized verbal instructions. Any material with an identifying name on it (i.e., informed consent sheet, receipt for money received, and interest in results of this study or participation in further studies) was put in a separate envelope and mixed with sheets of other participants immediately after signing. The task and questionnaires took a total of 45 min. Participants received reimbursement (5–8 €, approximately \$ 7–12) for their travel expenses, and the offer to receive a written report about the general results of the study. The study was approved by the local research ethics committee and is compliant with the World Medical Association's Declaration of Helsinki.

Task

We used the SET (Burgess et al. 1996) developed to meet the multitasking criteria (Burgess 2000) to measure

multitasking performance. The test contains six tasks, which are divided in sets of two: telling about their best holiday or a special event, writing down the name of pictures, and working on arithmetic problems. The participant has 10 min to work on these open-ended tasks and has to follow two rules: she or he should try to attempt each of the six tasks at least once, and working on the two tasks of the same kind in a row is not allowed. The participant is free to check a stopwatch as often as he or she likes. The score is obtained only on the basis of organization and strategy use, and not on the number of items completed. The performance is measured through the number of attempted tasks minus rule breaks (i.e., working on two tasks of the same kind in a row), minus one point if the participant worked on one of the six subtasks more than 45% of the total time.

Conditions

To compare the multitasking situation with different styles of working on the task, we included two further conditions. In the interleaving condition, participants had to switch tasks every 20 s, attending the task in the given order (i.e., telling, naming, and arithmetic problems). In the non-interleaving condition, participants also had to attend the task in the given order, spending one sixth of the time (i.e., 1 min and 40 s) on each task. The order to switch was standardized, from a prerecorded female voice. We chose the short period of 20 s to have a clearly interleaving structure. Participants were randomly assigned to one of the three conditions (i.e., multitasking, interleaving, non-interleaving; see Fig. 1).

The instructions for the tasks (i.e., telling stories, writing down the name of pictures, and arithmetic problems) were the same in all conditions. The experimenter stressed that the participant had a period of ten min to work on the tasks, that it was not important to finish each task, and that the participant should work on each of the six subtasks at least once. Conditions only differed in the rules concerning the organization of the tasks. The sentence for the multitasking condition, which was taken from the SET manual, was as follows: *But there is one important rule: You are not allowed to work on part A and part B of the same task in a row*. The sentence for the interleaving condition was: *But there is one important rule: You are supposed to spend the same amount of time on each task, but only 20 s, because 20 s, five times per task, times six tasks, is 10 min. Please work on the tasks in the order you see here.* The sentence for the non-interleaving condition was: *But there is one important rule: You are supposed to spend the same amount of time on each task, that is 1 min and 40 s, because 1 min and 40 s times six tasks is 10 min. Please work on the tasks in the order you see here.*

Mood measures

Participants were asked to fill out the profile of mood states (POMS; Bullinger et al. 1990) and the self-assessment manikin (SAM; Bradley and Lang 1994) to assess their mood state after the instruction for the SET, and a second time after task completion. The POMS has four scales: vigor, fatigue, anxiety/depression, and irritability. The SAM includes three items: valence, arousal, and dominance, each represented by five figural drawings on a nine-point scale (valence: 1 = smiling, happy figure to 9 = frowning, unhappy figure; arousal: 1 = excited, wide-eyed figure to 9 = relaxed, sleepy figure; dominance: 1 = small figure, dominated to 9 = large figure, in control).

Motivation measures

Furthermore, participants answered several questions on different scales measuring motivation right after completion of the task. All items had to be answered on a 10-point scale.

We used three self-developed items ("*I intended to do well on the task," "It makes a difference for me to be good at this task," "I would have been very disappointed if I failed at this task"*) asking for task commitment (Cronbach's $\alpha = .74$), with low values representing low task commitment. Furthermore, we summarized the items "*How effortful was the task for you?*" and "*How difficult was the task for you?*" to form one index (Cronbach's $\alpha = .77$). The anchors were 1 (*not difficult at all*) to 10 (*very difficult*). These items had been previously used (Gawrilow et al. 2011).

We also used a four-item scale to measure fear of failure (Cronbach's $\alpha = .82$): "*I was worried about the possibility of performing poorly,*" "*I was afraid that if I ask the experimenter a "dumb" question, she might not think I'm very smart,*" "*I just wanted to avoid to perform poorly in the task,*" and "*I worked harder because I was afraid to perform poorly.*" The items are based on a scale measuring performance–avoidance goals (Elliot 1999); low values represent low fear of failure.

With the Csikszentmihalyi model of flow as basis (Csikszentmihalyi and Csikszentmihalyi 1992), we also asked two questions as regards the perceived flow: "*What were the challenges in this activity?*" and "*What were your skills in this activity?*" The level of flow was based on the concurrence of both. When challenges and skills had the same value, the level of flow was ten; if challenge and skill differed by one, flow was nine. Therefore, flow had a possible range of 1 (i.e., low level of flow) to 10 (i.e., high level of flow).

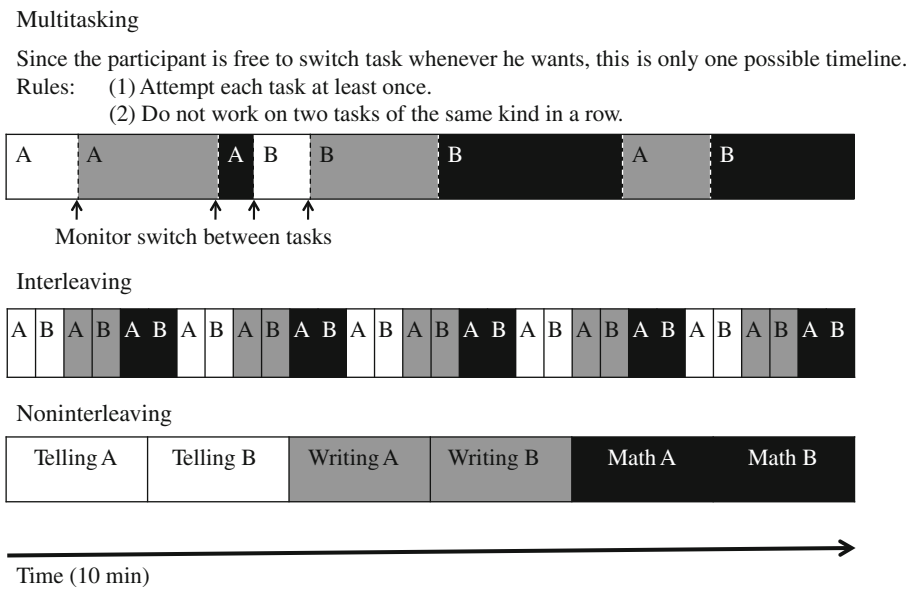

Fig. 1 Procedure of the conditions (multitasking, interleaving, non-interleaving); Telling = telling the best holiday (*A*) or a special event (*B*), Writing = writing down the name of pictures (*A* or *B*), Math = working on arithmetic problems (*A* or *B*)

Results

Statistical analyses

We tested for normal distribution of participant's performance on the SET and responses on questionnaire scales using the Kolmogorov–Smirnov test and histograms. Performance on the SET was not normally distributed according to the Kolmogorov–Smirnov test but the histogram revealed a normal kurtosis albeit a slightly non-normal skewness. According to the Kolmogorov–Smirnov test, some scales of the used questionnaires were not normally distributed either. Hence, we also checked the skewness and kurtosis for these scales indicating symmetric, moderate tailed distributions, respectively and therefore, approximate normally distributed data. Furthermore, it is important to note that ANOVAs and MANCOVAs are quite robust and problems in solutions might occur only when the sample is very small (Bortz and Döring 2006) and/or the data is non-normal in very different ways (e.g., some positively and some negatively skewed; Tabachnick and Fidell 2007). Therefore, we decided to compare group and condition differences through 2 (group: ADHD vs. no ADHD) × 3 (condition: multitasking vs. interleaving vs. non-interleaving) ANOVAs or MANOVAs on the SET and questionnaire scales. For analyzing correlations, we used Spearman's rho.

Performance

Participants with ADHD ($M = 5.13$, $SD = 1.41$) showed no impaired multitasking performance in the SET compared to the control group ($M = 5.21$, $SD = 1.31$), $t(27) = .16$, ns. For further exploration, we counted the number of items completed in the writing and the arithmetic tasks, and the results were correlated, $r(85) = .49$, $P < .001$; therefore, we formed one index using mean z-values. There was no difference between the number of items completed and the number of correct items in the following analyses; therefore, we only report the results for the number of items completed.

A 2 (group: ADHD vs. no ADHD) × 3 (condition: multitasking vs. interleaving vs. non-interleaving) ANOVA on number of items completed revealed no effect of group, $F(1,81) = .91$, ns, or condition, $F(2,81) = .36$, ns. When we excluded the interleaving condition from the analyses, we found a significant interaction of group × condition on number of items completed, $F(3,56) = 4.08$, $P < .05$. The ADHD group completed more items in the non-interleaving ($M = 83.62$, $SD = 23.81$) compared to the multitasking condition ($M = 69.81$, $SD = 23.33$); whereas the control group completed more items in the multitasking ($M = 85.57$, $SD = 26.08$) compared to the non-interleaving condition ($M = 76.14$, $SD = 16.32$).

Thus, contrary to our expectations, adults with ADHD did not perform poorly on the task as compared to adults without ADHD. However, as expected, the ADHD group seems to benefit the most from the condition that is structured the most (i.e., non-interleaving), which is not true for the control group without ADHD.

Additionally, we were interested in associations between the SET performance in the classical multitasking condition and DEX self-ratings. This is because (a) the DEX is supposed to reflect self-rated everyday executive functions and (b) we found that patients with ADHD report significantly more problems on this scale compared to our comparison group (Table 1). In the ADHD group, SET

performance and DEX self-ratings correlated positively but not significantly, $r(13) = .40$, ns; we found no correlation at all in the control group, $r(12) = .02$, ns.

Mood

POMS before conducting the SET

A 2 × 3 MANOVA on the four scales of the POMS after the instruction was given and before starting the task was computed. The analysis revealed a significant overall effect for group, $F(4,78) = 4.53$, $P < .001$. Participants with ADHD felt less vigor (ADHD: $M = 17.58$, SD = 5.24; control: $M = 20.68$, SD = 4.90), $F(1,81) = 8.21$, $P < .001$, more fatigue (ADHD: $M = 18.28$, SD = 7.59; control: $M = 15.27$, SD = 5.88), $F(1,81) = 11.19$, $P < .001$, and more anxiety/depression (ADHD: $M = 28.30$, SD = 10.98; control: $M = 21.17$, SD = 6.96), $F(1,81) = 12.10$, $P < .001$. No difference emerged for irritability.

POMS after conducting the SET

A 2 × 3 MANOVA for the four scales of the POMS revealed a significant overall effect for group, $F(4,78) = 2.60$, $P < .05$. The ADHD group still felt more fatigue (ADHD: $M = 15.11$, SD = 6.96; control: $M = 12.59$, SD = 5.13), $F(1,81) = 4.10$, $P < .05$, and more anxiety and depression (ADHD: $M = 23.67$, SD = 10.13; control: $M = 18.29$, SD = 6.25), $F(1,81) = 8.05$, $P < .01$, after completing the task. In addition, a significant interaction of group × condition on vigor, $F(1,81) = 3.10$, $P < .05$, and a marginally significant interaction on fatigue, $F(1,81) = 2.98$, $P < .05$, occurred. The interactions were caused by the non-interleaving condition compared with the other two conditions: whereas the ADHD group felt more vigor ($M = 21.06$, SD = 5.59) and less fatigue ($M = 12.07$, SD = 5.34) after completing the non-interleaving condition, the control group felt less vigor ($M = 18.64$, SD = 5.03) and more fatigue ($M = 13.78$, SD = 5.53) after completing the non-interleaving condition. Again, no significant effect for irritability emerged.

Single 2 × 3 ANOVAS for the postvalue of all four scales revealed that when the prevalue was used as a covariate, all group differences disappeared, vigor: $F(1,80) = .23$, *ns*; fatigue: $F(1,80) = .86$, ns; and anxiety/depression: $F(1,80) = .43$, ns. Thus, participants with ADHD in general have a worse mood in this experimental situation.

SAM before conducting the SET

A 2 × 3 MANOVA on the three items of the SAM was conducted. The analyses revealed a significant overall effect for group, $F(3,78) = 3.30$, $P < .05$. The ADHD group had a worse mood, $F(1,81) = 4.91$, $P < .05$ (ADHD: $M = 4.91$, SD = 1.68; control: $M = 4.19$, SD = 1.27), and felt less in control, $F(1,81) = 5.48$, $P < .05$ (ADHD: $M = 4.82$, SD = 1.45; control: $M = 5.59$, SD = 1.48) before starting the task. No difference emerged for arousal.

SAM after conducting the SET

A 2 × 3 MANOVA on the three items of the SAM revealed a significant overall effect for group, $F(3,78) = 6.14$, $P < .001$. The ADHD group had a worse mood, $F(1,80) = 3.94$, $P < .05$ (ADHD: $M = 4.43$, SD = 1.63; control: $M = 3.76$, SD = 1.56), was more aroused $F(1,80) = 10.36$, $P < .01$ (ADHD: $M = 4.27$, SD = 1.91; control: $M = 5.59$, SD = 1.85), and felt more dominated $F(1,80) = 9.51$, $P < .01$ (ADHD: $M = 4.60$, SD = 1.62; control: $M = 5.88$, SD = 1.45). Furthermore, there was a significant effect of condition on dominance, $F(2,80) = 4.14$, $P < .01$. The participants in the non-interleaving condition ($M = 3.43$, SD = .73) felt more in control compared with the interleaving ($M = 3.05$, SD = .81) and the multitasking condition ($M = 3.02$, SD = .86). Single ANOVAS for the postvalue of all three items revealed that when the prevalue was used as a covariate, the group difference in arousal, $F(1,80) = 8.60$, $P < .01$, and in dominance, $F(1,80) = 4.28$, $P < .05$, was still apparent.

Motivation

Task commitment

A 2 × 3 ANOVA on task commitment was computed. The analyses did not reveal a significant main effect of group, $F(1,80) = .23$, ns, and condition, $F(2,80) = .47$, ns. Both groups showed a task commitment on the same high level (ADHD: $M = 7.80$, SD = 1.85; control: $M = 7.73$, SD = 1.99).

Effort and difficulty

A 2 × 3 ANOVA on effort/difficulty revealed a significant main effect of group, $F(1,80) = 19.79$, $P < .001$, and condition, $F(2,80) = 6.81$, $P < .001$. In all conditions, participants with ADHD experienced the task as more difficult and effortful (ADHD: $M = 4.27$, SD = 2.23; control: $M = 2.60$, SD = 1.52). Post hoc tests revealed that the interleaving condition was more effortful and difficult ($M = 4.36$, SD = 2.20) compared with the non-interleaving condition ($M = 2.67$, SD = 1.35), $t(56) = 2.62$, $P < .001$.

Fear of failure

A 2 × 3 ANOVA on fear of failure revealed a significant main effect of group, $F(1,79) = 6.11$, $P < .05$, indicating that, in all conditions, participants with ADHD experienced more fear of failure (ADHD: $M = 4.77$, SD = 2.28; control: $M = 3.34$, SD = 2.18). T tests for each condition revealed that these group differences were only apparent in the multitasking condition, $t(27) = 2.21$, $P < .05$.

Flow

A 2 × 3 ANOVA on flow revealed a significant interaction of group and condition, $F(1,81) = 3.19$, $P < .05$. The interaction was caused by the interleaving compared with the multitasking and the non-interleaving condition. The control group felt more flow in the interleaving condition ($M = 7.86$, SD = 1.79), compared with multitasking ($M = 5.78$, SD = 2.88) and the non-interleaving conditions ($M = 5.64$, SD = 2.13). The ADHD group had the highest value of flow in the non-interleaving condition ($M = 7.19$, SD = 2.23), followed by multitasking ($M = 6.56$, SD = 2.19) and interleaving conditions ($M = 6.30$, SD = 2.95).

Furthermore, we analyzed the items for challenge and skills separately. A 2 × 3 ANOVA on challenge revealed a significant effect of group, $F(1,80) = 5.83$, $P < .05$. The ADHD group judged the task to be more challenging ($M = 5.11$, SD = 2.89) compared with the control group ($M = 3.80$, SD = 2.17). T tests for each condition separately only showed this effect in the multitasking condition, $t(27) = 2.26$, $P < .05$. Further planned contrasts revealed that the control group found the interleaving condition more challenging compared with the other two conditions, $t(40) = 3.31$, $P < .01$.

A 2 × 3 ANOVA on skill revealed a significant effect of condition, $F(2,80) = 4.03$, $P < .05$. Post hoc tests revealed that this difference was caused by the interleaving compared with the non-interleaving condition, $t(56) = 2.27$, $P < .05$. The participants in the interleaving condition judged their skills to be lower ($M = 5.55$, SD = 2.17) than in the non-interleaving condition ($M = 7.00$, SD = 1.76).

Discussion

We compared the performance of male adults with and without ADHD in three conditions: (a) a classical multitasking condition (SET; Burgess et al. 1996), (b) an interleaving condition in which tasks had to be performed interleavingly without planning or monitoring this process, and (c) a non-interleaving condition.

Contrary to our expectations, adults with ADHD did not show a significantly impaired multitasking performance in comparison to adults without ADHD. However, as expected, adults with ADHD showed deficits compared to adults without ADHD mainly in the multitasking condition: The ADHD group completed more items in the non-interleaving compared to the multitasking condition, whereas the control group completed more items in the multitasking compared to the non-interleaving condition. Thus, as expected, adults with ADHD performed the best in the condition which is structured the most (i.e., non-interleaving condition), whereas the control group demonstrated the best performance in the condition, which is least structured (i.e., multitasking condition).

As regards mood and motivation, we assumed that adults with ADHD experience a worse mood and motivation while solving the multitasking condition. Furthermore, we assumed that adults with ADHD show their best mood and motivation in the condition which is structured the most (i.e., non-interleaving condition) compared with the other conditions (i.e., multitasking, interleaving). Indeed, adults with ADHD felt more vigor and less fatigue in the non-interleaving condition compared with the control group and the other two conditions. A reason might be that the non-interleaving condition had the lowest demands: neither interleaving nor planning and/or monitoring was required. This was also supported by the ratings of participants with ADHD that in this condition they felt the most "in control." Consequentially, one might assume that adults with ADHD felt overchallenged by the experimental situation per se and that participants in the easier, non-interleaving conditions were just not confronted with this challenge. This fit of challenge and skills is also indicated by higher flow values by the ADHD group in the non-interleaving condition. Furthermore, adults with ADHD perceived the interleaving condition as more effortful and difficult compared with the non-interleaving condition. This is also indicated by the mood self-ratings and this was also the condition in which participants rated their skills to be the lowest.

However, adults without ADHD felt more vigor and less fatigue in the multitasking and interleaving conditions. Thus, the control group might have felt underchallenged (compared to the ADHD group) by the task and/or the experimental situation in general. In comparison with the ADHD group, the control group perceived the task as less difficult and effortful. In fact, the control group felt more vigor and less fatigue, had a better mood, felt less depression and less anxiety, and did not have such a high level of fear of failure compared to the participants with ADHD. If we assume that the control group was rather underchallenged by the experimental situation, this would have of course influenced their performance. However, the

best fit of challenge and skills, indicated by flow, for the control group was given in the interleaving condition. Furthermore, they solved the highest number of items in the multitasking condition. Hence, it could be that participants without ADHD solved more items in the multitasking condition and had a higher feeling of flow in the interleaving condition because these more complex conditions better suited their skills.

Thus, the experimental situation, regardless of condition, seemed to have been perceived differently by adults with ADHD compared with adults without ADHD. Adults with ADHD indicated less vigor, more fatigue, more depression, and more anxiety; they had worse mood and felt less in control after the instruction to perform the task (i.e., even before starting the task). After performing the task, adults with ADHD still felt less vigor (dependent on condition), more fatigue, more depression, and more anxiety; they had worse mood and felt less in control. In addition, they also felt more aroused, perceived the task as more difficult and effortful, had a greater fear of failure, and judged the task to be a greater challenge.

Implications for ADHD research

The findings have implications for research on adults with ADHD. Some authors assume that adults with ADHD (similar to children with ADHD; Hoza et al. 2002) overestimate their performance (Rapport et al. 2002; Friedman et al. 2003); others assume that adults with ADHD have outgrown these deficits in self-evaluation (Knouse et al. 2006) and are able to evaluate their performance correctly (Barrilleaux and Advokat 2009). Participants with ADHD in our study, however, seemed to underestimate their performance. This is indicated by their high ratings of perceived challenge by the task and high fear of failure as compared to the comparison group (in all conditions) although they did not perform worse compared to adults without ADHD in the SET. Furthermore, a comparison of self-ratings and ratings by significant others on the DEX indicated that ADHD participants themselves evaluate their abilities as measured in the DEX as more impaired than their significant others. Although it is important to note that this result is only valid for the subsample of patients with ADHD, whose significant others filled out respective ratings ($n = 25$), the ADHD group seemed to have the expectation to fail per se. Interestingly, albeit this correlation was not significant, ADHD adults who performed better on the SET even rated their daily executive functions to be worse. This effect might also be a sign of an underestimation of their own performance in adults with ADHD.

Interestingly, Rucklidge et al. (2007) found that adults with ADHD, compared with a nonclinical control group, have an internal-uncontrollable attributional style depending on the time of their ADHD diagnosis. In a sample of adults who had received their diagnosis only during adulthood, they observed the following: Without an ADHD diagnosis during childhood, the chronic inattention and hyperactivity-impulsivity difficulties (i.e., in school) are likely attributed by teachers, parents, and peers (and even by the ADHD participants themselves) to laziness, stupidity, depression, or lack of motivation (Brown 1995). Hence, ADHD patients who received their diagnosis only during adulthood, reported high levels of anxiety and depression.

Because most of our participants with ADHD had received their diagnosis late, this might have contributed to the different perception of the experimental situation by our participants with ADHD as compared to the participants without ADHD: implying anxiety, depression, and fear of failure in the ADHD group. An internal-uncontrollable attributional style implies that failure is attributed to one's own inability and that this is a stable condition and cannot be overcome by effort. This perception could have decreased effort in our participants with ADHD, and might have led to the feeling of less vigor and more fatigue.

Importantly, a missing significant correlation indicates that in the ADHD group self-rated executive functions (i.e., DEX) are unrelated to objective executive functions (i.e., SET). In the same vein, Barkley and Murphy (2010) assume that self-ratings of executive functions predict occupational adjustment better than objective executive function measures in patients with ADHD, assuming that ratings of executive functions in daily life are more predictive than executive functions per se. Thus, contrary to prominent theories explaining symptoms and difficulties of adults with ADHD mainly with deficits in executive functions, further factors—as for instance mood and motivation—seem to have an influence on performance in adults with ADHD. This is also indicated by the requested inclusion of daily executive function abilities (e.g., multitasking) into the set of diagnostic criteria for ADHD (Spencer et al. 2007).

With regard to children with ADHD, an elaborated ADHD model proposes a distinction between executive function and motivation control deficits. According to the dual pathway model of behavior and cognition introduced by Sonuga–Barke (2002), ADHD may not only pertain to a dysregulation of thought and action pathway (DTAP) but also to a motivational style pathway (MSP). Both children with ADHD DTAP and ADHD MSP meet criteria for the ADHD combined subtype even though they are characterized by distinct cognitive profiles as described below. The first pathway (ADHD DTAP) is manifested in a primary inhibitory dysfunction that is mediated by secondary cognitive and behavioral dysfunctions, which in turn lead to faulty task-engagement (e.g., deficits of shifting, working memory) and inattention-disorganization. The second

pathway (ADHD MSP) is characterized by a dysregulation of reward mechanisms leading to a higher preference for immediate rewards in children with ADHD and hyperactivity-impulsivity.

What happens to these differential pathways when patients with ADHD grow older? A recent study with young adults with ADHD supports a two-factor theory of ADHD in this age group (Nigg et al. 2005). Taking development into account, one might further expect that feedback of parents, teachers, and significant others have an important influence on ADHD MSP in particular. This is because, as Sonuga–Barke (2002) assumes, associative learning plays an important role in the development of ADHD MSP, and ADHD MSP is linked more to environmental instead of neurobiological risk factors in comparison to ADHD DTAP. However, we likewise expect influences on the first pathway (i.e., ADHD DTAP). This is because recent studies revealed that executive functions are malleable (i.e., Gawrilow et al. 2011). For instance, working memory functions can be improved by repeatedly exercising working memory tasks (i.e., Thorell et al. 2008), and inhibition or shifting performance can be enhanced via the self-regulatory strategy of planning (Gawrilow and Gollwitzer 2008; Gawrilow et al. 2011). Thus, one might assume that also variables like mood and motivation have a strong impact on executive functions, and further research might want to investigate long-term influences of mood and motivation on executive function performance of participants with ADHD.

Furthermore, our results suggest that a well-structured situation (i.e., non-interleaving condition), without interleaving, planning, and monitoring, leads to the best performance (i.e., number of items completed) and mood (i.e., vigor and flow) in male adults with ADHD. Interestingly, it has already been shown that children with ADHD can compensate their deficit in executive function through the use of a structured self-regulatory strategy (i.e., making if–then plans; Gawrilow and Gollwitzer 2008; Gawrilow et al. 2011; Paul–Jordanov et al. 2010). The mechanism underlying this elevated performance is the delegation of action control to prespecified critical environmental cues. Therefore, if–then plans help to structure a situation and also could be helpful for adults with ADHD. Further research needs to explore if forming if–then plans is helpful for adults with ADHD.

Limitations

As previously noted, our study has several limitations. One limitation is that the adults with ADHD in our sample were diagnosed late in their lives. It is therefore not possible to assess whether the perception of the experimental task situation was due to difficulties arising from the ADHD or from a (too) late diagnosis. Related to the fact that our participants were diagnosed late, it might be that our sample represents a specific ADHD sample. This assumption is supported by the fact that males with ADHD demonstrated no deficits in the Go/NoGo task (Table 1). Therefore, future research might want to include a comparison sample of adults that were diagnosed earlier and should also investigate if the difference in task perception can be replicated in samples of children and adolescents. Hence, to find out whether the ability to evaluate one's own performance correctly is due to fear of failure and reduced effort in adults with ADHD, individuals with ADHD that received their diagnosis late should be compared with individuals that received their diagnosis earlier in their lives (i.e., in childhood). In the same vein, comparable (cross-sectional) studies with children, adolescents, and young adults with ADHD might reveal interesting insights into the development of ADHD DTAP and MSP (Nigg et al. 2005; Sonuga–Barke 2002, 2003, 2005).

A second limitation is that we did not differentiate the different subtypes of ADHD. It might be that different subtypes of ADHD (i.e., inattentive, hyperactive–impulsive, or combined) have different attributions and perceptions of the task. A third limitation concerns our sample as well: we only included men with ADHD in our study. Thus, future studies might want to include women to account for gender $\times$ group (ADHD vs. control group) differences in the perception of the task at hand.

A fourth limitation refers to the task used in this study. One might wonder whether the SET actually reflects everyday executive functions (i.e., multitasking) and whether the test is sensitive enough to assess multitasking per se. In our data, we found neither a correlation between the SET and the DEX nor between the SET and the Go/NoGo task in the subsample of participants in the multitasking condition ($n = 15$ in the ADHD group). Thus, at least in this subsample of participants, the SET seems to be unrelated to both self-rated executive functions and inhibition functions measured with a Go/NoGo task. Furthermore, the SET performance of participants in this subsample resembles a ceiling effect with both adults with and without ADHD showing almost maximum SET scores. However, as to date there are to our knowledge no objective tests assessing everyday multitasking, further research might want to investigate the effects on interleaving and non-interleaving conditions in classical executive function tasks (e.g., Go/NoGo task).

Conclusion

Male adults with ADHD do not show an impaired multitasking performance compared to male adults without

ADHD. However, the ADHD group achieved the best performance (i.e., completed the most items), showed the best mood, and was most motivated in a well-structured non-interleaving condition. Further research is necessary to explore whether this result is due to an underestimation of ability by the adults through their late diagnosis. However, for adults with ADHD who received their diagnosis late, it seems reasonable to recommend an environment that is as structured as possible.

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