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The three-year outcome of emotional symptoms in clinically referred youth with ADHD and their relationship to neuropsychological functions

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Abstract

Background: Further knowledge is needed regarding long-term outcome of emotional symptoms, and the interplay between these symptoms and neuropsychological functioning in youth with attention deficit hyperactivity disorder (ADHD).
Objective: We aimed to explore the effect of performance-based neurocognitive functions and parent-rated behavioral executive functioning (EF) on self-rated and parent-rated internalizing symptoms longitudinally in clinically referred youth with ADHD (n = 137; mean age = 12.4 years). We also aimed to examine the change in self-rated emotional symptoms in the ADHD group and a Control group (n = 59; mean age = 11.9 years).
Method: At baseline, and three years later, parents completed rating scales of their child's ADHD symptoms (Swanson Nolan Pelham Scale, Version IV – SNAP-IV), emotional symptoms (Five To Fifteen Questionnaire, Strengths, and Difficulties Questionnaire), and EF (Behavior Rating Inventory of Executive Function). At the same time, the child completed self-report measures of Anxiety, Depression, and Anger Inventories (the Beck Youth Inventories) and neurocognitive measures (Conner's Continuous Performance Test, Version II (CPT-II), Working Memory and Processing Speed composites (Wechsler Intelligence Scales). Statistical analyses were linear and logistic mixed models.
Results: Using longitudinal data, parent- and self-ratings of emotional symptoms were associated with parent-ratings of EF behavior in youth with ADHD. Plan/organizing deficits were associated with Anxiety and Anger over and above other metacognitive subscales, while Emotional Control was related to Anger over and above other behavior regulation subscales. In the ADHD group, Anger symptoms improved across measuring points. When controlling for age, Anxiety, and Depression symptoms were largely stable in both groups, however at higher levels in the ADHD group. The differences in anxiety and depression symptoms across groups decreased over time.
Conclusions: The current study emphasizes the importance of identification, monitoring, and treatment of emotional symptoms, and behavioral aspects of EF in youth with ADHD.

Keywords: ADHD; emotional symptoms; follow-up; executive functioning; youth

Introduction

Emotional difficulties, most commonly irritability as a dispositional mood state (and anger as the emotion), depression, and anxiety, are common in individuals with Attention Deficit Hyperactivity Disorder (ADHD) (1, 2). These findings have led some to conclude that emotional impulsivity and/or poor emotion regulation may be core features of ADHD that help to explain the persistence of ADHD and its impact on overall functioning (3-5). Of course, irritability and other emotional difficulties are common to a wide range of disorders and may be common comorbidities rather than core features of ADHD (6). Setting aside the diagnostic issues, the course and outcome of emotional difficulties in individuals with ADHD, and whether the core features of ADHD impact their trajectory, remain understudied and poorly understood (1,2).

Two longitudinal studies of youth treated for ADHD report conflicting evidence for the stability of emotional problems, with these difficulties either remaining stable or improving (7, 8). Recent prospective studies have found that higher levels of irritability are associated with an increased risk of

depression in youth with ADHD (9). However, a longitudinal study found that only persistent irritability was significantly associated with the presence of concurrent depressive symptoms (10).

The relationship between executive functioning and emotional symptoms in ADHD

In cognitive models of ADHD, the core features of attention problems and impulsivity, are viewed as evidence of impaired executive functioning (EF) (11-13). In studies of individuals with ADHD, EF is often measured using rating scales, completed by parents, teachers, or the individual, and by performance-based tests. In partial support of the cognitive model, differences between ADHD and normal controls on the performance-based tests tend to fall into the small to moderate effect size range (11-13). These tests appear to capture the primarily cognitive aspects of EF and to identify those with scholastic difficulties (14-17). EF rating scales like the Behavior Rating Inventory of Executive Function (BRIEF)(18) are designed to measure behaviors reflecting EF in everyday (ecologically valid) settings (e.g., organizing materials; remembering information necessary to task completion; planning, initiating, shifting, and completing tasks; self-monitoring and problem-solving; emotional control). While scores on EF rating scales tend to correlate weakly with performance-based EF tests and have been challenged on their construct validity (16), scores on the BRIEF have been shown to differentiate youth with ADHD from typically developing controls in several studies (14, 17, 19-21)

While impairments in EF are argued to underpin the core features of ADHD, they are also associated with an increased risk for a wide range of disorders, including depression and anxiety, and what has been termed a general psychopathology factor (a person's liability to mental disorders generally) (22). Thus, it is possible that the increased prevalence of emotional difficulties in youth with ADHD are related to the severity of EF impairments. The few available studies exploring these relationships have yielded conflicting results. A recent study found that weak working memory, a component of EF, mediated increased negative affect and suicidal ideation, after controlling for symptoms of oppositional defiant disorder, in youth with ADHD (23). Two longitudinal studies found no significant association between performance-based neurocognitive functioning and depression (24, 25), while others have reported improved EF in ADHD youths with elevated symptoms of depression (26) or anxiety (27, 28). One meta-regression study found better response inhibition in medication-naive children with ADHD and comorbid anxiety than children with ADHD and no anxiety, with comorbid anxiety being unrelated to attention or working memory in clinically referred youth with ADHD (29). In respect of EF rating scales, studies have found that youth with ADHD and comorbid anxiety score higher than those with ADHD and no anxiety (20, 30-31). One study found that self-rated EF impairments were associated with higher levels of depression in adults with ADHD (32).

Aims

To date, no overarching theory has been put forward to explain the relationship between ADHD symptoms, executive functioning, and emotional difficulties in youth, including variables that might moderate or mediate these relationships. Most studies have examined these relationships in a pairwise and cross-sectional fashion. Even in that respect, executive functioning has received insufficient attention in relation to its association with emotional difficulties in youth with ADHD. The current study has two primary aims. First, we explored whether there may be any relationship between (1) emotional symptoms and parent-rated executive functioning, (2) emotional symptoms and neurocognitive functioning, and (3) emotional symptoms and ADHD symptoms, when using longitudinal data in clinically referred youth with a primary diagnosis of ADHD. Second, we explored the three-year course of self-rated emotional difficulties in the same youth with ADHD and additionally in a Control group of the same age. EF and neurocognitive impairments were indexed by the young person's performance on a computerized test of neurocognitive functioning, Wechsler Working Memory, and Processing Speed Indexes, and scores on a parent-completed EF rating scale. Emotional difficulties were indexed by parent ratings on a global measure of internalizing difficulties and the young person's scores on self-report measures of anger (as an emotion not as a behavior), depression and anxiety. Self-reported anger was chosen because, as measured by the scale, incorporates the dispositional mood state of irritability or distress tolerance.

Method

Participants

Participants with ADHD n = 137 (males = 96, females = 41), mean age = 12.4 years (SD = 3.1; range = 6.7–17.9) were recruited from consecutive diagnostic assessments at the Neuropsychiatric Unit of the Child and Adolescent Psychiatry (CAP) Clinic in Lund, Sweden. Controls n = 59 (male = 31, female = 28) were similarly aged (mean age = 12.0 years; SD = 2.2; range = 8.8–14.9) youths recruited from schools in the same region as the CAP. The study group has been described previously (33). The inclusion criteria for this longitudinal study were a

diagnosis of ADHD based on the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition (DSM-IV) (34). Written informed consent was obtained from participants ≥ 15 years old and parents of all participants. This study was approved by the Research Ethics Committee at Lund University, Lund, Sweden (Reg. No. 2012/88) and registered in ClinicalTrials.gov Protocol Registration and Result System (ID: NCT04201509, protocol ID: 2012/88).

Measures

Self-rated emotional symptoms

Self-rated emotional symptoms at baseline and follow-up were assessed via the Anxiety, Depression, and Anger Inventories of a Swedish-language (validated) version of the Beck Youth Inventories (BYI) (35, 36). The BYI also screens for disruptive behaviors and self-concept and was designed for use with youth aged 9-18-years. Each subscale contains 20 items, presented as brief self-statements that are rated on a four-point frequency scale (0 = never, 1 = sometimes, 2 = often, 3 = always). The Anxiety Inventory indicates specific worries about school performance, the future, negative reactions of others, fears, and physiological symptoms. The Depression Inventory includes items related to negative thoughts about self, life, and the future, feelings of sadness and guilt, and sleep disturbance. The Anger Inventory measures the child's personal experience of feelings and thoughts related to anger comprising negative thoughts about others, and physical arousal. Raw scores are standardized according to sex based on a Swedish reference sample (n = 2358). Higher T scores on all subscales indicate greater levels of impairment. The subscales of the BYI have been found to have good psychometric properties including high internal consistency reliability (.89–.94) (36) construct validity, and clinical utility (37).

Parent-rated emotional symptoms

Parent-Rated Emotional Symptoms at baseline were assessed using the Internalizing subscale (90th percentile cut-off) from the Five to Fifteen (FTF) scale (38). The FTF is a Nordic parent- and teacher-completed screen for development-related impairments and behavioral problems in children and adolescents and consists of 181 items rated on a three-point scale (0 = Does not apply, 1 = Applies sometimes/to some extent, and 2 = Applies). Only the internalizing subscale from the FTF is reported in this study, with the items assessing the child's self-esteem, depressive symptoms, nervousness, anxiety, self-harm behaviors, and psychosomatic manifestations of internalizing symptoms. The Internalizing scale has been found to have adequate good psychometric properties and to compare favorably to the internalizing scale of the Child Behavior Check List (CBCL) (39, 40).

Parent-Rated Emotional Symptoms at follow-up were assessed with the Emotional Symptoms subscale (90th percentile cut-off) of the Strengths and Difficulties Questionnaire (SDQ) (41). The SDQ was developed for general mental health screening in 3-17-year-olds in Great Britain and is available in child, parent, and teacher report versions. The first part of the SDQ consists of 25 questions grouped into five subscales. We used a Swedish version of the SDQ, validated in a Swedish child population (42), however with normative school-age SDQ data from Britain norms (43). The SDQ has good psychometric properties, including evidence of concurrent validity between the Total and Emotional Symptoms subscales of the SDQ and CBCL (44).

Parent-rated executive functioning

Parents rated the everyday behavioral manifestations of EF at baseline and follow-up using the Behavior Rating Inventory of Executive Function (BRIEF) (18). The BRIEF is an 86-item rating scale measuring everyday behaviors associated with EF in children aged 5–18 years, hereafter referred to as parent-rated EF. At follow-up, some participants were more than 18 years old, and their parents completed the 75-item BRIEF-Adult version (BRIEF-A) (45). Individual items are rated on a 3-point frequency scale (1 = never, 2 = sometimes, 3 = often), yielding an overall general executive composite (GEC) and two index scores, each of which is based on several subscales: the Behavior Regulation Index (BRI) consisting of the Inhibit, Shift, Emotional Control, and Monitor subscales; and the Metacognitive Index (MI) consisting of the Initiate, Working Memory, Plan/Organize, and Organization of Materials subscales. Metacognition refers to processes that supply the regulation of cognition (46). Raw scores are converted to age- and sex-specific T scores with a mean of 50 (standard deviation (SD) = 10), based on the American (USA) national standardization sample (N = 1,419; 815 girls, 604 boys, aged 5–18 years). Higher T scores indicate greater levels of impairment in EF. In the current study, we used a Swedish translation of the BRIEF subscales (translated and back-translated) (47), and normative data from the American standardization (18). The BRIEF has good psychometric support for the composite- and index scores including high internal consistency (.89–.98) and test-retest reliability (.76–.91) (18).

Parent-rated ADHD symptoms

Parent-rated ADHD symptoms at baseline were assessed using the Swanson-Nolan-Pelham Scale

(SNAP-IV) in both groups, while just the parents of the ADHD group completed the SNAP-IV at the follow-up (48, 49). The SNAP-IV is a DSM-IV-based ADHD rating scale in a parent and teacher report format consisting of 26 items rated on a 4-point scale (0 = not at all, 1 = just a little, 2 = quite a bit, 3 = very much). The SNAP-IV consists of three subscales: inattention symptoms (nine items), hyperactivity/impulsivity symptoms (nine items), and all items together yielding an "ADHD-combined score". The internal reliability coefficient for these three subscales is in the acceptable range (Cronbach alpha = .90, .79, and .89, respectively) (48, 49). We used a Swedish translation of the SNAP-IV, i.e., the DSM-IV ADHD symptoms (34). We analyzed continuous values, raw scores, of inattention symptoms, hyperactivity/impulsivity symptoms, and ADHD-combined score

Performance-based tests of neurocognitive functioning

The youth completed the second version of the Conners' Continuous Performance Test (CPT-II) at baseline and follow-up (50). The CPT-II is a non-verbal computerized, visual task of attention, vigilance, and response inhibition for individuals aged 6 years and above. The CPT-II yields an overall index, the Confidence Index, indicating the percentage degree of fit to the profile of clinical attention problems based on twelve performance measures. The Confidence Index and four subscales are used in this study: Omissions; Commissions; Hit Reaction Time (RT) (mean); and Hit RT Standard Error (SE). Raw scores are converted to age- and sex-specific T scores with a mean of 50 (SD = 10). Normative data (USA) was based on a standardization sample including 1,920 healthy individuals from the general population and 378 individuals with ADHD was used in the current study (50, 51). Psychometric support for the individual measures is provided in the manual: the subscales of the current study: split-half reliability (.65−.95); 3-month test-retest reliability coefficients (.55−.84) (50).

In addition to the CPT-II, at baseline and follow-up, depending upon age, the majority of participants completed the Working Memory and Processing Speed composites from the Swedish versions of Wechsler Intelligence Scales for Children, Fourth Edition (WISC-IV) (British data was compared with normative data from a Swedish population) (52) or youths 16 years and above, the Wechsler Adult Intelligence Scales, Fourth Edition (WAIS-IV) (Swedish normative data) (53). All composite scores are standardized according to age, with a mean of 100 (SD =15) (54, 55).

Procedure

Baseline assessments

Diagnosis of ADHD was based on the DSM-IV criteria (56) using information from multiple sources, including: a comprehensive psychiatric interview by a child and adolescent psychiatrist with the child and his or her parents; semi-structured telephone interviews with the child's teachers; parent-rated SNAP-IV, FTF, and BRIEF questionnaires; and the child-completed CPT-II and the BYI administered by a clinical psychologist. For most ADHD participants, the Wechsler Intelligence Scales were administered by the referring school psychologists prior to the child's assessment at the CAP clinic. The Control group completed the BYI at their schools. Their parents completed the SNAP-IV and answered some questions about their education level when they consented to participate in the study. Figure 1 presents descriptive information including the number of participants who completed each of the measures. All participants were medicine-naïve at the baseline assessment.

Follow-up assessments and attrition

After the child was assessed and diagnosed with ADHD at baseline, parents attended a psychoeducation program for parents of youths with ADHD, and most of the ADHD participants were started on an approved stimulant medication (81%). In Sweden, the most prescribed drug for childhood ADHD is methylphenidate with a modified (prolonged) release with a small minority prescribed atomoxetine, lisdexamphetamine, or guanfacine, including the time of this study (57). Approximately three years after the baseline assessment, participants in the ADHD and Control groups were invited for reassessment. The ADHD group completed a range of measures, and the Control group completed the BYI. Figure 1 shows how many participants completed the various measures at follow-up. Similar to previous studies (58-61) all ADHD participants were asked to stop any ADHD medication use 24 hours prior to the follow-up assessment and then asked about their current use of ADHD medications (yes/no) during the follow-up interview. For patients taking central stimulants, most of the drug has been eliminated from the body after 24 hours. Small quantities are still detectable up to 48 hours but are not considered to be of clinical importance (57). In terms of attrition, 111 of the 137 (81%) of the ADHD group, and 52 of the 59 (88%) of the Control group, attended the follow-up assessment.

Statistical analyses

Group comparisons for attrition were analyzed with Student's t-test and chi-square test using version 25 of SPSS (IBM Corp., Armonk, NY, USA). Mixed

model regression analyses were carried out using version 9.4 of SAS (SAS Institute Inc., Cary, NC, USA). All analyses were checked for collinearity and the effect of outliers. The current study is an exploratory prospective observational study and we used linear mixed models to find possible associations, however not aiming to establish causal relationships. As such, we did not correct for multiple analyses so as not to miss associations that could be tested with targeted hypotheses in future studies (62). For all analyses alpha < .05 was used. Unstandardized values of b in linear mixed models and odds ratio (OR) in logistic mixed models, as well as 95% corresponding confidence interval (CI), are presented.

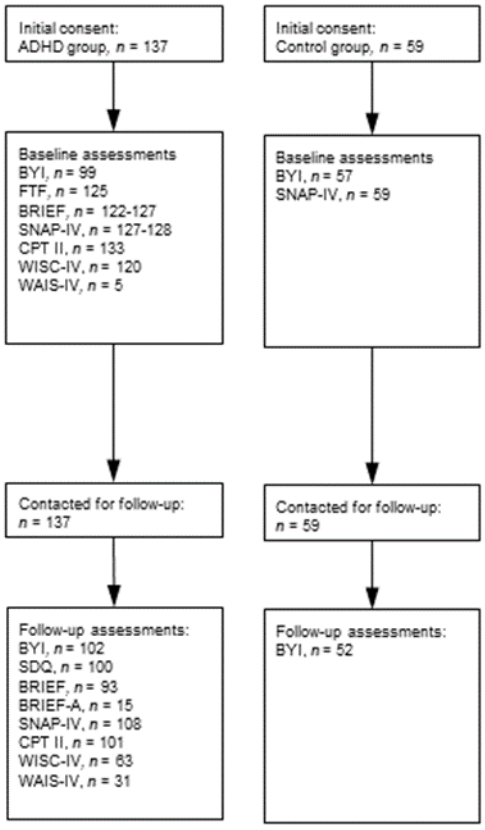

FIGURE 1. Flow-chart.

ADHD: Attention Deficit Hyperactivity Disorder. BYI: Beck Youth inventories. BRIEF-A: Behavior rating of executive function. A: Adult informant form. CPT-II: Conners' continuous performance test II. FTF: Five To Fifteen. SNAP-IV: Swanson-Nolan-Pelham scale, version IV. SDQ: Strenghts and Difficulties questionnaire. WISC-IV: Wechsler intelligence scales for children, fourth version. WAIS-IV: Wechsler Adult Intelligence scales, fourth version. The number of observations varied due to partial attrition. 22 children were too young to complete the BYI at baseline.

The independent variables

The independent variables measured at baseline and follow-up were: (1) parent-rated ADHD symptoms assessed using the SNAP-IV (unstandardized summary scores); (2) parent-rated EF assessed via the composites (BRI and MI) and subscales (Inhibit, Shift, Emotional Control, and Monitor subscales, Initiate, Working Memory, Plan/Organize, Organization of Materials) of the BRIEF (in sex- and age standardized T scores); and (3) performance-based tests of neurocognitive functioning measured in two ways: (a) the Confidence Index (percentage fit to clinical attention deficit profile), Omissions, Commissions, Hit RT (mean), and Hit RT SE subscales of the CPT II (sex- and age standardized T scores); and (b) the Working Memory and Processing Speed composites (age standardized intelligence quotient scores) from the age-relevant Wechsler Intelligence Scale.

The dependent variables

The dependent variables were (1) self-rated Anxiety, Depression, and Anger, assessed via the Inventories of the BYI at baseline and follow-up; and (2) a dichotomous variable termed "Parent-Rated Internalizing Symptoms" measured with the internalizing symptoms subscales of the FTF at baseline and the SDQ at follow-up. For both the FTF and SDQ internalizing symptom scales, a 90th percentile cut-off (based on sex- and age normative data) was used (0 = below cut-off; 1 = above cut-off).

The controlling variables

All analyses were controlled for age, ADHD medication status (yes/no), and parents' education level. Since we used measures standardized for sex, we did not control for sex.

Analyzing whether EF, neurocognitive functions, and ADHD symptoms had a significant effect on emotional symptoms

Linear mixed models were used to analyze whether measurements of parent-rated EF behavior and performance-based neurocognitive functioning and ADHD symptoms (parent-rated), measured at baseline and follow-up, had any significant effect on self-ratings of emotional symptoms, measured at baseline and follow-up. The linear mixed models minimized the effects of attrition by including all non-missing observations from both the baseline and follow-up assessments, i.e., baseline data were included in the models and affected the results even though there were no follow-up data in some cases. A random intercept model was used to account for within-subject variation over time. The possible relationships between each dependent variable, as indexed by self-ratings of the Anxiety, Depression, and Anger Inventories from the BYI were performed in two steps:

1. Unadjusted (crude), analyses of the possible relationships between each dependent variable and each independent variable. The independent variables were the composite scores of the measures: parent ratings of EF (BRI and MI scores from the BRIEF); performance-based tests of neurocognitive functioning (Confidence Index from the CPT-II; Working Memory and Processing Speed scores from the relevant Wechsler test); and parent-ratings of ADHD symptoms (ADHD-combined scores from the SNAP-IV). Composite scores with $p < .05$ were further analyzed.

2. The effect of the subscales of each composite score, with $p < .05$, on the dependent variables (self-rated Anxiety, Depression, Anger) were analyzed in four possible models. The independent variables in Model 1 were scores on the Inhibition, Shift, Emotional Control, and Monitor subscales of the BRI from the parent-rated BRIEF. The independent variables in Model 2 were scores on the Initiate, Working Memory, Plan/Organize, and Organization of Materials subscales from the MI from the parent-rated BRIEF. The independent variables in Model 3 were scores on the Omissions, Commissions, Hit RT (mean), and Hit RT SE subscales of the CPT-II, and the Working Memory and Processing Speed of the Wechsler Intelligence Scales. The independent variables in Model 4 were parent-rated scores on the Inattention and Hyperactivity/Impulsivity subscales from the SNAP-IV.

Logistic mixed models were used to analyze whether measurements of EF, neurocognitive functions, and ADHD symptoms, at baseline and follow-up, had any significant effect on parent-ratings of emotional symptoms. The analyses were conducted with the same independent variables in the same two steps, as described above for the linear mixed models.

Changes in self-rated emotional symptoms over time

Linear mixed models with an autoregressive covariance structure were used to evaluate change over time in self-rated emotional symptoms in the ADHD and Control Groups. An autoregressive covariance matrix structure is used to fit a model when the time between assessments is equal for all subjects, and the resulting parameter estimates assume that the variances in scores are constant across all measurement times. When an autoregressive covariance matrix is used to fit a model, there is generally no need to fit a random intercept. To estimate the effect in both groups using the same model, an interaction term between group and time was included.

Sensitivity analyses

If there were discrepancies between the significant results and results adjusted for controlling variables, we performed an unadjusted analysis with the same number of observations as the adjusted analysis.

Results

Sociodemographic characteristics, attrition, and clinical data

Of the 137 participants in the ADHD group at baseline, 96 (70%) were boys compared to 31 of 59 (52%) in the Control group ($\chi2(1) = 5.56$, $p = .018$). The sex ratio at follow-up was similar ($p = .017$). The two groups did not differ for mean age at baseline or follow-up (baseline: ADHD:12.36 (SD = 3.11), Controls:11.97 (SD = 2.15) ($p = .315$); follow-up: ADHD:15.23 (SD = 3.02); Controls:14.80 (SD = 2.03) ($p = .280$). The two groups did not differ ($\chi2(2) = 5.38$, $p = .08$) for parents' education level at baseline: Primary school only (to age 16): ADHD: 11%, Controls: 4%; High school only (age 16-19 years): ADHD: 46%, Controls: 35%; University or above: ADHD: 43%, Controls: 61%.

The two groups did not significantly differ ($p = .222$) in the proportion who completed both baseline and follow-up assessments: ADHD: 111/137 (81.0%); Controls 52/59 (88.1%). Within the ADHD group, participants who completed the follow-up had more severe parent-rated inattention symptoms than those lost to follow-up (SNAP-IV, mean difference (Mdiff) = 2.36; $t(126) = 2.09$, 95% confidence interval [CI] [0.13, 4.60], $p = .038$), and EF difficulties (BRIEF MI, Mdiff = 4.60; $t(123) = 2,15$, 95% CI [0.36, 8.35], $p = 0.034$). Twenty-two participants younger than 9 years old and another 16 children did not complete the BYI at the baseline assessment. Within the two groups, no significant differences were observed between completers and non-completers of the follow-up assessment for baseline scores in the following measures: 1) ADHD group: SNAP-IV Hyperactivity impulsivity symptoms ($p = .358$), BRIEF BRI ($p = .413$), BYI Anxiety ($p = .457$), BYI Depression ($p = .277$), BYI Anger ($p = .423$), CPT-II ($p = .662$ - $.741$), Working Memory ($p = .438$) and Processing Speed subscales ($p = .638$); 2) Control group: BYI Anxiety ($p = .460$), BYI Depression ($p = .545$), BYI Anger ($p = .224.662$ - $.741$), CPT-II ($p = .107$ - 805), Working Memory ($p = .191$), and Processing Speed subscales ($p = .110$). Table 1 presents descriptive clinical data for continuous values of the measures. The number of children in the ADHD group with parent-rated emotional symptoms ≥ 90th normative cut off at baseline was 58/125 (FTF), and at follow-up was 12/100 (SDQ).

TABLE 1. Mean values at baseline and follow-up, and standard deviations for the SNAP-IV, BRIEF, Conners' CPT-II, and Wechsler Intelligence Scales at baseline and follow-up.

	ADHD group						Control group					
	Baseline scores			Follow-up scores			Baseline scores			Follow-up scores		
Measures	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*	*Mean*	*SD*
BYI												
Anxiety	99	58.31	11.35	102	57.18	9.83	57	48.10	8.36	52	52.82	9.89
Depression	99	57.16	10.60	102	55.57	9.75	57	47.30	8.73	52	51.02	9.00
Anger	99	58.69	11.16	102	56.51	10.65	57	48.78	8.26	52	47.35	7.65
SNAP-IV												
ADHD-combined	127	30.54	10.25	108	24.31	10.94						
Inattention	128	18.04	5.05	108	15.11	6.30						
Hyperactivity/Imp	127	12.40	13.14	108	9.20	6.23						
BRIEF BRI	127	66.72	13.67	108	63.94	12.61						
Inhibition	127	65.66	13.09	108	61.44	12.43						
Flexibility	128	63.76	14.58	108	64.65	13.43						
Emotional Control	128	63.48	12.92	108	60.92	13.11						
Monitor	125	65.18	9.68	107	62.41	11.17						
BRIEF MI	125	68.65	9.09	108	65.75	10.71						
Initiate	128	65.23	9.50	108	64.48	10.72						
Working Memory	128	71.01	9.87	108	67.35	11.83						
Plan/Organize	122	67.98	10.00	106	64.96	11.38						
Organize Materials	128	58.34	10.57	108	58.05	10.68						
CPT-II												
Confidence Index	133	63.01	20.00	101	55.31	20.46						
CPT Omissions	133	58.08	15.36	101	53.16	15.62						
CPT Commissions	133	53.60	9.06	101	55.70	12.46						
CPT RT (mean)	133	53.42	12.54	101	52.62	10.88						
CPT RT (SE)	133	58.15	10.49	101	54.47	12.15						
Wechsler												
Working Memory	125	82.03	12.95	94	85.71	11.70						
Processing Speed	124	88.69	13.59	94	89.27	14.84						

ADHD: attention deficit hyperactivity disorder. BRI: behavioral regulation index. BRIEF: Behavior Rating Inventory of Executive Function. BYI: Beck Youth Inventories. CPT: continuous performance test. Hyperactivity/Imp: Hyperactivity/Impulsivity. MI: metacognition index. RT: reaction time. SE: standard error. SNAP-IV: Swanson-Nolan-Pelham scale, fourth edition.

The number of observations in the ADHD group varied due to partial attrition. 22 children in the ADHD group were too young to complete the BYI at baseline. The BYI was sex standardized in T scores (m = 50; SD = 10). The CPT II and BRIEF were age- and sex-standardized in T scores. Parent-rated SNAP-IV was measured as a summary scores. Higher scores indicate greater impairment in all measures except Wechsler Working Memory and Processing Speed (measured in age standardized IQ scores, m = 100, SD = 15).

The effect of EF, neurocognitive functions, and ADHD symptoms on self-rated emotional symptoms

Table 2 presents the results of the linear mixed models examining the effects of EF, neurocognitive functions, and ADHD symptoms on self-rated emotional symptoms (BYI Anxiety, Depression, and Anger). All analyses were adjusted for the controlling variables age, ADHD medication status (yes/no),

TABLE 2. TABLE 2. Estimates (*b*), 95% confidence intervals, and p-values for the effect of parent-rated EF and performance based neurocognitive tests and ADHD symptoms (measured at baseline and follow-up) on self-rated anxiety, depression and anger inventories at baseline and follow-up in the ADHD group.

Dependent variable	Crude/Models	Independent variable	*n*	*b*	95 % CI	*p*
Anxiety	Crude	BRIEF BRI	193	0.09	−0.07, 0.25	.131
	Crude	**BRIEF MI**	**190**	**0.16**	**−0.02, 0.34**	**.031**
	Crude	CPT-II Confidence Index	195	−0.001	−0.09, 0.09	.973
	Crude	Processing speed	181	0.05	−0.09, 0.19	.382
	Crude	Working Memory	182	−0.02	−0.18, 0.14	.752
	Crude	SNAP-IV ADHD-Combined	192	0.10	−0.06, 0.26	.113
	Model BRIEF MI	Initiate	188	0.10	−0.10, 0.29	.328
		Working Memory		−0.16	−0.34, 0.02	.074
		Plan/Organize		**0.30**	0.11, 0.50	**.003**
		Organization of materials		−0.14	−0.30, 0.02	.075
Depression	Crude	BRIEF BRI	193	0.09	−0.05, 0.23	.118
	Crude	**BRIEF MI**	**190**	**0.23**	**0.05, 0.41**	**.001**
	Crude	CPT-II Confidence Index	195	0.02	−0.05, 0.11	.632
	Crude	Processing Speed	181	0.04	−0.09, 0.17	.426
	Crude	Working Memory	182	−0.08	−0.24, 0.08	.154
	Crude	**SNAP-IV ADHD-Combined**	**192**	**0.16**	**0.02, 0.30**	**.007**
	Model SNAP-IV	**Inattention**	**192**	**0.48**	0.23, 0.73	**< .001**
		Hyperactivity/Impulsivity		−0.10	−0.33, 0.13	.389
	Model BRIEF MI	Initiate	188	0.09	−0.10, 0.28	.351
		Working Memory		0.01	−0.17, 0.19	.895
		Plan/Organize		0.18	−0.01, 0.38	.066
		Organization of Materials		−0.06	−0.21, 0.10	.445
Anger	Crude	**BRIEF BRI**	**193**	**0.27**	**0.13, 0.41**	**< .001**
	Crude	**BRIEF MI**	**190**	**0.28**	**0.08, 0.48**	**< .001**
	Crude	**CPT-II Confidence Index**	**195**	**0.07**	**−0.02, 0.16**	**.049**
	Crude	Wechsler Processing Speed	181	0.01	−0.15, 0.17	.854
	Crude	Wechsler Working Memory	182	−0.12	−0.29, 0.05	.050
	Crude	**SNAP-IV ADHD-Combined**	**192**	**0.28**	**0.12, 0.44**	**< .001**
	Model BRIEF BRI	Inhibition	190	0.13	−0.24, 0.18	.114
		Emotional Control		**0.23**	−0.16, 0.22	**.008**
		Flexibility		−0.10	0.03, 0.45	.176
		Monitor		0.06	−0.19, 0.14	.491
	Model BRIEF MI	Initiate	188	−0.03	−0.03, 0.29	.760
		Working Memory		0.03	0.06, 0.40	.779
		Plan/Organize		**0.24**	**−0.26, 0.05**	**.027**
		Organization of Materials		−0.02	−0.11, 0.22	.765
	Model performance-based EF	**CPT-II Omission**	**177**	**0.16**	**0.02, 0.31**	**.022**
		CPT-II Commission		−0.01	−0.20, 0.19	.993
		CPT-II RT (mean)		0.01	−0.21, 0.22	.978
		CPT-II RT SE		0.01	−0.22, 0.23	.939
		Wechsler Processing speed		0.08	−0.05, 0.20	.237
		Wechsler Working memory		−0.10	−0.23, 0.04	.158
	Model SNAP-IV	Inattention	192	0.27	−0.01, 0.55	.061
		Hyperactivity/Impulsivity		**0.30**	**0.05, 0.55**	**.018**

ADHD: attention deficit hyperactivity disorder. b: unstandardized estimate. BRI: behavioral regulation index. BRIEF: Behavior Rating Inventory of Executive Function. CPT: continuous performance test. MI: metacognition index. RT: reaction time. SE: standard error. SNAP-IV: Swanson-Nolan-Pelham scale, fourth edition.

The number of observations in the ADHD group varied due to partial attrition. The Anxiety Inventory (of the Beck Youth Inventories) was sex standardized in T scores (m = 50; SD = 10). The CPT II and BRIEF were age- and sex-standardized in T scores. Parent-rated SNAP-IV was measured as a summary score. Higher scores indicate greater impairment in all measures except Wechsler working memory and processing speed (measured in age standardized IQ scores, m = 100, SD = 15). Significant results in bold text.

and parents' education level. Significant results ($p < .05$) are reported.

There was a significant relationship between Anxiety and parent-rated EF (BRIEF MI) in unadjusted analyses, that did not remain significant in the adjusted analysis ($p = .238$). In the second step, Anxiety was significantly associated with Plan/Organize, in the model including all the MI subscales from the BRIEF. In relation to Depression, in the first step, there was a significant association with BRIEF MI and SNAP-IV ADHD-combined scores. In the second step, Depression was significantly associated with SNAP-IV Inattention symptoms in the model with the Inattention and Hyperactivity/Impulsivity subscales. In relation to Anger, in the first step, there were significant associations with the BRI and MI indexes from the BRIEF, and with the ADHD-Combined scores from the SNAP-IV. Anger was significantly associated with Conners' CPT II Confidence Index in the

TABLE 3. Odds ratios, 95% confidence intervals and p-palues for the effect of parent-rated EF and performance-based neurocognitive Tests and ADHD symptoms on parent-rated internalizing symptoms at baseline and follow-up.

Crude/Model	Independent Variables	n	OR [95% CI]	*p*
Crude	**BRIEF BRI**	**215**	**1.08 [1.04, 1.12]**	**< .001**
Crude	**BRIEF MI**	**213**	**1.10 [1.04, 1.15]**	**< .001**
Crude	CPT-II Confidence Index	212	1.01 [1.00, 1.02]	.109
Crude	Wechsler Processing Speed	197	1.00 [0.97, 1.03]	.887
Crude	**Wechsler Working Memory**	**197**	**0.96 [0.93, 0.99]**	**.008**
Crude	**SNAP-IV ADHD-Combined**	**218**	**1.08 [1.03, 1.13]**	**< .001**
Model SNAP-IV	**Inattention**	**218**	**1.09 [1.02, 1.16]**	**.010**
	Hyperactivity/Impulsivity		1.07 [1.02, 1.12]	**.008**
Model BRIEF BRI	Inhibition	211	0.98 [0.95, 1.02]	.367
	Emotional Control		**1.05 [1.01, 1.09]**	**.011**
	Flexibility		1.02 [0.99, 1.06]	.212
	Monitor		**1.05 [1.01, 1.10]**	**.026**
Model BRIEF MI	**Initiate**	209	**1.05 [1.01, 1.10]**	**.020**
	Working Memory		1.00 [0.96, 1.05]	.917
	Plan/Organize		1.04 [0.99, 1.09]	.088
	Organization of Materials		1.02 [0.98, 1.05]	.422
Model performance-based EF	CPT-II Omission	193	1.00 [0.97, 1.03]	.840
	CPT-II Commission		1.00 [0.96, 1.04]	.873
	CPT-II RT (mean)		0.97 [0.93, 1.02]	.242
	CPT-II RT (SE)		1.05 [1.00, 1.11]	.063
	Wechsler Processing Speed		1.01 [0.99, 1.04]	.259
	Wechsler Working memory		**0.97 [0.94, 1.00]**	**.026**

ADHD = attention deficit hyperactivity disorder; OR = odds ratio; CI = confidence interval; SDQ = Strengths and Difficulties Questionnaire: BRIEF = Behavior Rating of Executive Function; BRI = Behavior Regulation Index; MI = Metacognitive Index; CPT-II = Conners' Continuous Performance Test; SNAP-IV = Swanson-Nolan-Pelham scale, Fourth Edition.

The number of observations in the ADHD group varied due to partial attrition. Parent-Rated Internalizing Symptoms were measured using the Five to Fifteen questionnaire at baseline and the Strengths and Difficulties Questionnaire at follow-up, with a 90th cut-off according to normative data. The CPT II and BRIEF were age- and sex-standardized in T scores. Parent-rated SNAP-IV was measured as a summary score. Higher scores indicate greater impairment in all measures except Wechsler working memory and processing speed (measured in age standardized IQ scores, m = 100, SD = 15). Significant results in bold text.

unadjusted analysis but not the adjusted analysis (p = .080). In the second step, the Plan/Organize subscale, was significantly associated with Anger in the model with all BRIEF MI subscales, and the Emotional Control subscale was significantly associated with Anger in the model with the BRI subscales. The CPT Omissions subscale was significantly associated with Anger in the model with performance-based subscales.

Table 3 presents the results of logistic mixed models, examining the effect of EF, neurocognitive functions, and ADHD symptoms on Odds Ratio for Parent-Rated Emotional Symptoms. All analyses were adjusted for the controlling variables age, ADHD medication status (yes/no), and parents' education level. Significant results (p < .05) are reported. The dependent variable was measured with the FTF Internalizing subscale at baseline and SDQ Emotional Disorder subscale at follow-up, both using the normative cut-offs ≥ 90th percentiles. In the first step, Parent-Rated Emotional Symptoms were significantly associated with BRI and MI scores from the BRIEF, and also with Wechsler Working Memory, and SNAP-IV ADHD-Combined scores in unadjusted analyses, but these associations did not remain significant in adjusted analyses (Working Memory, p = .082; SNAP ADHD Combined score, p = .087). In the second step, Parent-Rated Emotional Symptoms were significantly associated with SNAP-IV Inattention symptoms in a model with both SNAP-IV subscales, while Initiate, Emotional Control, Monitor, Working Memory, and Hyperactivity/Impulsivity symptoms were significantly associated with parent-rated Emotional symptoms in models, when we did not adjust for age, ADHD medication status (yes/no), and parents' education level. When doing so, these variables did not remain significant (Initiate, p = .146, Emotional Control, p = .177, Monitor, p = .152, Working Memory, p = 325, Hyperactivity/Impulsivity symptoms, p = .810).

Changes in self-rated emotional symptoms between baseline and follow-up

Table 4 presents the results of the linear mixed models examining the changes in self-rated, sex standardized, T scores for the BYI Anxiety, Depression, and Anger inventories between baseline and follow-up for the ADHD and Control group, and the slope differences across groups. All analyses were adjusted for the controlling variables age, ADHD medication status (yes/no), and parents' education level. Significant results (p < .05) are reported. Compared to Controls, the ADHD group reported significantly higher Anxiety, Depression, and Anger T scores at baseline (Anxiety Mdiff = 9.92 T scores, p < .001; Depression Mdiff = 9.69 T scores, p < .001; <; Anger Mdiff = 10.27, p < .001) and at follow-up (Anxiety Mdiff = 4.37 T scores, p < .010; Depression Mdiff = 4.24 T scores, p < .010; <; Anger Mdiff = 8.96, p < .001). Anger T scores significantly declined between baseline and follow-up in the ADHD group. Anxiety and Depression T scores increased significantly in the Control group in unadjusted analyses, but not in adjusted analyses, Anxiety (p = .242), Depression (p = .331). The slope of the changes between baseline and follow-up differed significantly across groups for Anxiety and Depression. There was a significant effect of age on Anxiety (b = 0.65 99% CI [0.02, 1.28], p = .008) and Depression (b = 0.78 99% CI [0.15, 1.41], p = .002).

TABLE 4. Estimates (*b*), 95% confidence intervals, and p-values for the effect of follow-up time, and belonging to the ADHD group on Anxiety, Depression, and Anger subscales of the Beck Youth Inventories in the ADHD and the Control group, and slope differences across groups.

Model	Independent variables	*b*	95% CI	*p*
Anxiety	Slope ADHD group	−*0*.30	−0.96, 0.35	.361
	Slope Control group	**1.55**	**0.63, 2.47**	**.001**
	Slope difference	**−1.85**	**−2.98, −0.72**	**0.002**
Depression	Slope ADHD group	−*0*.49	−1.11, 0.12	.112
	Slope Control group	**1.32**	**0.47, 2.17**	**.003**
	Slope difference	**−1.82**	**−2.86, −0.77**	**0.001**
Anger	**Slope ADHD group**	**−*0*.89**	**−1.54, −0.24**	**.008**
	Slope Control group	−*0*.46	−1.37, 0.46	.328
	Slope difference	−*0*.44	−1.56, 0.69	0.444

ADHD = attention deficit hyperactivity/impulsivity disorder; b = unstandardized estimate; CI = confidence interval. Significant results in bold text.

Discussion

In the present study, we examined whether parent-rated EF behavior, performance-based neurocognitive functioning, and ADHD symptoms were associated with parent-rated and self-rated emotional symptoms in clinically referred children with ADHD. We also investigated the change over three years in self-rated anxiety, depression, and anger symptoms in the ADHD group and a Control group of the same age, and the slope differences across the groups.

The current longitudinal study found significant associations between self- and parent-rated emotional symptoms and parent-rated EF, in line with findings from previous cross-sectional studies (30-32, 63). Self-rated anger, and parent-rated emotional symptoms were associated with parent-rated behavior regulation and the metacognitive aspects of EF, while self-rated depression was associated with just the metacognitive aspects of EF. Planning and organizing deficits were associated with self-rated anxiety and anger over and above other aspects of metacognitive functioning, while emotional control was related to self-rated anger over and above other aspects of behavior regulation in youth with ADHD. A cross-sectional association between planning/organizing deficits and self-rated anxiety has previously been reported in young people with ADHD (30). Previous studies using cross-sectional designs have found conflicting results concerning associations between emotional symptoms (primarily parent-rated) and performance-based neurocognitive functioning in youth with ADHD (23, 26-29, 63). Except for the weak association between CPT Omissions and self-rated anger, we did not find any significant associations between emotional symptoms and performance-based neurocognitive functioning. This pattern of non-significant associations is in agreement with two longitudinal studies of youth with ADHD (24, 25). Consistent with Fenesy and Lee (2019) we found that parent-rated emotional symptoms, and self-rated depression and anger, were significantly associated with ADHD symptoms. These findings may reflect diagnostic overlap between inattention symptoms in ADHD and concentration difficulties in depression and/or previous observations that irritability, a common associated feature of ADHD and the underlying dispositional trait in anger, may serve as a common liability for depression in individuals with ADHD (9, 10, 23).

Although there were no significant changes over time in self-rated anxiety and depression for any of the groups, significantly different trends emerged between and within the groups. The ADHD group rated their symptoms of anxiety and depression higher than the control group at both baseline and follow-up, but the differences between the groups decreased over time. Anger symptoms improved in the ADHD but not in the Control group. Again, given the association between ADHD and anger, the latter as an emotion including irritability and distress tolerance, a hypothesis may be that ADHD treatment contributed to a decrease in self-rated anger. Despite the improvement, the ADHD group still reported significantly higher levels of anger than controls at both baseline and follow-up. Previous follow-up studies report improvements (64, 65), or largely stable emotional symptoms in youth treated for ADHD (5, 7, 8).

Across settings, and compared to easily observable behavioral disturbances, the internalizing features of emotional symptoms (fear, arousal, cognitive avoidance), often go undetected by parents and teachers, and this difference may be heightened in parents of children with ADHD. At the time of clinical referral for ADHD, there is naturally, an intense focus on assessing and treating the primary, and highly debilitating and disruptive, behavioral features of ADHD (66, 67). While necessary, ADHD-focused interventions may have an insufficient effect on comorbid emotional difficulties that further contribute to impairments in day-to-day functioning and the child's self-esteem (68). A more holistic approach may yield improved outcomes for youth with ADHD. For example, a meta-analysis found that adding increased physical exercise to standard ADHD treatment reduced ADHD and emotional symptoms and was associated with a reduction in EF-related behavioral impairments in youth with ADHD (69). The present findings of different trends in the course of emotional symptoms in the ADHD and Control groups, and the relationship between EF behavior and emotional symptoms in the ADHD group suggest further studies are needed with larger samples including clinical and non-clinical comparison groups. For example, more needs to be done to understand how these relationships interplay with functional impairments in everyday life and medical treatment. There is also a need for future studies on interventions concerning EF impairments.

Limitations

There are some limitations. The use of clinical data has contributed to methodological weaknesses concerning a lack of standardized semi-structured interviews evaluating comorbid psychiatric diagnosis. However, all diagnoses in the ADHD group were assessed by experienced psychiatrists and neuropsychologists working in specialist child and adolescent psychiatry services. In the absence of clinical interviews in the Control group, it is possible that some youth in that group suffered from some

other neurodevelopmental or psychiatric disorder. However, the parents in the Control group completed the SNAP-IV at baseline concerning ADHD symptoms. The clinical data at baseline yielded attrition concerning self-rated emotional symptoms primarily in the ADHD group because the youngest children were too young to complete self-ratings on emotional symptoms. Further, almost 20 percent of the participants did not complete any of the follow-up assessments. Attrition analyses showed that the parents of the drop-outs rated their inattention symptoms and metacognitive functioning worse than those who participated in the follow-up assessment. It cannot be ruled out that the attrition affected the results, despite the linear mixed model employed, using all available data so that the findings represent all participants. All measures have been standardized according to sex. Even so, the sex bias with more girls in the Control group is a limitation. Mean age was similar in both groups but the age range in the ADHD group was larger than in the Control group, for which reason we adjusted for age in all analyses. When it comes to assessment scales, we used different rating scales at baseline (the FTF) and follow-up (the SDQ) in the evaluation of the relationships between EF and parent-rated emotional symptoms. Both scales have shown good correspondence to the Child Behavior Checklist (CBCL), a widely used caregiver report form identifying problem behavior in children. Finally, it is important to note that there is a lack of theory to guide ADHD researchers in the selection and test of variables to accurately model the relationships among ADHD symptoms, executive functioning, emotional symptoms, or other factors that might moderate or mediate these relationships. Models testing causal relationships or interactions at this stage are likely to be premature, and it must be acknowledged that the present findings may be better explained by the influences of unmeasured (potentially confounding) variables.

The present study represents a first attempt to study the long-term effect of a wide range of EF measures, and neurocognitive tests on self-rated anxiety, depression, and anger symptoms and parental ratings of emotional problems broadly.

Conclusion

Longitudinal data of parent- and self-ratings of emotional symptoms were associated with parent-ratings of behavior regulation and metacognitive EF. Planning and organizing deficits were associated with self-rated anxiety and anger over and above other aspects of metacognitive functioning, while emotional control was related to self-rated anger over and above other aspects of behavior regulation in youth with ADHD. The ADHD group improved in terms of self-rated anger across measuring points, while anxiety and depression were largely stable in both groups. Youth with ADHD reported higher levels of anxiety, depression, and anger than the control group across the 3-year follow-up, however, the between-group differences for anxiety and depression, but not anger, decreased over time.

Clinical implications

Our finding of the long-term relationships between the everyday manifestations of executive functioning and emotional symptoms emphasizes the importance of identification, monitoring, and treatment of emotional symptoms, and behavioral aspects of EF in youth with ADHD.

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Disclosures

No potential conflict of interest was reported by the authors.

Data availability statement

Non-digital data supporting this study are curated at Child and adolescent psychiatry, Department of Clinical Sciences, Lund University, Skane University Hospital, Lund, Sweden. Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

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