Occupational status is compromised in adults with ADHD and psychometrically defined executive function deficits

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Abstract

Background

Problems related to executive functions (EF) are frequently reported in adults with ADHD, but only a subgroup shows deficits on commonly used neuropsychological tests designed to measure EF. The group with combined ADHD and EF problems may be characterized by more difficulties in daily life than those with EF problems or ADHD alone. In the present study, we examined functional impairment in this group by estimating EF using selected tests from the Delis-Kaplan Executive Function System (D-KEFS).

Methods

The sample included 79 adults with ADHD and 77 controls, recruited from a Norwegian clinical study on adults with ADHD. The ADHD sample was characterized by general abilities within the normal distribution range (Full Scale Intelligent Quotient > 80) and matched the control group in sex distribution. ADHD-symptoms and psychiatric comorbidity were assessed by questionnaires and psychiatric interviews. Subgroups with Executive Function Deficits (EFD) were defined within the ADHD- and the control group from their performance on selected subtests from D-KEFS.

Results

EFD was found in 24.3% of the ADHD group. This subgroup showed significantly higher frequency of unemployment, more reading and writing problems, lower IQ scores, and more self-reported ADHD-symptoms in childhood than the ADHD subgroup without EFD.

Conclusions

Psychometrically defined EFD was associated with functional impairment in a subgroup of adults with ADHD. This finding indicates that subtests from a test battery widely used in clinical assessments (i.e., D-KEFS) are useful to identify individuals at risk of functional impairments, and emphasizes the importance of effective treatment programs targeting EF.

Keywords

Executive function, D-KEFS, attention-deficit/hyperactivity disorder, executive function deficit, work status, ADHD

Background

Attention-deficit/hyperactivity disorder (ADHD) is a diagnosis defined by developmentally inappropriate levels of hyperactivity, inattention and impulsivity [1]. Approximately 40-60% of children with a diagnosis of ADHD are expected to have persisting symptoms into early adulthood [2, 3]. Studies have shown that this group displays a range of functional impairments, from work-related problems to difficulties in social life [4-6]. Kessler and collaborators [7] estimated that ADHD among workers was associated with an average of 35 days annual lost work performance. This represents 120 million days of annual lost work in the U.S. labor force, equivalent to $ 19.5 billion lost human capital. However, individuals with ADHD constitute a heterogeneous group with high inter-individual variability [8], and identification of potential risk factors for functional impairment is therefore important to understand different developmental pathways within the group.

One such risk factor is deficits of executive functions (EF), which is described as a core feature of ADHD [9, 10]. EF has been defined as "general-purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition" [11 p. 50]. As such, EF is important for adaptation, self-regulation, social cognition, independence and productivity, and deficits commonly leads to cognitive, emotional and behavioural impairment [12]. To prevent serious impairment of daily life function it may thus be essential to identify and help individuals with ADHD and EF deficits (EFD) [13].

However, it is not clear how to identify individuals with EFD. For instance, a neuropsychological assessment is expected to identify deficits in only a subgroup of individuals with ADHD. Nigg [14] has argued that this subgroup has distinct features, and

suggested inclusion of an executive deficit subtype of ADHD in the fifth version of the Diagnostic and Statistical Manual of Mental Disorder (DSM-5). Others have proposed that EFD is a more global feature of ADHD [15, 16], and that failure to identify this dysfunction may be related to the different results obtained in the structured test setting and by rating scales measuring daily functioning [15, 17]. In line with this, Toplak et al. [17] argue that the two methods assess different aspects of cognitive function. Accordingly, low correlations have been reported between self-reported and psychometric definitions of EFD [18]. If different methods tap different aspects of EF, it may be necessary to use both neuropsychological tests and rating scales to catch the wide range of EF problems in ADHD. We argue that the group with psychometrically defined EFD from test performance may be a particularly vulnerable group with substantial problems in daily-life activities [13, 14], underlining the importance of investigating functional impairment separately in this group.

Identification of individuals with EFD is not only dependent on the assessment method, but also the definition of EF. Miyake et al. [11] have suggested that the concept of EF comprises several subfunctions, such as inhibition, working memory and set-shifting, and that these subfunctions are involved in more complex, higher level functions, such as planning. They also found that EF is characterized by both unity and diversity. In line with this, there may be individual differences in functioning across different components of EF, and a test battery must therefore be rather extensive. The Delis-Kaplan Executive Function System [D-KEFS; 19] is one of the few standardized test batteries specifically designed to capture such a wide range of EF components. Other assets of D-KEFS include its sensitivity to even the mild EFD characterizing individuals with ADHD [20, 21].

In addition to the challenge of assessing and defining EF, there is no consensus on how to distinguish a "deficit" from a "normal" function. Doyle et al. [22] defined EFD as a score of ≥ 1.5 standard deviations below the mean of matched controls (or what is within the poorest 7th percentile for non-normal distributed variables) on two or more tests of EF. This definition led to better discrimination between ADHD and controls than a definition based on results from a single test [22]. Using Doyle's definition, Biederman et al. [23] showed that although EFD seemed to be independent of psychiatric comorbidity or severity of ADHD symptoms, EFD in ADHD was associated with low IQ and poor reading achievements, in addition to low academic and occupational functioning.

Several studies have investigated differences in EF between diagnostic subgroups of ADHD. Fewer studies have examined characteristics of the subgroup with neuropsychologically defined EFD, even though it may represent a distinct subgroup of ADHD [14]. Biederman and collaborators' [23] study is an exception. They included a set of standard neuropsychological tests selected from different test traditions to define a score of EFD, and called for other studies with the aim of replicating their findings. In the present study, we applied Doyle et al.'s definition of EFD on selected subtests from D-KEFS in a Norwegian sample of ADHD patients and controls. There are at least two arguments in favor of using the D-KEFS: 1) D-KEFS is widely used in the clinic, making the results more relevant for clinicians; and 2) use of a standardized test battery, developed within the same test tradition probably reduces error variance due to methodological differences between test measures. These advantages, in addition to the need for confirming the results from Biederman et al. [23] with other measures and in samples outside the US, motivated the present study. Subtests from D-KEFS were selected to cover a wide range of EF, including the subfunctions described by Miyake et al. [11]. From the results presented by Biederman et al. [23], we hypothesized that a higher proportion of the ADHD group than the control group would show

EFD, and that the combination of ADHD and EFD would be associated with low IQ, low education, problems with reading and writing and unemployment. As EFD and ADHD combined is likely to be associated with a more severe impairment in daily functioning than ADHD alone, we also expected a high percentage of adults with ADHD and EFD to have been diagnosed in childhood.

Methods

Participants in the main study: ADHD in Norwegian Adults

The present study is a substudy of the project "ADHD in Norwegian Adults", that currently includes 800 adult ADHD patients diagnosed according to DSM-IV criteria [1] and 909 control persons. In the ADHD group, 340 participants were recruited from a national registry of adults diagnosed in Norway from 1997 to May 2005, who had undergone a diagnostic evaluation performed by expert committees with competence in diagnosing ADHD in children and adults. This registry was established during a period when adults with ADHD/ Hyperkinetic disorder were only allowed to receive stimulants after systematic and mandatory diagnostic evaluation by one of the three regional diagnostic committees. This ensured a standardized diagnostic practice across the country and adherence to ADHD diagnostic criteria. The committees consisted of three to five clinicians with special expertise and experience in diagnosing ADHD. Patients were referred to the expert teams by their hospital doctors, general practitioners, or psychiatrists. The referral procedure required records with descriptions of current functioning and symptoms, collateral information about behavior in childhood as well as results from physical and psychiatric examinations. Based on these records, the committees confirmed or disproved the diagnosis of ADHD. Although ICD-10 was the official diagnostic system in Norway, allowance was made for the diagnosis of the

inattentive subtype in DSM-IV. Between 2005 and 2007, 1700 invitation letters were sent to adults with ADHD included in this registry. The rest of the ADHD group was recruited from clinicians (psychiatrists, general practitioners, and psychologists) from all over the country. They were invited to recruit adults with ADHD who were formally diagnosed according to the national guidelines based on the criteria used by the expert teams, but without the mandatory evaluation of the committees as this arrangement ceased in 2005. The inclusion criteria in this project were a diagnosis of ADHD or Hyperkinetic Disorder according to the DSM-IV or the ICD-10 criteria and an age of 18 years or above. There were no formal exclusion criteria.

In the control group, 715 individuals in the same age range as the patients were randomly recruited from the general population in Norway through the Medical Birth Registry of Norway (MBRN). This registry includes all persons born in Norway after 1st January 1967. A total of 2963 letters of invitation were sent to the randomly selected nationwide sample. In addition, a subsample of controls was recruited by means of local advertisements. All participants donated blood or saliva samples and completed questionnaires. For all patients, the referring clinicians provided details concerning diagnoses and treatment history. The project was approved by the Regional Committee for Medical and Health Research Ethics of Western Norway (IRB 00001872). More details concerning the main study are described in previous publications [4, 24, 25].

Participants in the present study

Participants living in and around Bergen were randomly selected from the main study and invited to take part in an extended assessment, including a psychiatric interview (to assess psychiatric comorbidity) performed by a psychiatrist, and neuropsychological testing

performed by a trained test technician. The ADHD-group included 79 individuals (mean age 34 years, range 19-59), of whom 22 were recruited through the expert teams and the rest by clinicians as described above. The control group (N=77, mean age 28.9 years, range 19-45) included individuals originally recruited from the MBRN (N=60) and by advertisement (N=17).

Participants with an IQ score below 80 (N=2, both from the ADHD group) and subjects with autism spectrum disorder, tics, Tourette syndrome, or epilepsy (N=4, 3 from the ADHD group) were excluded. Two of the participants in the control group had cut-off scores above the threshold for probable ADHD on the Adult ADHD Self Report Scale (ASRS) [26] in addition to fulfilling the criteria for both ADHD in childhood and adulthood on the psychiatric interview and were therefore also excluded. In the ADHD group, 71% presently used central stimulants or other ADHD medication. Since medication may influence test results, the participants were instructed not to take medication on the day of testing.

Questionnaires/tests used in the present study

Self-report questionnaires

The Wender Utah Rating Scale [WURS;27] was used to measure ADHD symptoms in childhood, and the ASRS to assess current ADHD symptoms. Cronbachs alpha coefficient for WURS was .960 and .954 for ASRS.

Screening questions

The participants answered 31 questions concerning socio-demographic and clinical factors. Information about lifetime comorbidities was collected by asking the participants about other disorders, including bipolar disorder, significant depression/anxiety disorders, reading/writing

difficulties, etc. The validity of these self-reported diagnoses has been established in a previous study [28].

Wechsler Abbreviated Scale of Intelligence

Two subtests (Matrix Reasoning and Vocabulary) from the Wechsler Abbreviated Scale of Intelligence (WASI) were used to estimate IQ according to the norms presented in the test manual [29].

Tests from D-KEFS

D-KEFS, developed by Delis, Kaplan and Kramer [19], was designed to measure several subfunctions of EF. Subtests from four of the nine D-KEFS tests were included in the present study, all measuring functions that have been reported to be affected in ADHD [25, 30, 31]. They were selected to cover a wide range of EF, including the three suggested by Miyake [11]. With these subtests, we computed an overall variable to define if the participants showed deficits on two or more EF subtests. The D-KEFS subtests are all commonly used, traditional tests that have been developed and modified by the authors of D-KEFS.

Trail Making Test (TMT)

The fourth condition was included as a measure of visual set-shifting and working memory. The participant is asked to alternate (drawing a line) between letter and number sequences, and the outcome measure is number of seconds used to complete the test.

Word Fluency Test

Three subscores were included. The first condition, where the participants are asked to search for words beginning with specific letters, was selected as a measure of word-generation. The

forth and fifth conditions, where the task is to alternate between two categories of words, were selected to measure different aspects of verbal category switching (number of correct responses and switching accuracy). The outcome measures are number of correct words and number of correct switches/switching accuracy for the first and the fourth/fifth conditions, respectively.

Color Word Interference Test (CWIT).

Two EF measures were included. The third condition (CWIT inhibition) was used as a measure of inhibition, while the fourth condition requires both inhibition and set-shifting abilities. The task in the third condition (CWIT inhibition) is to inhibit reading words denoting colors while naming the incongruent color of the word. In the fourth condition (CWIT inhibition/set-shifting), the test person is asked to alternate between naming the color of the word (inhibiting the automatic response of reading) and reading the word whenever the word is framed. The outcome measure is seconds used to complete each condition.

Tower Test

The total achievement score was included as a measure of working memory function, inhibition, and the ability to plan ahead. In this test, the participant is instructed to build a tower while following certain rules. The achievement score is based on time, number of moves and if the tower is correct.

Relation between conditions within EF-tests

Although the conditions/subtests within each test have been designed to measure various functions, they may still target the same underlying theoretical construct. The two last conditions of the Word Fluency Test are used to measure set-shifting, while the inhibition and

inhibition/set-shifting conditions from the CWIT are used as measures of inhibition. Pearson bivariate correlation analyses performed in both groups to investigate relations between the set-shifting conditions within each test, revealed high correlations within both groups of participants (CWIT inhibition and inhibition/set-shifting conditions: ADHD-group, r=.616, P<.001, Control-group, r=.561, P<.001, Word-Fluency Test, the two set-shifting conditions: ADHD-group, r=843, P<.001, Control-group, r=.917, P<001). Deficit on two conditions within one test was therefore counted as a deficit on one test.

Calculation of deficit

In accordance with Biederman et al. [32], EFD was defined as raw scores on two or more tests that were at least 1.5 standard deviations from the mean of the control group if the variable was normally distributed. If the variable was non-normally distributed, the threshold was defined as within the poorest 7th percentile (TMT, inhibition condition from CWIT and Tower Test). See Table 1 for means and standard deviations on the D-KEFS subtests.

[INSERT TABLE 1 HERE]

Socio-demographic and clinical data in the ADHD- and control group

Statistically significant differences were observed between the ADHD group and control group in age, mean IQ and years of education, but not in sex distribution. A significantly higher proportion of individuals in the ADHD group were unemployed, had or have had different comorbid disorders/problems (alcohol problems, problems with other drugs, depression/anxiety, bipolar disorder, problems with reading and writing), or had parents or siblings with ADHD. Although all patients had symptoms and impairments consistent with

ADHD before seven years of age, only 9.6% of the patients received a formal diagnosis of

ADHD in childhood. There were no significant differences ($p > 0.05$) in IQ, ASRS or WURS

scores between controls recruited from the MBRN or through advertisement. See Table 2 for

socio-demographic- and clinical information and data on comorbidity. Different sample sizes

in different conditions are due to missing data. There were several reasons for missing data.

For some of the variables, the participants had probably overlooked questions, or forgotten to

include the clinical data sheets provided by their physicians. For the variable "in work", some

are not included because they did not fit the categories "in work" or "out of work", e.g.

students.

[INSERT TABLE 2 HERE]

Statistical analyses

Differences between the ADHD- and control group in frequency of EFD (according to

Doyle's definition) and between the four groups (ADHD with EFD, ADHD without EFD,

control with EFD, control without EFD) in occupational and educational status, psychiatric

comorbidity, ADHD symptoms, medication and diagnosis in childhood, were investigated

using χ^2 (Pearson) analyses for categorical dependent variables and ANOVA with correction

for multiple comparisons (Tukey HSD) for continuous dependent variables. Welch statistics

were used whenever there was violation of the assumptions of Equality of Covariance or

Equality of Error Variance. Only results from parametric statistical analyses are reported, as

the significance levels were consistent with the levels generated by the non-parametric

analyses. For significant results, we controlled for age by using binary logistic regression

analyses for categorical dependent variables and one-way ANCOVA for continuous

dependent variables. For significant differences between the groups stratified by EF, we also

controlled for reading and writing problems. Significance level was set to 0.05 for all analyses.

Results

EFD (Executive Function Deficit) in the ADHD and in the control group

According to the definition of EFD used in the present study, 24.3% of the participants with

ADHD and 10.8% of the controls were classified as having EFD, a statistically significant

difference (χ^2(1, N=148) = 4.666 p=.031) that was not retained when age was included as a

covariate in the binary logistic regression analysis (p = 0.098).

Frequency of deficits on the EF tests

The ADHD group had a higher frequency of deficits than the controls on all selected D-KEFS

measures. However, the group differences were statistically significant only for the CWIT

(χ^2(1, N=148) = 10.207, p=.002), with 32.4% of the participants being impaired on one or two

of the CWIT subtests in the ADHD group, and 10.8% in the control group. Separate analyses

of the two CWIT subtests showed a significant group difference for the inhibition/set-shifting

condition (i.e., condition 4), with 28.4% showing deficit in the ADHD group and 6.8% in the

control group (p<0.001). The group differences were still significant after including age as a

covariate (see Table 3 for details). The groups were not different with regard to sex on any

subtest.

[INSERT TABLE 3 HERE]

Differences between the groups with and without EFD

The ADHD group with EFD was significantly older, had lower IQ score, more frequent reading and writing problems and higher WURS scores than the ADHD group without EFD. Furthermore, the work status in the ADHD group with EFD was significantly different from the work status in the other groups. While 52.1% were employed in the ADHD group without EFD, the percentage of employed participants was only 6.7 in the ADHD group with EFD. In contrast, all controls with EFD were employed. The differences between the ADHD subgroups remained statistically significant after including age and reading and writing problems as covariates. There was no significant difference between the ADHD subgroups regarding use of ADHD medication. None in the ADHD group with EFD compared to 12.7% in the ADHD group without EFD had been diagnosed in childhood, a difference that was statistically non-significant. No significant differences were found between the ADHD subgroups regarding psychiatric comorbidity and education. For more information about group differences, see Tables 4a and b.

[INSERT TABLE 4 a and b HERE]

Discussion

The present study confirmed and extended the findings from the study by Biederman et al. [23], showing a severe functional impairment in adults with ADHD who also show EFD. Both studies used the definition suggested by Doyle et al. [22] to define EFD, but the present study included results on subtests within a more homogeneous test battery- the D-KEFS. As expected, EFD in the ADHD-group was associated with significantly more functional deficits than in the control group. For example, all participants in the control group with EFD were employed, while this was true for only 6.7% of the ADHD group with EFD. Furthermore, the

ADHD group with EFD had lower IQ scores, higher frequency of reading and writing problems, and higher scores on the WURS than the ADHD group without EFD. Surprisingly, none in the ADHD group with EFD, compared to 12.7% in the ADHD group without EFD, had been formally diagnosed with ADHD during childhood. In accordance with previous studies, no group differences were found with regard to psychiatric comorbidity.

Contrary to our expectations from Biederman et al.'s study [23], the difference in frequency of EFD between the ADHD and control group was not statistically significant when age was included as a covariate. On average, the ADHD group was five years older than the control group, and previous studies have shown a decline in EF with age [33]. This decline may therefore explain the lack of group difference in frequency of EFD when controlling for age. The lack of difference between the groups is probably due to heterogeneity, and supports the importance of examining subgroups with different characeristics in ADHD. Frequency of EFD in the ADHD group was in line with previous studies suggesting that approximately 30% of individuals with ADHD show deficits on neuropsychological tests measuring EF [23, 32]. The cognitive heterogeneity confirmed by the present study emphasizes the importance of a neuropsychological examination, not primarily as a tool to diagnose ADHD, but to characterize strengths and weaknesses of importance for developing individualized intervention procedures [34, 35].

A particularly relevant test in such an examination seems to be the inhibition/set-shifting subtest from the CWIT, where the largest difference in frequency of deficit between the ADHD group and the control group was found. This may be explained by the complexity of the task, which probably renders it sensitive to subtle deficits of EF. This is supported by research showing that adding a set-shifting condition to a test of EF increases its sensitivity to

dysfunctions associated with the frontal lobes [36]. The complexity of the inhibition/set-shifting condition from the CWIT probably reflects the interplay between set shifting and response inhibition, and performance is thus likely to be dependent on more than just an additive effect [25]. Despite this, Lippa & Davis [37] found that in a mixed group of patients referred to neuropsychological testing, many patients performed better on the inhibition/set-shifting than on the inhibition condition. This was later confirmed in a study of patients with schizophrenia [38] and suggests that the inhibition/set-shifting condition is not necessarily more difficult than the inhibition condition. The results in the present study may be explained by the ADHD group showing a reduction in learning effect from the former condition, or that the CWIT subtest measures an aspect of set-shifting abilities that represents a specific problem in individuals with ADHD [25]. In both cases, our findings indicate that this test is especially sensitive to problems related to ADHD, and that it should be included as part of a neuropsychological assessment of individuals with ADHD.

A high proportion within the ADHD group with EFD was currently unemployed, but this was also true for more than 50% of the ADHD group without EFD. Interestingly, all individuals in the control group with EFD were employed. This suggests that ADHD has a strong impact on work status [39]. However, the extremely low rate of employment in the ADHD group with EFD (6.7%) confirms that the combination of ADHD and EFD has a compound effect on function in adulthood.

Despite the significant difference in employment rate, no significant difference between the ADHD subgroups was found for level of education. The result may be due to small sample sizes, but also to characteristics of the educational system in Norway. Education is more accessible and affordable than, for example, in the USA [40], making it easier to complete an

educational programme in Norway. Length of education in Norway may therefore be a poor indicator of functional impairment. This is supported by the higher frequency of reading and writing problems in the ADHD group with EFD, which is in accordance with the study by Biederman and colleagues [23], showing that deficits of EF in ADHD are associated with poor reading achievement, and a recent study where the group with reading disability and ADHD scored lower on tests from the D-KEFS than those with only ADHD [41]. The IQ level was also lower in the ADHD subgroup with EFD, consistent with studies showing that a deficit in EF is related to IQ [42-44]. Biederman et al. [23] pointed out that since ADHD itself takes a toll on the development of intelligence [45-48], the combination of ADHD and EFD have a considerable impact on intellectual function, and probably also on what is commonly referred to as the g-factor of cognitive function [49]. In accordance with this, we argue that if the group with psychometrically defined EFD is a qualitatively distinct subgroup, this group may also be characterized by qualitatively different functioning in many domains. It is therefore possible that this subgroup has lower IQ because of a different aetiology, without any causal link between IQ and EFD. This is supported by the independent familial segregation of EF and intelligence measures shown by Rommelse et al. [50] in families with ADHD.

Despite the significant functional impairment found in the ADHD group with EFD, the higher scores on the WURS in this subgroup were not expected, as former studies have shown limited or no relationship between symptoms of ADHD and EF [23, 32]. However, it has been shown that symptom remission is associated with improvement in neuropsychological functioning [51]. On the other hand, WURS has also been associated with a high level of false positives [52], and reports on the WURS items indicate that they may reflect present personality traits rather than symptoms specific to an ADHD diagnosis [53]. This was

supported by the present study, showing a non-significant difference on the ASRS between the ADHD groups with and without EFD, indicating that EFD in ADHD is not just due to quantitative differences in the severity of the disorder, but also qualitative differences between subgroups. It is also possible that lack of treatment in childhood may lead to both more severe symptoms in childhood and a more severe EFD in adulthood. In accordance with this, none in the ADHD group with EFD obtained an official diagnosis of ADHD or had been treated in childhood. As early treatment of ADHD is a predictor of employment in adults [4], it is essential to identify ADHD as early as possible and start interventions to improve everyday functioning in adulthood.

Limitations

The findings of above average IQ levels in both the ADHD and the control group, combined with a high non-response rate, suggest a selection bias towards recruitment of well-functioning individuals in both groups. Still, the present study as well as a previous study from our research group found that the ADHD group was severely impaired [4], especially with regard to occupational success. Because of the high prevalence of co-existing psychiatric conditions in ADHD [54], a clinical control group would probably have provided insight into the specificity of the neuropsychological deficits observed in the present study. This would also have been useful because WURS may reflect current personality traits [53] and because both the ASRS and WURS in some studies have shown relatively low discriminative validity [52, 55]. In addition, we cannot conclude that functional impairment is caused by the EFD. It is for example possible that being unemployed leads to EFD instead of the other way around, although this is not supported by the results in the control group.

We aimed to cover a wide range of subfunctions defined within the concept of EF. However,

the concept of EF is complex and difficult to define, and the subtests from D-KEFS have probably not covered all aspects of EFD in ADHD. In addition, it could be argued that IQ, more basic functions and other aspects of EF should have been controlled for. However, there are reasons for not controlling for these functions: 1) Although IQ accounts for much of the variance in another measure of cognitive function, this may be due to a common latent variable, such as ADHD itself, explaining both results [56]. Controlling for IQ could therefore lead to controlling for a part of the disorder itself. 2) Reliability, or the estimate of how much of the test variance that is actually true variance, is low for most of the D-KEFS contrast scores (scores included to control for basic functioning). This indicates that most of the variance is measurement error variance. It has therefore been suggested that D-KEFS contrast measures should not be used in neuropsychological decision making [57]. 3) We wanted to compare the results from the present study with the Biederman et al. [23] study, which did not include such measures.

Nevertheless, we examined the influence of basic functions and IQ on our results by running some additional analyses to compare the frequencies of deficits between the ADHD-and control -group on the standardized contrast scores. The results were in line with results from the summary scores, showing significant group difference between the ADHD and control group on the inhibition/set-shifting condition of the CWIT (p=0.001) and no significant differences between the two groups on the other D-KEFS measures. This indicates that the differences between the contrast measures (also corrected for age) are in line with results from analyses including the primary summary scores. This shows that the results in the present study are most likely due to EFD rather than abilities related to more basic functions. The inclusion of several EF tests may also have reduced some of the "noise" from basic conditions. In addition, we performed additional analyses where we correlated the different D-KEFS

subtests with IQ, and found no correlations in the ADHD with EFD group. This indicates that although IQ in this group is lower than in the group without EFD, IQ is not directly associated with the deficit. Finally, it is important to highlight that we have only examined psychometrically defined EFD in this study. Other subgroups may also have EF problems, but at a level that is not detected by the neuropsychological tests. Despite this, our results supported that the group with neuropsychologically defined EFD seems to be a specific subgroup associated with more negative functional impairment [14]. The findings of the present study are thus highly relevant for clinicians in their work when selecting screening procedures and developing interventions.

Conclusions

This study confirms and strengthens previous findings suggesting that ADHD in combination with EFD is associated with a more extensive functional impairment than either ADHD or EFD alone. The deficits were detected by tests from a widely used test battery (i.e. D-KEFS), which reinforces the clinical utility of the present study. The findings also underline that ADHD is a heterogeneous disorder, and suggest that characterization of subgroups is important when developing targeted interventions.

Competing interests

The authors have no competing interests. During the previous three years, Dr. Haavik has participated in continuing medical education programs sponsored by Novartis, Lilly and Janssen-Cilag.

Authors contributions

While HBH has written the manuscript and analyzed the data, AJL, LS and MBP have contributed with relevant literature and comments, interpretations of the results and improvement of language. JH has provided comments on the manuscript. All authors have been involved in the planning and the design of the study.

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References

1. Association AP: *Diagnostic and statistical manual of mental disorders: DSM-IV. 4th ed*. Washington, DC: American Psychiatric Association; 1994.

2. Lara C, Fayyad J, de Graaf R, Kessler RC, Aguilar-Gaxiola S, Angermeyer M, Demytteneare K, de Girolamo G, Haro JM, Jin R, et al: **Childhood predictors of adult attention-deficit/hyperactivity disorder: results from the World Health Organization World Mental Health Survey Initiative.** *Biological psychiatry* 2009, **65:**46-54.

3. Faraone SV, Biederman J, Mick E: **The age-dependent decline of attention deficit hyperactivity disorder: a meta-analysis of follow-up studies.** *Psychol Med* 2006, **36:**159-165.

4. Halmoy A, Fasmer OB, Gillberg C, Haavik J: **Occupational outcome in adult ADHD: impact of symptom profile, comorbid psychiatric problems, and treatment: a cross-sectional study of 414 clinically diagnosed adult ADHD patients.** *Journal of attention disorders* 2009, **13:**175-187.

5. Gjervan B, Torgersen T, Nordahl HM, Rasmussen K: **Functional impairment and occupational outcome in adults with ADHD.** *Journal of attention disorders* 2012, **16:**544-552.

6. Biederman J, Faraone SV, Spencer TJ, Mick E, Monuteaux MC, Aleardi M: **Functional impairments in adults with self-reports of diagnosed ADHD: A**

controlled study of 1001 adults in the community. *The Journal of clinical psychiatry* 2006, **67**:524-540.

7. Kessler RC, Adler L, Ames M, Barkley RA, Birnbaum H, Greenberg P, Johnston JA, Spencer T, Ustun TB: **The prevalence and effects of adult attention deficit/hyperactivity disorder on work performance in a nationally representative sample of workers.** *J Occup Environ Med* 2005, **47**:565-572.

8. Wahlstedt C, Thorell LB, Bohlin G: **Heterogeneity in ADHD: neuropsychological pathways, comorbidity and symptom domains.** *Journal of abnormal child psychology* 2009, **37**:551-564.

9. Castellanos FX, Sonuga-Barke EJ, Milham MP, Tannock R: **Characterizing cognition in ADHD: beyond executive dysfunction.** *Trends in cognitive sciences* 2006, **10**:117-123.

10. Barkley RA: **Differential diagnosis of adults with ADHD: the role of executive function and self-regulation.** *J Clin Psychiatry* 2010, **71**:e17.

11. Miyake A, Friedman NP, Emerson MJ, Witzki AH, Howerter A, Wager TD: **The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis.** *Cogn Psychol* 2000, **41**:49-100.

12. Eslinger PJ, Flaherty-Craig CV, Chakara FM: **Rehabilitation and management of executive function disorders.** *Handb Clin Neurol* 2013, **110**:365-376.

13. Miller M, Nevado-Montenegro AJ, Hinshaw SP: **Childhood executive function continues to predict outcomes in young adult females with and without childhood-diagnosed ADHD.** *J Abnorm Child Psychol* 2012, **40**:657-668.

14.   Nigg JT, Willcutt EG, Doyle AE, Sonuga-Barke EJ: **Causal heterogeneity in attention-deficit/hyperactivity disorder: do we need neuropsychologically impaired subtypes?** *Biological psychiatry* 2005, **57**:1224-1230.

15.   Barkley RA, Fischer M: **Predicting impairment in major life activities and occupational functioning in hyperactive children as adults: self-reported executive function (EF) deficits versus EF tests.** *Developmental neuropsychology* 2011, **36**:137-161.

16.   Brown TE: **Executive Functions and Attention Deficit Hyperactivity Disorder: Implications of two conflicting views.** *International journal of Disability, Development and Education* 2006, **53**:35-46.

17.   Toplak ME, West RF, Stanovich KE: **Practitioner review: do performance-based measures and ratings of executive function assess the same construct?** *J Child Psychol Psychiatry* 2013, **54**:131-143.

18.   Biederman J, Petty CR, Fried R, Black S, Faneuil A, Doyle AE, Seidman LJ, Faraone SV: **Discordance between psychometric testing and questionnaire-based definitions of executive function deficits in individuals with ADHD.** *J Atten Disord* 2008, **12**:92-102.

19.   Delis DC, Kaplan E, Kramer JH: *Delis-Kaplan Executive Function System.* . San Antonio, TX: The Psychological Corporation; 2001.

20.   Wiers RW, Gunning WB, Sergeant JA: **Is a mild deficit in executive functions in boys related to childhood ADHD or to parental multigenerational alcoholism?** *J Abnorm Child Psychol* 1998, **26**:415-430.

21. Swanson J: **The Delis-Kaplan Executive Function System.** *Canadian Journal of School Psychology* 2005, **20:**117-128.

22. Doyle AE, Biederman J, Seidman LJ, Weber W, Faraone SV: **Diagnostic efficiency of neuropsychological test scores for discriminating boys with and without attention deficit-hyperactivity disorder.** *Journal of consulting and clinical psychology* 2000, **68:**477-488.

23. Biederman J, Petty C, Fried R, Fontanella J, Doyle AE, Seidman LJ, Faraone SV: **Impact of psychometrically defined deficits of executive functioning in adults with attention deficit hyperactivity disorder.** *The American journal of psychiatry* 2006, **163:**1730-1738.

24. Lundervold AJ, Adolfsdottir S, Halleland H, Halmoy A, Plessen K, Haavik J: **Attention Network Test in adults with ADHD - the impact of affective fluctuations.** *Behavioral and brain functions : BBF* 2011, **7:**27.

25. Halleland HB, Haavik J, Lundervold AJ: **Set-shifting in adults with ADHD.** *Journal of the International Neuropsychological Society : JINS* 2012, **18:**728-737.

26. Kessler RC, Adler L, Ames M, Demler O, Faraone S, Hiripi E, Howes MJ, Jin R, Secnik K, Spencer T, et al: **The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population.** *Psychological medicine* 2005, **35:**245-256.

27. Ward MF, Wender PH, Reimherr FW: **The Wender Utah Rating Scale: an aid in the retrospective diagnosis of childhood attention deficit hyperactivity disorder.** *The American journal of psychiatry* 1993, **150:**885-890.

28. Halmoy A, Halleland H, Dramsdahl M, Bergsholm P, Fasmer OB, Haavik J: **Bipolar symptoms in adult attention-deficit/hyperactivity disorder: a cross-sectional study of 510 clinically diagnosed patients and 417 population-based controls.** *The Journal of clinical psychiatry* 2010, **71**:48-57.

29. Wechsler D: *Wechsler Abbreviated Scale of Intelligence. WASI. Manual.* San Antonio, TX: The Psychological Corporation; 1999.

30. Wodka EL, Loftis C, Mostofsky SH, Prahme C, Larson JC, Denckla MB, Mahone EM: **Prediction of ADHD in boys and girls using the D-KEFS.** *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists* 2008, **23**:283-293.

31. Boonstra AM, Oosterlaan J, Sergeant JA, Buitelaar JK: **Executive functioning in adult ADHD: a meta-analytic review.** *Psychological medicine* 2005, **35**:1097-1108.

32. Biederman J, Monuteaux MC, Doyle AE, Seidman LJ, Wilens TE, Ferrero F, Morgan CL, Faraone SV: **Impact of executive function deficits and attention-deficit/hyperactivity disorder (ADHD) on academic outcomes in children.** *Journal of consulting and clinical psychology* 2004, **72**:757-766.

33. De Luca CR, Wood SJ, Anderson V, Buchanan JA, Proffitt TM, Mahony K, Pantelis C: **Normative data from the CANTAB. I: development of executive function over the lifespan.** *J Clin Exp Neuropsychol* 2003, **25**:242-254.

34. Pritchard AE, Nigro CA, Jacobson LA, Mahone EM: **The role of neuropsychological assessment in the functional outcomes of children with ADHD.** *Neuropsychol Rev* 2012, **22**:54-68.

35. Haavik J, Halmoy A, Lundervold AJ, Fasmer OB: **Clinical assessment and diagnosis of adults with attention-deficit/hyperactivity disorder.** *Expert Rev Neurother* 2010, **10:**1569-1580.

36. Bohnen N, Twijnstra A, Jolles J: **Performance in the Stroop color word test in relationship to the persistence of symptoms following mild head injury.** *Acta Neurol Scand* 1992, **85:**116-121.

37. Lippa SM, Davis RN: **Inhibition/switching is not necessarily harder than inhibition: an analysis of the D-KEFS color-word interference test.** *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists* 2010, **25:**146-152.

38. Savla GN, Twamley EW, Thompson WK, Delis DC, Jeste DV, Palmer BW: **Evaluation of specific executive functioning skills and the processes underlying executive control in schizophrenia.** *Journal of the International Neuropsychological Society : JINS* 2011, **17:**14-23.

39. Kupper T, Haavik J, Drexler H, Ramos-Quiroga JA, Wermelskirchen D, Prutz C, Schauble B: **The negative impact of attention-deficit/hyperactivity disorder on occupational health in adults and adolescents.** *Int Arch Occup Environ Health* 2012, **85:**837-847.

40. Usher A, Medow J: **Global Higher Education Rankings 2010. Affordability and Accessibility in Comparative Perspective.** 2010.

41. Stern SK, Morris MK: **Discrimination of ADHD and reading disability in adults using the D-KEFS.** *Arch Clin Neuropsychol* 2013, **28:**125-134.

42.   Sonuga-Barke EJ, Lamparelli M, Stevenson J, Thompson M, Henry A: **Behaviour problems and pre-school intellectual attainment: the associations of hyperactivity and conduct problems.** *Journal of child psychology and psychiatry, and allied disciplines* 1994, **35:**949-960.

43.   Woods SP, Lovejoy DW, Stutts ML, Ball JD, Fals-Stewart W: **Diagnostic utility of discrepancies between intellectual and frontal/executive functioning among adults with ADHD: considerations for patients with above-average IQ.** *Archives of clinical neuropsychology : the official journal of the National Academy of Neuropsychologists* 2000, **15:**775.

44.   Tillman CM, Bohlin G, Sorensen L, Lundervold AJ: **Intellectual deficits in children with ADHD beyond central executive and non-executive functions.** *Arch Clin Neuropsychol* 2009, **24:**769-782.

45.   Faraone SV, Biederman J, Lehman BK, Spencer T, Norman D, Seidman LJ, Kraus I, Perrin J, Chen WJ, Tsuang MT: **Intellectual performance and school failure in children with attention deficit hyperactivity disorder and in their siblings.** *Journal of abnormal psychology* 1993, **102:**616-623.

46.   Barkley RA: *Attention Deficit Hyperactivity Disorder and IQ.* New York: Guilford; 1995.

47.   Mahone EM, Hagelthorn KM, Cutting LE, Schuerholz LJ, Pelletier SF, Rawlins C, Singer HS, Denckla MB: **Effects of IQ on executive function measures in children with ADHD.** *Child Neuropsychol* 2002, **8:**52-65.

48.   Sonuga-Barke EJ, Daley D, Thompson M, Swanson J: **Preschool ADHD: exploring uncertainties in diagnostic validity and utility, and treatment efficacy and safety.** *Expert Rev Neurother* 2003, **3**:465-476.

49.   Deary IJ, Spinath FM, Bates TC: **Genetics of intelligence.** *Eur J Hum Genet* 2006, **14**:690-700.

50.   Rommelse NN, Altink ME, Oosterlaan J, Buschgens CJ, Buitelaar J, Sergeant JA: **Support for an independent familial segregation of executive and intelligence endophenotypes in ADHD families.** *Psychol Med* 2008, **38**:1595-1606.

51.   Young S, Gudjonsson GH: **Growing out of ADHD: the relationship between functioning and symptoms.** *J Atten Disord* 2008, **12**:162-169.

52.   Suhr J, Zimak E, Buelow M, Fox L: **Self-reported childhood attention-deficit/hyperactivity disorder symptoms are not specific to the disorder.** *Compr Psychiatry* 2009, **50**:269-275.

53.   Hill BD, Pella RD, Singh AN, Jones GN, Gouvier WD: **The Wender Utah Rating Scale: Adult ADHD diagnostic tool or personality index?** *J Atten Disord* 2009, **13**:87-94.

54.   Sobanski E, Bruggemann D, Alm B, Kern S, Deschner M, Schubert T, Philipsen A, Rietschel M: **Psychiatric comorbidity and functional impairment in a clinically referred sample of adults with attention-deficit/hyperactivity disorder (ADHD).** *European archives of psychiatry and clinical neuroscience* 2007, **257**:371-377.

55.   Soderstrom S, Pettersson R, Nilsson KW: **Quantitative and subjective behavioural aspects in the assessment of attention-deficit hyperactivity disorder (ADHD) in adults.** *Nord J Psychiatry* 2013.

56.   Dennis M, Francis DJ, Cirino PT, Schachar R, Barnes MA, Fletcher JM: **Why IQ is not a covariate in cognitive studies of neurodevelopmental disorders.** *J Int Neuropsychol Soc* 2009, **15:**331-343.

57.   Crawford JR, Sutherland D, Garthwaite PH: **On the reliability and standard errors of measurement of contrast measures from the D-KEFS.** *J Int Neuropsychol Soc* 2008, **14:**1069-1073.

Tables

Table 1
Means and SD on D-KEFS tests in the ADHD and control group

	ADHD (N=74)		Control (N=74)		
	Mean	SD	Mean	SD	P
Trail Making Test, number-letter switching, time	76.7	23.5	66.4	20.4	.005
Word Fluency Test, letter fluency, total correct	40.8	12.6	43.1	11.2	.240
Word Fluency Test, switching, total correct	14.5	3.1	14.5	2.5	.977
Word Fluency Test, switching accuracy	13.2	3.1	13.2	2.7	.978
Color-Word Interference Test, inhibition, time	55.4	12.9	50.4	10.1	.010
Color-Word Interference Test, inhibition/switching,	68.7	23.6	55.4	10.3	.000
Tower Test, total achievement score	17.3	3.3	18.4	3.8	.045

Table 2
Socio-demographical and Clinical Data

	ADHD			Control			
	M/%	S	N*	M/%	S	N*	P
Age, years	34.0(M)	9.6	74	28.9(M)	6.8	74	<.001
Males	45.9(%)		74	41.9(%)		74	.619
Education, years	12.6(M)	2.4	74	15.2(M)	2.6	74	<.001
Total IQ	110.4(M)	12.7	71	115.7(M)	9.3	74	.005
In work	40.0(%)		63	86.7(%)		45	<.001
WURS, mean score	56.3(M)	17.6	65	17.0(M)	11.2	70	<.001
ASRS, mean score	49.3(M)	9.0	71	21.9(M)	8.4	72	<.001
ᵃPrescribed medication (central stimulantia or other medication for ADHD)	71.0(%)		62				
ADHD diagnosis received in childhood	9.6(%)		73	0.0(%)		74	.006
Lifetime difficulties with reading and writing	41.9(%)		74	9.5(%)		74	<.001
Lifetime problems with alcohol	18.9(%)		74	0.0(%)		74	<.001
Lifetime problems with other drugs	23.3(%)		73	1.4(%)		74	<.001
Lifetime depression/anxiety	59.5(%)		74	12.2(%)		74	<.001
Lifetime bipolar disorder	4.1(%)		74	0.0(%)		74	.078
Executive impairment	24.3(%)		74	10.8(%)		74	.031

*N varies due to missing data and reflects number of participants investigated for each variable
ᵃall participants were asked not to take medication for ADHD the day of testing

Table 3
Frequency of impairment on D-KEFS tests

	ADHD (N=74)	Control (N=74)	
	%	%	P
Trail Making Test, number-letter switching, time	17.6	8.1	.085
Word Fluency Test, letter fluency, total correct	13.5	5.4	.092
Word Fluency Test, switching, total correct	8.1	4.1	.302
Word Fluency Test, switching accuracy	12.2	9.5	.597
Word Fluency Test, switching accuracy and switching total correct combined	13.5	9.5	.439
Color-Word Interference Test, inhibition, time	14.9	6.8	.112
Color-Word Interference Test, inhibition/switching, time	28.4	6.8	.001
Color-Word Interference Test, inhibition and inhibition/switching combined	32.4	10.8	.001
Tower Test, total achievement score	18.9	13.5	.372

Table 4a
Demographic and clinical functioning, statified by impairment in Executive Functioning.

	ADHD with EFD(N=18)		ADHD without EFD (N=56)		Control with EFD (N=8)		Control without EFD (N=
	M/%	SD	M/%	SD	M/%	SD	M/%	SD
Age, years	38.2(M)	10.1	32.7(M)	9.2	26.3(M)	5.6	29.2(M)	6.9
Males	44.4(%)		46.4(%)		25.0(%)		43.9(%)	
Education, years	11.3(M)	1.5	13.0(M)	2.5	13.6(M)	2.3	15.3(M)	2.6
In work	6.7(%)		52.1(%)		100(%)		85.4(%)	
Total IQ	99.0(M)	11.8	113.3(M)	11.5	109.6(M)	10.0	116.5(M)	9.0
WURS, mean score	66.1(M)	19.7	53.3(M)	16.0	20.9(M)	14.9	16.5(M)	10.8
ASRS, mean score	51.7(M)	7.1	48.4(M)	9.4	23.5(M)	5.7	21.7(M)	8.6
*Prescribed medication (central stimulantia or other medication for ADHD)	61.5(%)		73.5(%)					
ADHD diagnosis received in childhood	0.0(%)		12.7(%)		0(%)		0(%)	
Lifetime difficulties with reading and writing	66.7(%)		33.9(%)		50.0(%)		4.5(%)	
Lifetime problems with alcohol	22.2(%)		17.9(%)		0(%)		0(%)	
Lifetime problems with other drugs	22.2(%)		23.6(%)		0(%)		1.5(%)	
Lifetime depression/anxiety	61.1(%)		58.9(%)		12.5(%)		12.1(%)	
Lifetime bipolar disorder	5.6(%)		3.6(%)		0(%)		0(%)	

*all participants were asked not to take medication for ADHD the day of testing

Table 4b
Demographic and clinical functioning, statified by impairment in Executive Functioning. Comparison between different groups

Group comparisons	ADHD with EFD ADHD without EFD	ADHD with EFD Control with EFD	ADHD with EFD Control without EFD	ADHD without EFD Control with EFD	ADHD without EFD Control without EFD	Control with EFD Control without EFD
	P	P	P	P	P	P
Age, years	ns	p<0.01	p<0.001	ns	ns	ns
Males	ns	ns	ns	ns	ns	ns
Education, years	ns	ns	p<0.001	ns	p<0.001	ns
In work	p<0.05	p<0.05	p<0.05	ns	p<0.05	ns
Total IQ	p<0.001	ns	p<0.001	ns	ns	ns
WURS, mean score	p<0.05	p<0.001	p<0.001	p<0.001	p<0.001	ns
ASRS, mean score	ns	p<0.001	p<0.001	p<0.001	p<0.001	ns
*Prescribed medication (central stimulantia or other medication for ADHD)	ns	ns	ns	ns	ns	ns
ADHD diagnosis received in childhood	ns	ns	ns	ns	p<0.05	ns
Lifetime difficulties with reading and writing	p<0.05	ns	p<0.05	ns	p<0.05	p<0.05
Lifetime problems with alcohol	ns	ns	p<0.05	ns	p<0.05	ns
Lifetime problems with other drugs	ns	ns	p<0.05	ns	p<0.05	ns
Lifetime depression/anxiety	ns	p<0.05	p<0.05	p<0.05	p<0.05	ns
Lifetime bipolar disorder	ns	ns	ns	ns	ns	ns