Development and Psychopathology (2024), **36**, 1489–1502
doi:10.1017/S0954579423000743

CAMBRIDGE UNIVERSITY PRESS

Regular Article

Predictors of executive function trajectories in adolescents with and without ADHD: Links with academic outcomes

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Abstract

Changes in executive function (EF) occur during adolescence with several factors (e.g., parenting styles, socioeconomic status) influencing the development of EF abilities. These changes are important as EF has been strongly linked with a range of outcomes including academic achievement, job performance, and social–emotional well-being. However, few studies have examined variability in EF trajectories during this critical developmental period, or trajectories in samples known to have specific impairments with EF, such as adolescents diagnosed with attention-deficit/hyperactivity disorder (ADHD). The present study examined differential trajectories of three domains of parent-rated EF in 302 adolescents (167 males; Mage = 13.17 years) with and without ADHD (53.6% with ADHD) from grade 8 to 10. The study also explored whether adolescent ADHD, parent ADHD, and parents' own EF predicted EF trajectories in addition to the longitudinal relation between trajectories and academic outcomes. Findings suggest that adolescence is marked by significant variability in EF development due to factors such as ADHD status, parent ADHD, and parent EF ability. Additionally, adolescents who displayed poor EF abilities throughout middle and high school had significantly lower grade point averages and poorer parent-, teacher-, and self-reported academic outcomes. Implications for interventions targeting EF deficits among adolescents with and without ADHD are discussed.

Keywords: attention-deficit/hyperactivity disorder; executive functioning; academic performance; adolescence

(Received 26 September 2022; revised 7 June 2023; accepted 7 June 2023; first published online 12 July 2023)

Executive function (EF) is a set of higher-order cognitive processes, such as working memory, inhibitory control, and cognitive flexibility, that guides purposeful, goal-directed behavior (Best & Miller, 2010). EF abilities have been linked with a range of outcomes such as academic achievement (Biederman et al., 2004; Langberg et al., 2013), job performance (Miller et al., 2012), and social–emotional well-being (Miller & Hinshaw, 2010). Significant developmental changes in EF occur during adolescence with several factors (e.g., socioeconomic status [SES], IQ) influencing the development of EF abilities (Best & Miller, 2010; Boelema et al., 2014). Though research documents a general developmental trajectory of improvement in EF during adolescence (e.g., Ferguson et al., 2021; Shanmugan & Satterthwaite, 2016), to our knowledge only three studies have looked at whether there is variability in the development of EF during this critical developmental period (Friedman et al., 2016; Miller et al., 2013; Qian et al., 2013). However, these three studies used community samples and performance-based measures of EF. No study to date has examined differential trajectories of EF rather than changes at the group level on average in a comprehensively diagnosed sample of adolescents with attention-deficit/hyperactivity disorder (ADHD) relative to controls using behavioral ratings of EF. Given this backdrop, the present study sought to examine differential trajectories of EF using parent-reported behavioral ratings of three domains of EF (behavioral, cognitive, and emotional) in a sample of adolescents with and without ADHD, a clinical population known to experience significant EF deficits (e.g., Thorell, 2007; Willcutt et al., 2005). Furthermore, this study explored whether adolescent ADHD status, parent ADHD status, and parents' own EF abilities predicted these EF trajectories above and beyond relevant demographic factors (biological sex, medication status, behavior therapy status, utilization of an Individualized Education Program [IEP] or 504 plan, SES, IQ), and examined the relation between these differential trajectories of EF and several academic outcomes. Importantly, we collected ratings of academic functioning from parents and teachers, intensive daily-data over a 2-week period, and more objective assessments, such as grade point average (GPA) and assignments turned in, to provide a comprehensive assessment of academic outcomes.

Normative developmental trajectory of EF during adolescence

Whereas the foundational components of EF such as inhibition and shifting develop in early childhood, EF abilities continue to develop and strengthen during adolescence (Best & Miller, 2010; Boelema et al., 2014). Adolescence is a critical period for development of new, and maturation of existing, EF abilities (Luciana, 2016). For

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Cite this article: Shroff, D. M., Dunn, N. C., Green, C. D., Breaux, R., Becker, S. P., & Langberg, J. M. (2024). Predictors of executive function trajectories in adolescents with and without ADHD: Links with academic outcomes. *Development and Psychopathology* **36**: 1489–1502, https://doi.org/10.1017/S0954579423000743

example, Boelema et al. (2014) found significant improvements in all six measured components of EF – focused attention inhibition, sustained attention, speed of processing, working memory, and shift attention – from early to late adolescence.

The transition to adolescence is associated with an increased demand for self-regulation in academic and interpersonal domains; therefore, there is a need to exert higher cognitive control (Brieant et al., 2022; Burnett et al., 2013). Notably, EF plays an important role in shaping an adolescent's social, emotional, and educational competencies (Bierman et al., 2008; Brieant et al., 2022; Nyongesa et al., 2019). Given this, it is critical to examine factors affecting EF development during this time period (Diamond, 2013; Nyongesa et al., 2019) and to screen and implement intervention strategies for EF problems (Tonkin, 2001). Understanding factors that shape EF development will enhance interventions to improve such adaptive behaviors (Gray-Burrows et al., 2019).

Measurement of EF

Prior longitudinal work on EF trajectories has used group-based approaches and performance-based measures of EF (Nyongesa et al., 2019). Performance or task-based approaches have several strengths, including lack of rater bias. However, they exhibit low correlations with ratings of EF and have been criticized for having low ecological validity (Nyongesa et al., 2019). As such, it is also important to understand EF trajectories using self and informant reports of EF. Therefore, our study employed parent report of EF to measure behavioral manifestations of adolescent EF difficulties in daily life.

Individual and family factors that influence EF

Several individual and family factors influence the development and maturation of EF. Individual factors such as IQ (Ardila et al., 2000, Hackman et al., 2015) and family factors such as SES (Last et al., 2018; Ursache & Noble, 2016) and parenting (Fay-Stammbach et al., 2014) have been found to have a significant effect on the development of EF abilities. Specifically, children and adolescents with a higher IQ and from a higher SES have better EF abilities (Last et al., 2018), whereas youth from lower SES backgrounds and whose parents use negative parenting strategies (e.g., corporal punishment, emotionally reactive responses) have worse EF (Bernier et al., 2010; Hughes & Ensor, 2009).

One proposed mechanism for the relation between family factors and youth EF is parents' own EF abilities. Initial evidence of intergenerational transmission of EF has been established from early childhood (i.e., as early as 4 months) through adolescence (e.g., Bridgett et al., 2013; Cuevas et al., 2014; Deater-Deckard, 2014; Jester et al., 2009). However, most of this research has focused on toddlerhood and the preschool years, which is not surprising given that this is when some EF abilities first emerge. Only two studies to date have examined how parent EF abilities impact EF development during adolescence (Friedman et al., 2008; Jester et al., 2009). Specifically, Jester et al. (2009) found that parent EF was significantly associated with adolescent EF, independent of IQ, in a sample of 434 adolescents at ages 12–14 ($M = 13.7$) and then again at ages 15–17 ($M = 16.5$). Friedman et al. (2008) found similar results in a twin study examining three aspects of EF – inhibiting dominant responses, updating working memory representations, and shifting between task sets – in a sample of 582 adolescents ages 13–17 years. Latent variable analysis showed that individual differences in adolescent EF were entirely accounted for by genetic factors beyond the contributions of IQ, using performance-based EF tasks to measure parent and adolescent EF abilities (Friedman et al., 2008). Given a growing body of research suggesting that behavioral ratings of EF offer distinct information from EF tasks and might carry higher ecological validity (Baars et al., 2015; Barkley & Murphy, 2011; Langberg et al., 2013), it is critical for research to examine this familial transmission effect using self- and informant-report measures. Additionally, both of the previous studies utilized community samples; it is important to understand if EF trajectories and their predictors differ across clinical samples such as between adolescents with ADHD versus typically developing adolescents.

EF abilities among adolescents with ADHD

ADHD is a highly heritable disorder that is characterized by difficulties in organization, planning, remembering details, and paying attention (Martel et al., 2007). It is well-established that individuals with ADHD display higher levels of EF deficits in daily life activities and on performance-based tasks, relative to individuals without ADHD (see Willcutt et al., 2005 for a review; pooled effect sizes: $rs = .46–.69$; Gordon & Hinshaw, 2020; Miller et al., 2013). In fact, research has shown that on average, children with ADHD experience a 3-year lag in their EF skills, relative to their typically developing peers (Berger et al., 2013). Studies by Miller et al. (2013) and Gordon and Hinshaw (2020) compared the developmental trajectories of EF between 140 females with ADHD and 88 females without ADHD. They found that females with ADHD differed from controls in their trajectories of EF development, such that they displayed consistently lower EF abilities compared to females without ADHD. Additionally, for females with ADHD, change in EF over time was associated with ADHD symptom change, indicating that ADHD symptoms can increase or partially remit as a result of EF development. This finding was corroborated by another recent study in which Silverstein et al. (2020) showed strong positive relations between ADHD symptoms and daily life EF deficits.

In fact, EF has been proposed to be a potential endophenotype for ADHD (Fu et al., 2021; Luo et al., 2019), suggesting that part of the heritability of ADHD can be linked to the familial transmission of EF. As such, this study aims to gain a better understanding of whether parent EF abilities predict the developmental trajectory of EF in adolescents with ADHD compared to typically developing adolescents. Enhancing the field's understanding of the potentially distinct and divergent development and maturation of EF abilities for adolescents with ADHD could lead to proposing targeted approaches for improving EF in these at-risk adolescents.

EF and academic outcomes

The association between EF abilities and academic performance is robust (Spiegel et al., 2021; Zelazo et al., 2016). Studies have shown that EF is associated with educational success throughout development, with EF directly and indirectly predicting classroom difficulties (Zelazo et al., 2016), overall school achievement (e.g., Bull & Scerif, 2001; Mazzocco & Kover, 2007), reading and mathematics (e.g., Morrison et al., 2010: Peng et al., 2016; Peng et al., 2018), high school completion (Vitaro et al., 2005), and college graduation (McClelland et al., 2013). As such, understanding whether differential developmental EF trajectories predict academic outcomes for adolescents with and without ADHD will enable us to better identify at-risk adolescents who may benefit from interventions targeting EF deficits, which can directly and indirectly influence academic success.

Present study

Given this backdrop, the present study aimed to address three aims: (1) to identify differential trajectories of EF (behavioral, emotional, and cognitive regulation) from middle school to high school (fall of 8th grade, spring of 8th grade, and fall of 10th grade) in a sample of adolescents with and without comprehensively diagnosed ADHD; (2) to investigate whether parent EF, parent ADHD, and adolescent ADHD status predicted these differential EF trajectories; and (3) to analyze the association between the identified EF trajectories and a range of objective and parent-, teacher-, and adolescent-reported academic outcomes in adolescents. Parents provided ratings of both their adolescent's EF and their own EF as well as their own symptoms of ADHD. Examining EF deficits at multiple timepoints during adolescence will provide a better understanding of differences in development and maturation of EF abilities across this critical developmental period. Additionally, using daily ratings collected from teachers and adolescents to assess academic performance (motivation for schoolwork, effort put forth in classwork, quality of completed work, percentage of assignments turned in) ensures higher accuracy in the reporting of difficulties as they arise and are related to daily life activities. Based on prior research with adolescent participants (Boelema et al., 2014; Torgalsbøen et al., 2021), we hypothesized that three EF trajectories would exist for behavioral, emotional, and cognitive domains of EF (low EF deficits that remain stable or improve across adolescence, moderate EF deficits that remain stable or improve across adolescence, and high EF deficits that remain stable or improve across adolescence). Further, we hypothesized that ADHD status (Gordon and Hinshaw, 2020; Miller et al., 2013; Willcutt et al., 2005), parent ADHD (Joyner et al., 2009; Schroeder & Kelley, 2009), and parent EF abilities (Friedman et al., 2008; Jester et al., 2009) would be significant predictors of EF trajectories for all three domains, controlling for relevant covariates (SES, medication status, behavior therapy status, utilization of an IEP or 504 plan, biological sex, IQ). Finally, we hypothesized that these trajectories would be associated with a robust multi-source multi-method assessment of academic outcomes, including homework performance, academic motivation, and assignment completion with the consistently high EF deficits group having significantly worse academic outcomes.

Method

Participants

Participants were 302 adolescents (167 males) and a primary caregiver (84.1% mothers, 13.2% fathers, 2.6% other caregivers) recruited from local schools in the Southeastern and Midwestern United States in the8th grade. At the time of recruitment, adolescents were between 13 and 14 years of age ($M = 13.17$, $SD = 0.40$). About half of the sample (53.6%) received an ADHD diagnosis based on the Children's Interview for Psychiatric Syndromes (ChIPS; Weller et al., 1999) diagnostic interview with parents, which included assessment of age of onset, duration, cross-setting impairment, and common comorbid conditions. Adolescents identified as predominantly White (81.8%), with 7.9% identifying as biracial/multiracial, 5.3% as Black, and 4.6% as Asian. Participants came from a range of socioeconomic backgrounds (M family income = \$93,179, SD = \$34,847).

Procedures

Adolescents and their parents were recruited as part of a larger longitudinal study of adolescents with and without ADHD [R305A160126]. Inclusion criteria included: (1) estimated full scale IQ ≥ 80; (2) enrollment in 8th grade; and (3) enrollment in regular education classes. Exclusion criteria included: (1) not meeting criteria for either the ADHD or comparison group; (2) prior diagnosis of an organic sleep disorder; and (3) meeting criteria for autism spectrum disorder, bipolar disorder, or a dissociative or psychotic disorder. Adolescents received an ADHD diagnostic evaluation during the initial assessment and were required to meet all Diagnostic and Statistical Manual for Mental Disorders, Fifth Edition (DSM-5) criteria for ADHD predominately inattentive presentation or combined presentation on the ChIPS to be eligible for the ADHD group. To be eligible for the comparison group, three or fewer symptoms had to be endorsed in both the inattention and hyperactivity/impulsivity domains. Youth that did not meet full criteria for an ADHD diagnosis but had more than three symptoms in either the inattention or hyperactivity/impulsivity domains were excluded from the study. Parent ratings of adolescent EF abilities were collected at three of the five study timepoints (T1: fall of 8th grade, $N = 302$; T2: spring of 8th grade, $n = 284$; T3: fall of 10th grade, $n = 283$).

Measures

Behavior Rating Inventory of Executive Function – Second Edition (BRIEF-2)

Impairments in adolescent EF were assessed using the BRIEF-2 (Gioia et al., 2015). Parents completed the BRIEF-2 parent form at T1, T2, and T3. This rating form consists of 55 statements about different domains of adolescents' EF skills such as "My child has trouble accepting a different way to solve a problem with things such as schoolwork, friends, or tasks" and "My child is not aware of how his/her behavior affects or bothers others." Responses were provided on a 3-point Likert scale ranging from *Never* to *Often*. The BRIEF-2 generates three broad indices: behavioral regulation index (BRI), emotion regulation index (ERI), and cognitive regulation index (CRI), which together form the Global Executive Composite score. The BRI includes the Inhibit and Self-Monitor clinical scales, which assesses an adolescent's ability to effectively modulate behavior. The ERI includes the Shift and Emotional Control scales and measures an adolescent's ability to manage their emotions and emotional responses as well as appropriately adjust to changes in the environment. The CRI includes the Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials scales and assesses an adolescent's ability to effectively problem solve and regulate cognitive processes. In the present study, we used the BRI, ERI, and CRI scores as a measure of adolescent EF difficulties, where higher scores reflect greater deficits in EF. Adolescent EF deficit scores are presented in Table 1; adolescents with ADHD had significantly greater EF deficits in all three domains at all three timepoints relative to adolescents without ADHD. Reliability was good in this sample for all timepoints (αs = .87–.89).

Barkley Deficits in Executive Functioning Scale – Short Version (BDEFS-S)

Parents completed the BDEFS-S (Barkley, 2011) at the T2 assessment. The BDEFS-S is a self-report form with 20 statements (e.g., "I don't seem to process information as quickly or accurately

Table 1. Means and standard deviations of demographic variables and adolescent and parent EF deficits across ADHD and comparison groups

	ADHD group, *M* (*SD*) or %	Comparison group, *M* (*SD*) or %	*t* (*df*) or χ^2
Age	13.17 (0.41)	13.18 (0.40)	−0.26 (300)
Biological sex (% female)	35.2%	55.7%	12.80***
Race (% white)	79.6%	84.3%	1.09
Ethnicity (% Hispanic/Latino)	4.3%	5.0%	0.08
Full scale IQ estimate	104.75 (13.89)	109.67 (12.31)	−3.23 (300)**
Internalizing disorder diagnosis (e.g., anxiety, depression)	32.1%	20.7%	4.96*
Externalizing disorder diagnosis (e.g., ODD, CD)	21.6%	4.3%	19.20***
Two parent home	71.0%	82.1%	5.25
Family income	$85,124 (35,891)	$102,500 ($31,213)	−4.50 (300)***
Adolescent EF deficits – T1			
Behavior regulation index	61.51 (10.75)	45.89 (7.65)	156.53 (302)***
Emotion regulation index	60.45 (11.08)	48.92 (9.05)	115.68 (302)***
Cognitive regulation index	68.10 (8.73)	47.73 (8.13)	205.81 (302)***
Adolescent EF deficits – T2			
Behavior regulation index	62.80 (9.85)	47.04 (8.62)	148.59 (280)***
Emotion regulation index	61.68 (11.21)	49.53 (9.45)	114.50 (280)***
Cognitive regulation index	67.44 (8.65)	48.53 (8.33)	191.82 (280)***
Adolescent EF deficits – T3			
Behavior regulation index	56.17 (10.60)	44.70 (5.46)	109.61 (252)***
Emotion regulation index	55.97 (11.49)	46.51 (7.93)	94.65 (252)***
Cognitive regulation index	62.89 (10.13)	47.10 (7.67)	132.47 (252)***
Parent EF deficits – T2	51.69 (26.53)	43.61 (23.82)	2.68 (284)**
Parent ADHD – T2	1.39 (0.35)	1.31 (0.27)	17.88 (286)

Note. *$p < .05$, **$p < .01$, ***$p < .001$; descriptive statistics are reported for T1 unless otherwise specified.

as others") that evaluate dimensions of adult EF in daily life activities over the past 6 months. Parents report on the frequency of thoughts and behaviors that reflect EF deficits. Responses are provided on a 4-point Likert scale ranging from Never/Rarely to Very Often. For the present study, we used the summary score as a measure of parent EF. Parent EF scores are presented in Table 1; parents of adolescents with ADHD had significantly more EF difficulties than parents of adolescents without ADHD. Reliability was high in the current sample ($\alpha = .91$).

Barkley Adult ADHD Rating Scale – Fourth Edition (BAARS-IV)

Parents completed the BAARS-IV (Barkley, 2011) at the T2 assessment. The BAARS-IV is a self-report form that assesses current and childhood ADHD symptoms and domains of impairment. Responses are provided on a 4-point Likert scale from Never/Rarely to Very Often. For the present study, we used the mean score for ADHD symptoms, which is presented in Table 1. Parents of adolescents with ADHD had higher levels of ADHD symptoms, although this difference was not statistically significant. Reliability was good in the current sample ($\alpha = .87$).

Academic outcomes

Homework performance questionnaire (HPQ). The HPQ (Power et al., 2007) consists of 22 items that assess student's homework performance, and each item is rated on a 7-point scale ranging from 0 (Never/Rarely, 0%–10% of the time) to 6 (Almost Always/Always, 91%–100% of the time). Parents and teachers reported on the frequency of behaviors with items worded such that higher scores indicate less impairment at T3. For the current study, the total mean score was used. Reliability was high in the current sample for parent report and moderate for teacher report ($\alpha s = .92$ and .71, respectively).

Daily diary ratings. At T3, adolescents and teachers completed daily ratings on adolescent motivation for schoolwork, effort put forth in classwork, and the quality of completed work, for a 2-week period; teachers also reported on the percentage of assignments the adolescents turned in daily. Motivation, effort, and work quality were rated on a 4-point Likert scale ranging from 1 (*Not at all motivated, Barely any effort*, and *Poor quality*, respectively) to 4 (*Very motivated, A lot of effort*, and *Great quality*, respectively). The percentage of assignments turned in was rated on a 5-point Likert scale ranging from 1 (*0%–10%*) to 5 (75%–100%). The daily diary ratings were averaged across ten school days to create the motivation, effort, work quality, and assignments turned in variables used in this study. Reliability was high for all daily diary ratings within subjects ($\alpha s = .92$–.95 for teachers, $\alpha s = .95$–.99 for adolescents). However, inter-rater reliability for daily diary ratings were low in the current sample ($\alpha s = .36$–.43).

Grade point average. Following the end of their 10th grade year (i.e., corresponding to T3), grades for the four core subject areas:

English, Science, Math, and History were collected and used to calculate GPA on a 4-point scale (As = 4.0, Bs = 3.0, Cs = 2.0, Ds or below = 1.0). Since not all high schools allowed GPA to go above a 4.0 (i.e., using a weighted system for honors/advanced placement classes), values were capped at 4.0.

Demographic variables

Parents reported on adolescent biological sex and family income on a demographic form. Parents reported on adolescent medication status, behavior therapy status, and utilization of an IEP or 504 plan on the Services for Children and Adolescents – Parent Interview (Jensen et al., 2004). IQ was assessed using the two-subtest estimate on the Wechsler Abbreviated Scale of Intelligence-II (Wechsler, 2011).

Analytic plan

Descriptive statistics were created for relevant variables and correlations between the outcome variables, predictor variable, and variables shown in the literature to be associated with EF were examined. Next, a repeated measures ANOVA was run to examine change in EF on average from fall of 8th grade to fall of 10th grade. Finally, we ran growth mixture models (GMM) to explore the differential trajectories of adolescent EF from fall of 8th grade to fall of 10th grade, which accounted for unequal spacing between time points (i.e., timepoints were set at 0, 1, 4; approximately 6 months between time 1 and time 2 and approximately 18 months between time 2 and time 3). GMM examine multiple unobserved (latent) classes that can differ in intercepts and slopes, and allow for class-specific variations in these parameters (Jung & Wickrama, 2008; Lubke & Muthén, 2007; Ram & Grimm, 2009). GMM were run using the "3-step" approach for model estimation (Vermunt, 2010), which allows for the incorporation of predictors and/or outcomes while still protecting the class formation determined in the first step (i.e., unconditional model) from the potential influence of covariates (Muthén, 2003) by using the auxiliary variable option in Mplus.

When determining the number of classes in the unconditional model, an increasing number of classes were examined to determine the best fit for the data. Model fit was determined using Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), Lo–Mendell–Rubin adjusted likelihood ratio test (LMR), bootstrapped parametric likelihood ratio test (BLRT), entropy, classification probabilities (how distinct each class is from the other classes), and signs of model instability (e.g., class membership of less than 10%), consistent with prior recommendations (Muthén & Muthén, 2000; Tein et al., 2013). Better model fit was indicated by having the majority of model fit indicators in a model's favor as indicated by AIC and BIC decreasing, LMR and BLRT remaining significant, entropy values approaching 1 indicating clear delineation of classes (Celeux & Soromenho, 1996), and classification probabilities remaining $\geq .70$. Once the best fitting model was determined, models were examined to determine if trajectories had significant slopes (i.e., indicating either improvement or worsening in EF difficulties; non-significant slope indicated stable EF difficulties). Given prior research, family income, IQ, biological sex, adolescent medication status, behavior therapy status, IEP/ 504 plan status were included as covariates in the second step, after distinct trajectories were identified. Missing data were addressed using maximum likelihood estimation with robust standard errors in all models. Next, we examined if adolescent ADHD status, parent ADHD status, and parent EF difficulties were predictors of membership in the identified latent classes using the R3STEP auxiliary function, which runs multinomial logistic regressions. Finally, we examined if latent class membership was associated with differential academic outcomes based on parent-, teacher-, and self-report at T3 using the DE3STEP auxiliary function.

Results

Preliminary analyses

Descriptive statistics and correlations for baseline variables are presented in Table 2. All three domain of adolescent EF deficits (BRI, ERI, and CRI) were significantly correlated with parent EF deficits, parent ADHD, adolescent ADHD status, and SES at all 3 timepoints. In contrast, IQ was only significantly correlated with the CRI domain of adolescent EF deficits at all 3 timepoints. Additionally, biological sex was correlated with adolescent EF deficits in the BRI domain only at T1 and with adolescent EF deficits in the CRI domain at all 3 timepoints. A repeated measures ANOVA demonstrated a statistically significant decrease in adolescent EF deficits, F (2, 244) = 39.56, $p < .001$, on average from fall of 8th grade ($M = 57.62$, $SD = 12.66$) to fall of 10th grade ($M = 53.45$, $SD = 11.27$).

Trajectories of adolescent EF abilities

Behavior regulation index

A three-class model was the best fitting model for adolescent BRI trajectories, exhibiting strong model fit indices for all indicators, except for the LMR, and acceptable discrimination of classes as indicated by the classification probabilities and entropy (Table 3). As can be seen in Figure 1a, the first trajectory had BRI difficulties within normal limits in fall of 8th grade ($M = 41.85$, $SE = 1.45$) that remained stable from 8th to 10th grade (Low Stable BRI; 55 adolescents; 18% of sample; non-significant slope: $b = -0.50$, $SE = 0.39$, $p = .198$). The second trajectory also had BRI difficulties within normal limits in fall of 8th grade ($M = 47.60$, $SE = 1.27$) that remained stable from 8th to 10th grade (Moderate Stable BRI; 107 adolescents; 35% of sample; non-significant slope: $b = 0.54$, $SE = 0.72$, $p = .448$). The third trajectory had BRI scores just below the clinical level in fall of 8th grade ($M = 64.74$, $SE = 1.22$) that improved from 8th to 10th grade (High Improving BRI; 141 adolescents; 47% of sample; significant slope: $b = -1.63$, $SE = 0.26$, $p < .001$). The Low Stable BRI class had significantly less members who were attending behavior therapy at T1, T2, and T3 relative to the two other classes, ps < .030. Additionally, the Low Stable BRI class had significantly less members who were receiving an IEP/504 plan than the two other classes at T3, ps < .001. Classes did not significantly differ on any other covariates.

Emotion regulation index

A three-class model was the best fitting model for adolescent ERI trajectories, with strong model fit indices for all indicators and acceptable discrimination of classes as indicated by the classification probabilities and entropy (Table 3). The first trajectory had ERI difficulties within normal limits in fall of 8th grade ($M = 42.88$, $SE = 0.60$) and had their EF abilities improve from 8th to 10th grade (Low Improving ERI; 47 adolescents; 16% of sample; significant slope: $b = -0.55$, $SE = 0.15$, $p < .001$). The second trajectory also had ERI difficulties within normal limits in fall of 8th grade ($M = 45.51$, $SE = 0.92$), that remained stable from 8th to 10th grade (Moderate Stable ERI; 183 adolescents; 60% of sample;

Table 2. Means, standard deviations, and correlations between study variables

		EF deficits T1			EF deficits T2			EF deficits T3		
	M (*SD*) or %	BRI	ERI	CRI	BRI	ERI	CRI	BRI	ERI	CRI
Adolescent outcome variables										
Adolescent EF deficits – T1	57.62 (12.66)									
BRI		–	.74**	.72**	.83**	.64**	.63**	.74**	.52**	.60**
ERI			–	.65**	.65**	.84**	.56**	.59**	.70**	.49**
CRI				–	.68**	.62**	.90**	.62**	.54**	.83**
Adolescent EF deficits – T2	57.91 (12.49)									
BRI					–	.75**	.73**	.80**	.63**	.87**
ERI						–	.68**	.67**	.77**	.61**
CRI							–	.65**	.58**	.88**
Adolescent EF deficits – T3	53.45 (11.27)									
BRI								–	.77**	.73**
ERI									–	.66**
CRI										–
Predictor variables										
Parent EF deficits	28.00 (7.04)	.18**	.19**	.22**	.24**	.23**	.23**	.14**	.17**	.20**
ADHD status	53.6% with ADHD	.64**	.49**	.77**	.65**	.51**	.74**	.56**	.43**	.61**
Parent ADHD	1.35 (.32)	.25**	.30**	.26**	.33**	.33**	.27**	.23**	.24**	.25**
Covariates										
Family income	$93,179 ($34,847)	−.27**	−.22**	−.27**	−.24**	−.25**	−.27**	−.17**	−.15**	−.19**
ADHD medication status	31.1% on medication	.49**	.39**	.49**	.46**	.43**	.46**	.42**	.36**	.47**
Biological sex	55.3% male	.13*	.02	.18**	.12	.04	.19**	.06	.02	.17**
IQ	107.03 (13.39)	−.09	−.00	−.14*	−.10	−.03	−.16**	−.06	−.00	−.13**

Note. ADHD = attention-deficit/hyperactivity disorder; EF = executive function; BRI = Behavior Regulation Index; ERI = Emotion Regulation Index; CRI = Cognitive Regulation Index; higher sores on EF variables indicate greater deficits. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .00$.

non-significant slope: $b = -0.29$, $SE = 0.20$, $p = .148$). The third trajectory had borderline clinical levels of ERI difficulties in fall of 8th grade ($M = 62.04$, $SE = -1.23$) that improved from 8th to 10th grade (High Improving ERI; 73 adolescents; 24% of sample; significant slope: $b = -1.23$, $SE = 0.22$, $p < .001$). These trajectories are presented in Figure 1b. The Low Improving ERI class had significantly less members who were attending behavior therapy at T1 and T2 relative to the High Improving ERI class, $ps < .015$. Additionally, the Low Stable ERI class had significantly less members who were receiving an IEP/504 plan than the two other classes at T3, $ps < .001$. Classes did not significantly differ on any other covariates.

Cognitive regulation index

A three-class model was also the best fitting model for adolescent CRI trajectories, with strong model fit indices for all indicators except LMR and acceptable discrimination of classes as indicated by the classification probabilities and entropy (Table 3). As can be seen in Figure 1c, the first trajectory had CRI difficulties within normal limits in fall of 8th grade ($M = 41.64$, $SE = 1.05$) that remained stable from 8th to 10th grade (Low Stable CRI; 52 adolescents; 17% of sample; non-significant slope: $b = -0.76$, $SE = 1.09$, $p = .486$). The second trajectory also had CRI difficulties within normal limits in fall of 8th grade ($M = 49.97$, $SE = 3.51$), with these difficulties remaining stable from 8th to 10th grade (Moderate Stable CRI; 82 adolescents; 27% of sample; non-significant slope: $b = -0.18$, $SE = 0.43$, $p = .668$). The third trajectory had clinical levels of CRI difficulties in fall of 8th grade ($M = 68.67$, $SE = 2.74$) that significantly improved from 8th to 10th grade (High Improving CRI; 168 adolescents; 56% of sample; significant slope: $b = -1.27$, $SE = 0.20$, $p < .001$). The Low Stable CRI group had significantly less members on medication at T1, T2, and T3 relative to the two other groups $ps < .001$. Additionally, the Low Stable CRI group had significantly less members attending behavior therapy and receiving an IEP/504 plan at T3 relative to the two other groups $ps < .001$. Classes did not significantly differ on any other covariates.

Predictors of latent class membership

ADHD status significantly predicted membership in the three identified BRI latent class trajectories. Adolescents with ADHD were significantly more likely to be in the High Improving than Low Stable and Moderate Stable classes (odds ratio = 104.30 and 31.66, respectively), $ps < .001$. Parent ADHD symptoms also significantly predicted membership in the three identified BRI latent class trajectories. Adolescents in the High Improving class had parents with significantly higher ADHD symptoms than the Low Stable and Moderate Stable (odds ratio = 35.94 and 17.53, respectively) classes, $p = .009$ and .012, respectively. However, parent EF abilities did not predict class membership when accounting for adolescent ADHD status, parent ADHD symptoms,

Table 3. Model fit statistics for unconditional executive function trajectories models

Classification model	AIC	BIC	Sample size-adjusted BIC	LMR	*p*	BLRT	*p*	Entropy	Classification probabilities	Class size
Behavior regulation index										
1 Factor	5909.22	5938.93	5913.56	–	–	–	–	–	–	302
2 Factor	5803.08	5851.36	5810.13	112.21	<.001	−2946.61	<.001	.70	.89, .94	149, 154
3 Factor	**5761.25**	**5828.09**	**5771.01**	**50.08**	**.063**	**−2888.54**	**<.001**	**.72**	**.84, .80, .93**	**107, 55, 141**
4 Factor	5752.79	5838.21	5765.27	17.83	.022	−2862.62	.208	.77	.94, .92, .82, .81	55, 111, 56, 81
Emotion regulation index										
1 Factor	5934.14	5963.85	5938.48	–	–	–	–	–	–	302
2 Factor	5767.98	5816.26	5775.03	170.20	<.001	−2959.07	<.001	.79	.98, .89	184, 119
3 Factor	**5739.71**	**5806.56**	**5749.48**	**36.97**	**.044**	**−2870.99**	**<.001**	**.79**	**.81, .87, .80**	**47, 183, 73**
4 Factor	5736.78	5822.20	5749.25	12.50	.431	−2851.86	.267	.65	.82, .81, .74, .78	47, 123, 52, 81
Cognitive regulation index										
1 Factor	5793.21	5822.92	5797.55	–	–	–	–	–	–	302
2 Factor	5708.30	5756.54	5715.31	83.43	.003	−2884.33	<.001	.79	.88, .97	97, 205
3 Factor	**5683.04**	**5749.83**	**5692.74**	**34.07**	**.208**	**−2841.15**	**.030**	**.76**	**.84, .81, .94**	**52, 82, 168**
4 Factor	5669.75	5755.09	5682.15	22.50	.584	−2823.52	.188	.80	.93, .81, .80, .89	118, 34, 34, 116

Note. Bolded row represents the best fitting growth mixture model. AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; LMR = Lo–Mendell–Rubin adjusted likelihood ratio test; BLRT = bootstrapped parametric likelihood ratio test. The LMR and BLRT compare the fit of one model to the previous (k-1 factor) model.

income, medication status, behavior therapy status, IEP/ 504 plan status, IQ, and sex, *p*s > .244.

For the ERI, only adolescent ADHD status significantly predicted membership in the three identified latent classes. Specifically, adolescents with ADHD were significantly more likely to be in the High Improving than Low Improving and marginally more likely to be in the Moderate Stable classes, odds ratio = 43.63 and 9.46; $p = .032$ and .062, respectively. In contrast, parent ADHD symptoms and EF abilities did not predict class membership, accounting for adolescent ADHD status, parent ADHD symptoms, and relevant covariates (i.e., income, medication status, behavior therapy status, IEP/ 504 plan status, IQ, sex), *p*s > .113.

ADHD status also significantly predicted membership in the three identified CRI latent class trajectories, such that adolescents with ADHD were significantly more likely to be in the High Improving than Low Stable and Moderate Stable classes, odds ratio = 37.11 and 20.06, respectively, *p*s < .001. Similarly, parent EF difficulties significantly predicted membership in the three identified BRI latent class trajectories, such that adolescents in the High Improving group had parents with significantly more EF difficulties than the Low Stable and Moderate Stable classes, odds ratio = 14.93 and 17.53, respectively, *p*s < .001. Parent ADHD symptoms did not predict class membership, accounting for adolescent ADHD status, parent EF difficulties, and relevant covariates (i.e., income, medication status, behavior therapy status, IEP/ 504 plan status, IQ, sex), *p*s > .229.

Association between latent class membership and academic outcomes

Means and standard errors for the academic outcomes of the three latent classes for the BRI, ERI, and CRI are presented in Tables 4, 5, and 6, respectively.

Homework performance

Members of the High Improving latent class displayed significantly poorer homework performance in 10th grade relative to the two other latent classes based on parent and teacher report, $\chi^2 = 5.29$–158.44, all *p*s < .021. Additionally, the Moderate Stable class was significantly lower than the Low Stable class for parent and teacher-reported HPQ for BRI, $\chi^2 = 6.27$ and 6.29, *p*s = .012, respectively, and parent report for CRI, $\chi^2 = 11.61$, $p = .001$.

Motivation for schoolwork and effort put into classwork

With regard to motivation, members of the High Improving latent class had significantly lower motivation in 10th grade than the other two classes based on self-report, $\chi^2 = 3.88$–8.77, *p*s < .050, respectively. For teacher-reported motivation, the High Improving class had significantly lower motivation than the other two classes for the CRI, $\chi^2 = 5.05$ and 7.63, $p = .025$ and .006, than the Moderate Stable class for the BRI, $\chi^2 = 12.20$, $p < .001$; groups did not differ based on the ERI for teacher-reported motivation.

Similarly, members of the High Improving latent class self-reported significantly less effort in 10th grade than the Low Improving latent class for BRI, $\chi^2 = 6.67$, $p = .010$, than the other two latent classes for ERI and CRI, $\chi^2 = 3.96$–13.09, *p*s < .047. For teacher-reported effort, members of the High Improving latent class were significantly lower than the Moderate Stable class for BRI and CRI, $\chi^2 = 7.82$ and 7.33, $p = .005$ and .007, respectively; they did not differ for ERI.

Work quality and percentage of assignments turned in

With regard to work quality, members of the High Improving latent class had significantly poorer quality work in 10th grade than the Low Stable/Low Improving class based on self-report for BRI and ERI, $\chi^2 = 6.19$ and 8.82, $p = .013$ and .003, than both classes for CRI, $\chi^2 = 8.23$ and 20.22, $p = .004$ and $p < .001$. Similarly, for teacher-reported work quality, the High Improving latent class had

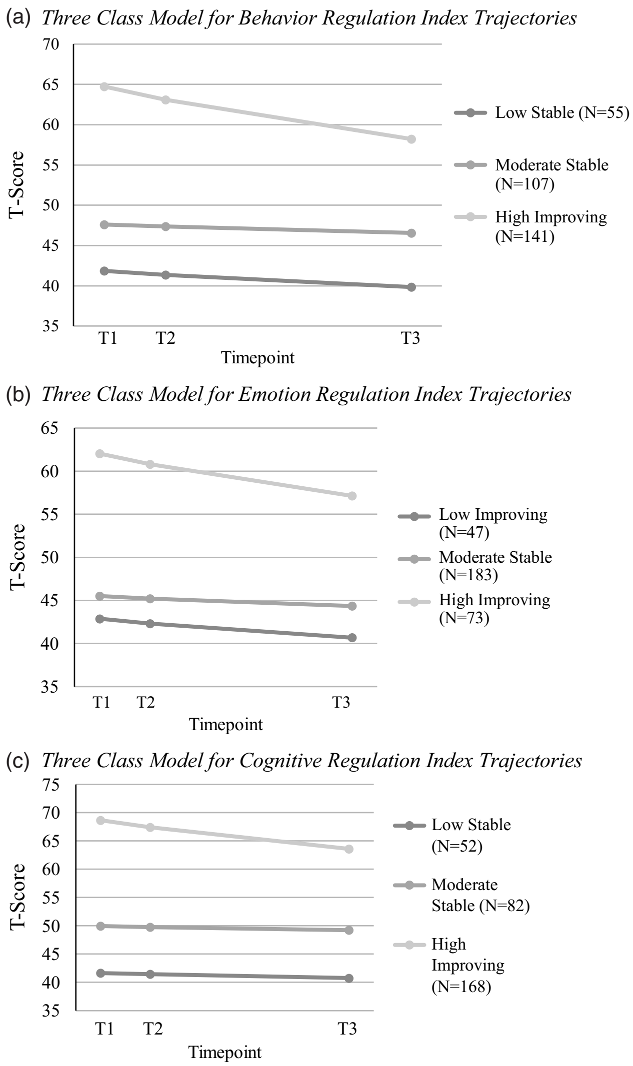

Figure 1. (a) Three-class model for behavior regulation index trajectories. (b) Three-class model for emotion regulation index trajectories. (c) Three-class model for cognitive regulation index trajectories. *Note.* Executive function difficulties are reported as *T*-scores; values within normal limits range from 40 to 60, *T*-scores between 60 and 65 are considered borderline clinical, and *T*-scores of 65 or above indicate clinical concern.

significantly lower quality work in 10th grade than the Moderate Stable class for BRI, $\chi^2 = 13.51$, $p < .001$, than both classes for the CRI, $\chi^2 = 4.93$ and 15.29, $p = .026$ and $p < .001$; they were unrelated to ERI class membership for self-reported work quality.

Members of the High Improving latent class turned in significantly fewer assignments relative to members of the other two latent classes for BRI, $\chi^2 = 6.40$ and 7.17, $p = .011$ and .007, and CRI, $\chi^2 = 15.00$ and 16.53, ps $< .001$. They were unrelated to ERI class membership for teacher-reported work quality.

Grade point average

Finally, when considering GPA in 10th grade, members of the High Improving latent class had significantly lower GPAs on average relative to the other two latent classes for BRI, ERI, and CRI, $\chi^2 = 17.74$–67.79, ps $< .001$. Additionally, members of the Moderate Stable latent class had significantly lower GPAs on average than members of the Low Stable latent class for CRI, $\chi^2 = 4.68$, $p = .030$.

Discussion

This study sought to examine trajectories of EF abilities (measured across behavioral, emotional, and cognitive domains) during adolescence, factors that predicted these differential trajectories, and the association of these trajectories with academic outcomes in a sample of adolescents with and without ADHD. The results of this study identified three distinct trajectories of EF development across behavioral, emotional, and cognitive domains from early to mid-adolescence. Consistent with normative development (Nyongesa et al., 2019), the first two trajectories include adolescents who display low levels of EF difficulties (within normal limits) that remain stable or slightly improve across adolescence and adolescents who display moderate levels of EF difficulties (within normal limits) that remain stable across adolescence. The third trajectory included adolescents who demonstrated high EF difficulties (indicating clinical or subclinical concern) that improve across adolescence. Furthermore, these results suggest that factors such as adolescent ADHD status, parent ADHD, and parent EF ability predict risk for such ongoing deficits, as indicated by membership in the High Improving trajectory. Further, adolescents in the High Improving group (showing clinical EF deficits in 8th grade but no longer displaying clinical or subclinical deficits by 10th grade) still had significantly lower GPAs and poorer parent, teacher, and self-reported academic outcomes in 10th grade relative to adolescents who never displayed clinical deficits. This underscores the importance of intervening early as well as continuing to support these adolescents even after their EF difficulties are in the normal limits range. In contrast, adolescents without ADHD, and those with parents without ADHD and with low EF difficulties (within normal limits), were more likely to fall in the Low Stable/Improving or Moderate Stable trajectories and to have better academic outcomes. Strengths of this study include having a subsample of adolescents diagnosed with ADHD, use of a multi-informant and multi-method assessment of academic outcomes (including use of daily assessment from teachers and adolescents), and assessing EF abilities over three timepoints throughout the adolescent developmental period. These findings and their clinical implications are discussed below.

Variability in and predictors of EF abilities during adolescence

Results of the present study support and extend the limited prior research examining trajectories of EF abilities across adolescence (Miller et al., 2013; Qian et al., 2013). Specifically, prior research on the development of EF abilities across adolescence suggests that, on average, all aspects of EF improve during the adolescent developmental period (e.g., Best & Miller, 2010; Boelema et al., 2014). Although understanding development on average is important, it is critical to identify individual variation in such trajectories to identify at-risk youth and intervene accordingly. Consistent with this literature, we found that, on average, adolescents in our sample showed improvements in EF abilities across mid-adolescence. However, for adolescents who exhibit clinical deficits in EF during early adolescence, they either continued to display EF difficulties in the subclinical range (CRI) or just below the subclinical range (ERI and BRI) in mid-adolescence. Additionally, visual inspection of the study data revealed that a small percentage (14%) of adolescents who displayed clinical deficits in EF in 8th grade continued to display clinical levels of EF deficits in 10th grade, but these adolescents were not captured as a separate class due to the relatively small

Table 4. Means and standard errors for academic outcomes of three latent classes for the behavior regulation index

Academic outcomes	Low stable class, M (SE)	Moderate stable class, M (SE)	High improving class, M (SE)	χ^2	Significant group comparisons
Homework performance					
HPQ – PR	2.47 (0.04)	2.31 (0.05)	1.79 (0.06)	81.06***	H < L, M; M < L
HPQ – TR	6.27 (0.10)	5.89 (0.12)	5.29 (0.14)	33.52***	H < L, M; M < L
Motivation for schoolwork and effort put into classwork					
Motivation – TR	2.51 (0.13)	2.61 (0.05)	2.33 (0.06)	12.23**	H < M
Motivation – AR	3.11 (0.09)	3.04 (0.06)	2.84 (0.07)	6.93*	H < L, M
Effort – TR	2.51 (0.13)	2.61 (0.06)	2.37 (0.06)	7.83*	H < M
Effort – AR	3.31 (0.10)	3.16 (0.06)	3.01 (0.06)	7.09*	H < L
Work quality and assignments turned in					
Work quality – TR	2.33 (0.16)	2.39 (0.06)	2.05 (0.06)	14.08**	H < M
Work quality – AR	3.19 (0.10)	3.00 (0.06)	2.90 (0.06)	6.27*	H < L
Assignments turned in	3.91 (0.06)	3.92 (0.05)	3.70 (0.06)	8.50*	H < L, M
GPA	3.43 (0.10)	3.34 (0.06)	2.68 (0.10)	33.32***	H < L, M

Note. HPQ = Homework Performance Questionnaire; PR = parent report; TR = teacher report; AR = adolescent report; GPA = grade point average. Means followed by a common letter are not significantly different. Means followed by a different letter are significantly different; for homework performance and grade point average, different letters denote significant difference at an alpha level of 0.001; for motivation for schoolwork, effort put into classwork, work quality, and assignments turned in, different letters denote significant difference at an alpha level of 0.05. *$p < .05$, **$p < .01$, ***$p < .001$.

Table 5. Means and standard errors for academic outcomes of three latent classes for the emotion regulation index

Academic outcomes	Low improving class, M (SE)	Moderate stable class, M (SE)	High improving class, M (SE)	χ^2	Significant group comparisons
Homework performance					
HPQ – PR	2.45 (0.05)	2.39 (0.05)	1.92 (0.04)	78.41***	H < L, M
HPQ – TR	6.17 (0.12)	5.68 (0.18)	5.55 (0.11)	16.80***	H < L, M
Motivation for schoolwork and effort put into classwork					
Motivation – TR	2.51 (0.12)	2.59 (0.07)	2.41 (0.05)	4.15	–
Motivation – AR	3.15 (0.09)	3.13 (0.09)	2.86 (0.05)	12.65**	H < L, M
Effort – TR	2.54 (0.13)	2.58 (0.09)	2.44 (0.05)	2.34	–
Effort – AR	3.35 (0.09)	3.24 (0.09)	3.02 (0.05)	13.09**	H < L, M
Work quality and assignments turned in					
Work quality – TR	2.38 (0.13)	2.30 (0.10)	2.16 (0.05)	3.67	–
Work quality – AR	3.21 (0.09)	3.06 (0.09)	2.91 (0.05)	9.97**	H < L
Assignments turned in	3.88 (0.06)	3.92 (0.06)	3.76 (0.05)	4.98	–
GPA	3.39 (0.10)	3.37 (0.07)	2.86 (0.07)	28.04***	H < L, M

Note. HPQ = Homework Performance Questionnaire; PR = parent report; TR = teacher report; AR = adolescent report; GPA = grade point average. Means followed by a common letter are not significantly different. Means followed by a different letter are significantly different; for homework performance and grade point average, different letters denote significant difference at an alpha level of 0.001; for motivation for schoolwork, effort put into classwork, work quality, and assignments turned in, different letters denote significant difference at an alpha level of 0.05. *$p < .05$, **$p < .01$, ***$p < .001$.

sample size in the current study. These findings underscore the importance of examining individual developmental pathways rather than change among a group on average, but also suggest that at-risk youth can be identified early given the high stability of difficulty in this at-risk subsample. As such, youth who score in the clinical range of EF difficulties in middle school should be referred for intervention, given evidence that they are likely to stay high in EF deficits into high school.

Accordingly, understanding risk factors for which youth fall into this subsample is critical. Prior research has linked individual and family factors such as IQ and SES to the development of EF abilities (e.g., Hackman et al., 2015, Hughes & Ensor, 2009). Our study sought to examine individual and family factors, specifically parent ADHD and EF and adolescent ADHD status that are more readily addressed via intervention. Our findings support and add to the limited research with community samples linking parent EF and ADHD status to adolescent EF (Friedman et al., 2008; Jester et al., 2009), which found adolescent EF to be significantly associated with parent EF/genetic factors, independent of IQ between the ages of 12–17 years using performance-based measures of EF. However, in our sample, this finding was only supported for the BRI and CRI, as difficulties in these two indices map on more directly with deficits in parent EF abilities. Given emerging evidence that behavioral ratings of EF are ecologically

Table 6. Means and standard errors for academic outcomes of three latent classes for the cognitive regulation index

Academic outcomes	Low stable class, *M (SE)*	Moderate stable class, *M (SE)*	High improving class, *M (SE)*	χ^2	Significant group comparisons
Homework performance					
HPQ – PR	2.55 (0.03)	2.39 (0.04)	1.80 (0.05)	157.44***	H < L, M; M < L
HPQ – TR	6.32 (0.08)	6.16 (0.08)	5.19 (0.12)	60.22***	H < L, M
Motivation for schoolwork and effort put into classwork					
Motivation – TR	2.58 (0.08)	2.61 (0.07)	2.36 (0.05)	9.41**	H < L, M
Motivation – AR	3.23 (0.09)	3.06 (0.09)	2.83 (0.06)	14.97**	H < L, M
Effort – TR	2.56 (0.09)	2.62 (0.06)	2.38 (0.05)	8.17*	H < M
Effort – AR	3.41 (0.08)	3.22 (0.07)	2.97 (0.06)	21.58***	H < L, M
Work quality and assignments turned in					
Work quality – TR	2.38 (0.13)	2.43 (0.07)	2.06 (0.06)	18.54***	H < L, M
Work quality – AR	3.28 (0.09)	3.11 (0.07)	2.83 (0.05)	23.61***	H < L, M
Assignments turned in	3.97 (0.04)	3.96 (0.04)	3.69 (0.06)	18.44***	H < L, M
GPA	3.57 (0.07)	3.40 (0.06)	2.71 (0.08)	69.34***	H < L, M; M < L

Note. HPQ = Homework Performance Questionnaire; PR = parent report; TR = teacher report; AR = adolescent report; GPA = grade point average. Means followed by a common letter are not significantly different. Means followed by a different letter are significantly different; for homework performance and grade point average, different letters denote significant difference at an alpha level of 0.001; for motivation for schoolwork, effort put into classwork, work quality, and assignments turned in, different letters denote significant difference at an alpha level of 0.05.
$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

valid and offer distinct, complementary information to performance-based measures (Nyongesa et al., 2019), our examination of these relations using behavioral ratings of parent and adolescent EF is an important addition to the literature. Additionally, this is the first study to examine this association in adolescents with ADHD, a clinical sample characterized by EF difficulties. Our findings indicate that parents who have high levels of EF difficulties are more likely to have adolescents who continue to display high levels of EF deficits throughout adolescence, as well as adolescents with moderate deficits that improve during adolescence. Given this, it will be important for future research to examine how assessing or targeting parent EF abilities may lead to improvements in youth EF abilities over time. Based on our current findings, adding components to help parents address their own potential difficulties with aspects of EF, such as available in current adult interventions (e.g., Hepark et al., 2019; Mitchell et al., 2017), may promote accelerated attainment of positive clinical outcomes. Further, interventions could have parents and adolescents work together on their own EF abilities, where parents could model engagement in the intervention.

Similarly, we found that youth with ADHD were significantly more likely to display High Improving EF difficulties (and less likely to display Low Stable/Improving or Moderate Stable EF difficulties) relative to adolescents without ADHD. This is consistent with prior research suggesting a developmental lag in EF skills and significant EF difficulties on average among youth with ADHD (e.g., Willcutt et al., 2005). Although ADHD is a neurodevelopmental disorder, interventions can help reduce the frequency of symptom occurrence and reduce impairment associated with the disorder (see Evans et al., 2018), with medication being better at reducing symptoms but behavior therapy leading to the greatest impact on impairment (Sibley et al., 2014). In particular, interventions targeting organization, time management, and planning difficulties among adolescents with ADHD may prove particularly useful in addressing impairment and provide opportunities to rehearse skills that will improve EF abilities with time.

Association between EF trajectories and academic outcomes

This study also adds to the literature by examining associations among various developmental trajectories and academic outcomes. Membership in the High Improving and, to a lesser extent, the Moderate Stable EF trajectories was significantly associated with worse academic outcomes based on an objective measure (i.e., GPA) and parent, teacher, and adolescent report, including poorer homework performance, work quality, motivation, and effort, and less teacher-reported assignments turned in. These findings are consistent with prior research showing the robust association between EF abilities and academic performance (e.g., Allan et al., 2014; Zelazo et al., 2016), and importantly, extend these findings to daily adolescent and teacher ratings of academic performance during the school week.

Collectively, these findings suggest that higher levels of EF deficits in early adolescence may hinder implementation of adaptive self-regulatory strategies that are critical for academic success during the transition from middle school to high school. These findings are noteworthy as academic demands increase rapidly during middle school including greater demands on organizational and planning abilities over extended periods of time with less external supports (Eccles, 2004; Rudolph et al., 2001), which requires the development of better self-regulation in response (Burnett et al., 2013). These demands are only heightened during high school with more challenging courses, higher levels of independence for completing assignments, large exams, and long-term projects occurring throughout the semester (Jacobson et al., 2011). As such, adaptation to the academic demands of middle and then high school is significantly impacted by children's performance-based EF skills (Jacobson et al., 2011; Langberg et al., 2013). Accordingly, and as these trajectories indicate, it is highly important to assess for and intervene on EF difficulties during middle school to improve the trajectory of academic performance in the critical transition from middle to high school. Since EF has been shown to predict high school completion and college performance and graduation (Dvorsky & Langberg, 2019;

McClelland et al., 2013; Vitaro et al., 2005), the High Improving trajectory may be at a greater risk for negative outcomes (e.g., high school dropout) if such EF difficulties are not addressed. Taken together, our results indicate that adolescents with subclinical and clinical levels of EF deficits may benefit from targeted interventions for improving EF deficits during the middle school years.

Clinical implications

Given our finding that youth with ADHD were more likely to fall in the High Improving trajectory, with membership in these being associated with poorer academic outcomes, existing skills-based interventions that provide repeated opportunities to improve EF abilities may offer a promising direction for improving academic outcomes for these at-risk adolescents. Interventions for students with ADHD exist at both the middle school (e.g., Langberg et al., 2018) and high school (e.g., Sibley, 2016) level, and have resulted in improvements in objective (i.e., GPA) and parent/teacher-reported outcomes (e.g., Breaux et al., 2019). These interventions target EF deficits by providing the necessary strategies to meet the increasing academic demands that adolescents face during the transition to middle and high school (e.g., breaking larger assignments into chunks and plan for when to complete the various components). Moreover, some of these interventions also work with parents to support adolescents in acquiring these strategies and skills, such as by providing incentives for meeting targeted goals, and discussing strategies for better organization. Given our finding that parent EF ability predicted differential EF trajectories, such interventions could also add components specifically targeting parent EF to ensure that parents have the necessary tools to support their adolescents. Alternatively, there are standalone interventions targeting EF abilities in adults (e.g., Hepark et al., 2019; Mitchell et al., 2017). Similarly, the impact of such adult-focused interventions on parenting behaviors and youth EF abilities is an important area for future research.

Finally, our findings highlight the clinical utility and ecological validity of using parent-reported behavioral ratings to capture impairment and change in adolescent EF over time. Parent-reported behavioral ratings may provide an efficient and effective means of early identification and intervention for adolescents with subclinical and clinical levels of EF deficits, and may protect these at-risk adolescents from worse academic outcomes. It will be critical for future research to explore whether teacher-reported ratings of EF deficits in adolescents can prove equally effective, given that such ratings would be easier for schools to implement.

Limitations

The findings and clinical implications of this study should be interpreted within the context of several limitations. First, several questions on the BRIEF-2 ask about abilities that directly overlap with DSM-5 criteria for mental health disorders (including ADHD). It is important to acknowledge that this might potentially limit our findings and therefore, an examination of the study aims which utilizes performance- and report-based measures of EF in future research is warranted. Second, despite a strength of the study being our assessment of adolescent EF abilities across three timepoints, and during the transition from middle to high school, our knowledge about changes in EF abilities is somewhat limited by the unequal spacing across time points (i.e., two timepoints in 8th grade, none in 9th grade, and one in 10th grade). In particular, 9th grade is when many students enter high school, so understanding predictors of which students are and are not able to rise to the increased challenges during this time would be beneficial. Third, parent EF was measured at our second time point; however, since EF abilities are relatively stable during middle adulthood (Friedman et al., 2016) this is less of a concern. Fourth, since our data included measures of adolescent EF abilities at three timepoints, only linear models could be estimated. Future research should include a larger number of timepoints to capture a potentially more accurate representation of trajectories of EF development across adolescence (e.g., quadratic). Finally, our sample was predominately white and from a middle to high SES. Given that EF abilities differ based on SES (e.g., Last et al., 2018), and that EF abilities explain some of the socioeconomic and racial differences in academic achievement (Nesbitt et al., 2013), it is critical for future research to include more diverse samples.

Conclusion

This study provides important insight into EF development across adolescence in a sample of adolescents with and without ADHD. Findings underscore that although the majority of youth experience improvements in EF abilities across the adolescent developmental period, youth who exhibit clinically significant deficits in early adolescence continue to display subclinical or just below subclinical deficits, with adolescents with ADHD and parents with ADHD and poor EF abilities being more at-risk for displaying this at-risk developmental trajectory. Further, findings indicate that clinical EF difficulties in 8th grade are associated with worse academic outcomes in 10th grade, even for adolescents who improve in EF abilities from 8th to 10th grade. Together these findings highlight that intervention efforts to target EF abilities of adolescents, particularly with ADHD, and their parents could help reduce risk for negative academic outcomes.

Funding statement. This research was supported by the Institute of Education Science (IES), U.S. Department of Education (grant R305A160126), PI: Joshua M. Langberg and Stephen P. Becker.

Competing interests. None.

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