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Charles B. Fleming

Amy L. Stevens

Marla Vivero

Irina Patwardhan

Timothy D. Nelson

See next page for additional authors

Authors

Charles B. Fleming, Amy L. Stevens, Marla Vivero, Irina Patwardhan, Timothy D. Nelson, Jennifer Mize Nelson, Tiffany D. James, Kimberly Andrews Espy, and W. Alex Mason

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Executive Control in Early Childhood as an Antecedent of Adolescent Problem Behaviors: A Longitudinal Study with Performance-based Measures of Early Childhood Cognitive Processes

Charles B. Fleming,[1] Amy L. Stevens,[2] Marla Vivero,[3] Irina Patwardhan,[2] Timothy D. Nelson,[3] Jennifer Mize Nelson,[3,4] Tiffany D. James,[4] Kimberly Andrews Espy,[5] and W. Alex Mason[6]

1. Center for the Study of Health and Risk Behaviors, University of Washington, 1100 NE 45th St., #300, Seattle, WA 98195, USA
2. Boys Town, Child and Family Translational Research Center, 13971 Flanagan Blvd., #101, Boys Town, NE 68010, USA
3. Department of Psychology, University of Nebraska–Lincoln, 238 Burnett Hall, Lincoln, NE 68588, USA
4. Office of Research and Economic Development, University of Nebraska–Lincoln, 301 Canfield Administration, Lincoln, NE 68588, USA
5. Office of the Provost and Vice President for Academic Affairs, University of Texas at San Antonio, One UTSA Circle, Main Building, Suite 4.120, San Antonio, TX 78249, USA
6. Department of Preventive Medicine, University of Tennessee Health Science Center, 66 N. Pauline St., Suite 637, Memphis, TN 38163, USA

Corresponding author – Charles B. Fleming, email cnbflem@u.washington.edu

Abstract
Identifying childhood cognitive processes that predict adolescent problem behaviors can help guide understanding and prevention of these behaviors. In a community sample of 313 youth recruited in a small Midwestern city between 2006 and 2012 (49% male, 64% European American), executive control and foundational cognitive abilities were assessed at age 5 in a lab setting with performance-based measures. In adolescence, youth provided self-report of problem behaviors in surveys administered annually between ages 14 and 16. Executive control was negatively associated with externalizing behavior problems and adolescents getting in trouble at school, accounting for foundational cognitive abilities and family background covariates. Executive control had negative but nonsignificant associations with internalizing problems and substance use initiation. The findings point to deficits in executive control as a childhood risk factor for later problems and a potential target for preventive interventions.

Keywords: executive control, foundational cognitive abilities, externalizing problems, internalizing problems, substance use

Introduction

Executive control, sometimes referred to as executive function (Diamond 2013), consists of mental abilities for intentionally directing thoughts, emotions, and behaviors (Espy et al. 2016). Extensive prior research has linked executive control—as well as related constructs of hyperactivity, attention problems, impulsivity, emotion dysregulation, poor self-regulation, and lack of effortful control—to later problem behaviors (Moffitt et al. 2011; Nelson et al. 2019; Sibley et al. 2014). Most of this research has relied on parent-, teacher-, or self-report of childhood deficits in inhibition or impulse control, clinical diagnosis of attention deficit disorder, or measures based on performance-based tasks that do not distinguish between executive control and foundational cognitive abilities. Foundational cognitive abilities include visual/spatial perception, sensory processing, verbal abilities, and concept formation and underlie performance of a wide array of cognitive tasks (Espy et al. 2016). With the limitations of prior research in mind, the current study used performance-based measures of executive control and foundational cognitive abilities to examine whether these aspects of childhood cognitive processes are antecedents of multiple adolescent behavior problems, including substance use, externalizing problems, getting into trouble in school, and internalizing problems.

Childhood Antecedents of Adolescent Problem Behaviors

Early adolescence is characterized by the emergence of a constellation of risky and problem behaviors. One of these behaviors is substance use. According to nationwide US data from 2019, initiation prevalence by 10th grade (approximately age 16) was 42% for alcohol, 15% for cigarettes, and 31% for marijuana (Johnston et al. 2020). Early substance initiation is a form of rule breaking and risk taking for adolescents commonly associated with externalizing behaviors that include other forms of rule-breaking and risk taking, such as defiance, conflict with peers, and aggression (Farmer et al. 2016). Externalizing behaviors during this developmental period often take place at school and result in adolescents getting into

trouble with school staff. Another correlate of early substance use is internalizing problems (Hussong et al. 2011). Depression and anxiety can increase in early adolescence, with prevalence of depression showing particularly large increases among girls (Chaplin et al. 2009; Van de Velde et al. 2010), and may be associated with use of substances to cope with negative emotions (Cooper 1994).

Given the overlap between substance use initiation, externalizing problems (including troubles at school), and internalizing problems, it is important to understand the degree to which early childhood risk factors that can be targeted by prevention efforts have unique or shared associations with those outcomes. Unique risk factors suggest specific intervention targets that might alter developmental pathways leading toward particular outcomes, whereas shared risk factors suggest a common set of intervention targets that could impact an array of problem and risky behaviors.

Research on constructs related to executive control has commonly relied on either survey-based measures of child behaviors thought to reflect underlying deficits in cognitive processes (e.g., Kertz et al. 2016; Pentz and Riggs 2013) or on clinical diagnoses for disorders such as attention deficit hyperactivity disorder (Charach et al. 2011; Sibley et al. 2014). These measurement approaches have limitations. Parent-report measures are subject to systematic error confounded with parent background and the parents' own temperament; teacher reports are limited to characterization of behavior patterns in the school context, which may not be representative of how children behave outside the classroom; and child self-reports are subject to social desirability bias and have limited value until children are into the middle of their elementary school years. Clinical diagnoses are limited by not being sensitive to variation at the subclinical level for constructs that are dimensional in nature. Due to the limitations of these methods of measuring executive dysfunction, it would be preferable to have a performance-based approach.

Measurement of Executive Control in Childhood

The current study builds off work that has developed performance-based measures of cognitive processes, administered in a controlled laboratory setting (Espy et al. 2016). Executive control itself has three components: working memory, inhibitory control, and flexible shifting (Espy et al. 2016). These components overlap, however, and may not be distinct from one another in early childhood, suggesting that executive control in the preschool years is best modeled as a unitary construct (Nelson et al. 2016; Wiebe et al. 2011), whereas executive control appears to differentiate into its distinct components later in development (Brydges et al. 2014; Lee et al. 2013). In measuring executive control in early childhood, it is important to account for variation in foundational cognitive abilities, because they affect performance on executive tasks.

To avoid conflating executive control with foundational cognitive abilities, a bi-factor structural equation modeling approach was developed (Espy et al. 2016), in which orthogonal latent factors are specified, with a foundational cognitive abilities factor having loadings both on widely used indicators of foundational cognitive abilities (Woodcock et al. 2001) as well on multiple executive control tasks designed to measure working memory, inhibitory control, and flexible shifting. In this model, the executive control factor is

indicated by residual variation in the executive control task scores after accounting for foundational cognitive abilities. This approach results in a measure of executive control independent of foundational cognitive abilities. Further, the measurement approach avoids limitations of survey measures and is sensitive to subclinical variation in dimensional constructs.

Executive Control and Adolescent Problem Behaviors

Executive control may be directly linked with substance use and externalizing behaviors, both within and outside the school context, through each of the three dimensions of executive control that emerge as distinct components later in childhood and early adolescence (Nelson et al. 2019). Working memory involves holding information in the mind over a period of time and may be activated when weighing behaviors such as alcohol consumption, defiance of parents, or escalation of conflict with peers in relation to norms and rules and to likely future negative consequences. Inhibitory control enables individuals to control impulses to engage in risky behaviors or use maladaptive coping strategies that may be rewarding in the short term or provide immediate relief when under emotional distress. Finally, flexible shifting allows for considering alternative behaviors, some of which will be constructive and safe. Working together, all three dimensions of executive control might, through controlling attention, emotions, and behaviors, protect against engaging in risky or problem behavior.

Executive control may also play a role in lessening internalizing problems (Nelson et al. 2018). Generally, executive control can be utilized to activate processes that neutralize stress, depression, or anxiety symptoms (Koster et al. 2011). Strong working memory can make individuals resilient to short-term disappointments by helping them weigh long-term goals and rewards against short-term disappointments. Inhibitory control allows individuals to reign in negative thoughts and emotions and disrupt negative feedback cycles. Flexible shifting helps individuals consider emotional or social problems from different angles, rather than focusing on one negative and destructive interpretation. Again, all three dimensions working together allow for constructive problem solving, leading to more positive mindset and behaviors and reduced internalizing problems.

Research has found evidence for associations between deficits in executive control (both globally and specific aspects of executive control) and health-compromising behaviors, including adolescent substance use (Nelson et al. 2019). Much of this research has been based on cross-sectional or short-term longitudinal designs (e.g., with measures of executive control from late childhood or early adolescence) and a narrow focus on specific aspects of executive control, most commonly inhibitory control, studied in isolation. A smaller literature has used longer-term longitudinal data and task performance measurement of executive control using multifaceted, performance-based task batteries (e.g., Sitnick et al. 2017).

An earlier study using data from the same ongoing longitudinal project that provided data for the current study found that poor executive control in preschool, represented in a bi-factor model with foundational cognitive abilities, predicted both greater depression and anxiety symptoms in late elementary school, pointing to the role that executive control may play in regulating emotions and the emergence of internalizing problems in

childhood (Nelson et al. 2018). In this study, the unique association with oppositional defiant symptoms was smaller and nonsignificant, with foundational cognitive abilities appearing to be the more salient precursor. Another study from this project examined the role of executive control and foundational cognitive abilities in predicting broader constructs of adaptive and maladaptive functioning in late elementary school (Mason et al. 2020), and found that both executive control and foundational cognitive abilities were negatively associated with a measure of maladaptive functioning that included both internalizing and externalizing behaviors in childhood. Neither study extended into the critical period of adolescence, nor included substance use and getting into trouble in school as well as internalizing and externalizing problems. The current study includes all of these outcomes with a goal of understanding the degree to which executive control has unique versus shared associations with multiple correlated adolescent outcomes.

Current Study

This study extended prior work by examining executive control and foundational cognitive abilities in preschool, represented in a bi-factor model with performance-based measures assessed in a laboratory setting, as predictors of early adolescent initiation of substance use, externalizing behaviors (without reference to a specific context), getting into trouble in school, and internalizing problems. Analyses controlled for family socioeconomic status, family history of alcohol problems, and child sex and age, all of which may have associations with early childhood cognitive processes (Clark et al. 2016; Mason et al. 2020) and may also be associated with adolescent problem behaviors (Chassin et al. 1997; Farrington et al. 2016). Further, given sex differences in the emergence of internalizing problems in adolescence, this study examined whether associations between executive control and foundational cognitive abilities in early childhood and early adolescent behavioral outcomes differ by sex. The guiding hypothesis was that preschool executive control would be negatively associated with early adolescent problem behaviors. Specific relationships with different dimensions of problem behavior were assessed, but prior research led to the hypothesis that there would be associations with both externalizing and internalizing problems and that negative associations would also be present for the related constructs of substance use initiation and getting into trouble in school. Analyses concerning differences in associations by sex were exploratory, although this study tested the hypothesis that the association between executive control and internalizing problems would be stronger for girls, for whom internalizing problems in adolescence are more common than among boys (Chaplin et al. 2009; Van de Velde et al. 2010).

Methods

Participants

Data are from 313 children (48.9% male) who are part of an ongoing project examining the development of executive control and its relationship with a range of health outcomes (Espy et al. 2016). Families with preschool age children were recruited from a small Midwestern city between 2006 and 2012. Bilingual children, for whom English might not be

the primary language spoken, and children diagnosed with speech or language delays at enrollment or by the end of the elementary school phase of the study were excluded since language ability can affect performance on executive control tasks and the study aimed to capture the development of executive control in a typically developing sample. Children with a diagnosed developmental or behavioral disorder prior to enrollment and families who were planning to move from the area were excluded, but the project did not exclude children diagnosed with a behavioral or emotional disorder after enrollment.

Children who completed an age 5 years and 3 months laboratory visit and were followed in subsequent phases of the study compose the sample for the current study. The racial/ethnic composition of the sample is 63.6% European American, 13.4% Hispanic, 3.8% African American, 0.3% Asian, and 18.8% multiracial, similar to the population of the area in which the project took place during the enrollment period. The last phase of recruitment, during which 108 families were enrolled, oversampled for socioeconomic risk. Out of the analytic sample used in the current study, 53.7% received public medical assistance and 37.1% were households headed by one parent at enrollment. The median household income at enrollment was $42,000 per year, and 39.8% of mothers had a college or post-graduate degree. More information on the preschool age period of the project is available elsewhere (James et al. 2016).

Procedures

Measures of family socioeconomic status and family history of alcohol problems were gathered at enrollment from a background survey completed during the family's first laboratory visit. The sample was enrolled in four cohorts (ages 3 years, 3 years 9 months, 4 years 6 months, and 5 years 3 months) and assessed in a lab setting with a battery of executive control tasks every 9 months through the age 5 years and 3 months laboratory session. At the end of the preschool phase (age 5 years 3 months for 244 youth participants in the sample of the current study, but age 6 years for 69), children completed the Woodcock-Johnson-III Brief Intellectual Assessment (WJ-III; Woodcock et al. 2001) to assess foundational cognitive abilities. In a second phase of the project, children were followed annually from grades one through four, including laboratory visits and surveys of teachers.

An adolescent phase of the project provided data for the outcomes in the current study. Beginning in 2017, participants were assessed annually around the time of their birthdays from ages 14 through 18. These assessments involved both an in-person lab visit, during which the Youth Self Report survey (YSR; Achenbach 1991) was administered to youth, and a phone survey that included questions about getting into trouble in school and substance use initiation. The adolescent phase extends the cohort-sequential design of this ongoing project, with participants ranging from age 10 to 16 years at the beginning of adolescent data collection. In other words, some participants were not yet 14 by the end of the first year of data collection and some were already beyond their 16th birthday when data collection for the adolescent phase started. The current study used data collected through March of 2020, by which time a majority of participants were old enough to provide data on early adolescent outcomes. Out of the 313 children who participated at 5 years 3 months, 208 completed at least one in-person age 14–16 assessment and 229 completed at least one phone survey. Measures of externalizing and internalizing problems and

getting in trouble in school were based on average scores across available time points. For the two YSR measures, these average scores were based on one time point of data for 79 participants, two time points for 76, and three for 53; for the trouble in school measure, scores were based on one time point of data for 84 participants, two time points for 94, and three for 64. The measure of substance use initiation was based on the last age 14–16 survey completed, which was age 14 for 47 participants, age 15 for 51, and age 16 for 131.

Of the 313 who completed the age 5 years 3 months assessment, those providing no data at the adolescent time points were primarily from families who declined to participate in the adolescent phase or could not be located. Those families missing at the adolescent follow-up period did not significantly differ from those who completed adolescent assessments with respect to sex of child. There were differences by indicators of socioeconomic status. At baseline, compared to families who did at least part of the adolescent assessments, families lost to follow-up had lower mean income-to-needs ratio than those retained in the adolescent phase ($d = 0.28$, $p = 0.033$) and were headed by mothers with less education ($d = 0.36$, $p = 0.005$). Adult participants in the project gave informed consent, and child participants gave assent during the child and adolescent phases. The Institutional Review Board of the University of Nebraska–Lincoln approved all procedures.

Measures

Preschool executive control and foundational cognitive abilities

Executive control was measured with nine tasks, administered during a laboratory session, that assess working memory, inhibitory control, and flexible shifting (Espy et al. 2016; James et al. 2016). Tasks measuring *working memory* were Nine Boxes (adapted from Diamond et al. 1997), Delayed Alternation (Espy et al. 1999; Goldman et al. 1971), and Nebraska Barnyard (adapted from Noisy Book; Hughes et al. 1998). *Inhibitory control* tasks were Big-Little Stroop (adapted from Kochanska et al. 2000), Go/No-Go (adapted from Simpson and Riggs 2006), Shape School-Inhibit Condition (Espy 1997; Espy et al. 2006), and Snack Delay (adapted from Kochanska et al. 1996; Korkman 1998). *Flexible shifting* was measured with Shape School-Switching Condition (Espy 1997; Espy et al. 2006) and Trails-Switching Condition (modified from Espy and Cwik (2004)) tasks. Indicators of the preschool foundational cognitive abilities factor were measured at the end of the preschool period (age 5 years 3 months or 6 years) with the Verbal Comprehension, Concept Formation, and Visual Matching subtests from the Woodcock Johnson WJ-III (Woodcock et al. 2001). In the analysis models, executive control and foundational cognitive abilities were specified as latent variables using the bi-factor model (Espy et al. 2016), wherein all the executive control tasks load on both executive control and foundational cognitive abilities factors, the foundational cognitive abilities factor loads also on WJ-III scores, and the correlation between executive control and foundational cognitive abilities is constrained to zero. The models provide a measure of executive control in which variance in task performance due to foundational cognitive abilities is accounted for, creating a measure of executive control independent of foundational cognitive abilities.

Adolescent externalizing and internalizing problems

Measures of externalizing and internalizing problems came from the YSR (Achenbach 1991). Items in the YSR offer response options of 0 = Not true, 1 = Somewhat or sometimes true, and 2 = Very true or often true. The broadband externalizing problems scale is the sum of scores on items from the syndrome scales of rule-breaking and aggressive behavior. The broadband internalizing problems scale is the sum of scores on items from syndrome scales of anxious/depressed, withdrawn/depressed, and somatic complaints. For both measures, averaged raw scores on these scales across all available age 14–16 time points were used. Both the externalizing and internalizing scores were positively correlated across time points (rs = 0.43–0.79).

Getting into trouble in school

A measure of getting into trouble in school was based on the sum of seven items that asked how often participants had been in trouble during the prior year for misbehavior or non-compliance of varying levels of severity including disrupting class, skipping class, talking back to teachers, and not handing homework in on time. Alpha = 0.76. Each item offered response options ranging from 0 = never to 7 = 40+ times. As with externalizing and internalizing problems, scores were averaged across available age 14–16 time points. Correlations across adjacent time points were $r = 0.61$ between age 14 and 15 and $r = 0.45$ between ages 15 and 16.

Substance use initiation

In each adolescent phone survey, participants were asked about lifetime use of substances including alcohol, cigarettes, smokeless tobacco, and marijuana. Substance use initiation was a dichotomous measure based on whether a participant reported lifetime use of alcohol (more than a sip), cigarettes, smokeless tobacco, or marijuana by the last interview completed. For example, initiation was based only on the age 14 survey for those that only completed the age 14 survey, but was based on initiation by age 16 for those who completed an age 16 survey.

Covariates

The age of participants at the last phone survey completed was included as a covariate, ranging from 14 to 16 years. Child sex, coded 1 = male and 0 = female, was included as a covariate and was also used to define groups for multiple group analyses. Two measures of family socioeconomic status were based on mother's highest level of education and family income-to-needs ratio, both assessed in the parent intake interview at enrollment in the project. Income-to-needs ratio was log transformed to reduce the influence of outliers and both measures of socioeconomic status were *z*-scored. Family history of alcohol problems was based on an item in the intake interview that asked if any of the child's biological parents or grandparents had ever been "diagnosed or treated" for an alcohol problem (coded 0 = no family history of alcohol problem, 1 = family history of alcohol problems).

Analysis

Models were estimated with Mplus version 8 (Muthén and Muthén 2017). Specification of the bi-factor model was the same as in prior project studies (Espy et al. 2016; Mason et al. 2020; Nelson et al. 2018), including correlating the residual error terms for the two Shape School indicators (i.e., the Inhibit and Switching conditions) because of shared stimuli and response format. An initial Confirmatory Factor Analysis (CFA) model was run to assess overall associations among all study variables. In this model, all measured variables were treated as normal and continuous, and Maximum Likelihood Robust estimation was used with the assumption that data were missing at random (MAR) after taking into account all model covariates. As noted above, the primary source of missing data was noncompletion of surveys during the adolescent phase of the project, with those lost to follow-up being more like to come from lower income families than those who completed adolescent surveys. Inclusion of income-to-needs ratio in the CFA model thus partially accounts for this source of differential attrition. For the structural model, each adolescent outcome was regressed simultaneously on executive control, foundational cognitive abilities, and the background covariates. All exogenous variables were allowed to correlate, except no correlation was estimated between executive control and foundational cognitive abilities, since the bi-factor model specifies those factors as orthogonal. In addition, correlations among the residuals of the outcome variables were estimated. In the final structural model, substance use initiation was specified as dichotomous with a probit model, and the Weighted Least Squares Mean and Variance adjusted (WLSMV) estimator was used. The WLSMV estimator also allows for the inclusion of cases with partially missing data and, in the case of our models, adjusts for differential attrition associated with family income, although information from a more limited portion of the covariance matrix is used in accounting for missing data than in full information maximum likelihood estimation (Muthén and Muthén 2017).

Multiple group analyses were used to compare associations between early childhood cognitive processes and adolescent outcomes by sex of the youth participant. First, invariance in the bi-factor measurement model was assessed for configural, metric, and scalar invariance (Dimitrov 2010; Pendergast et al. 2017). The fit of the configural invariance model was assessed by examining model chisquare and comparative fit indices, using guidelines for adequate and good fit (Hu and Bentler 1999; Marsh et al. 2004). In comparing the metric invariance model (in which factor loadings were constrained to equality across groups) and the scalar invariance model (in which factor loadings and indicator intercepts were constrained to equality across groups), differences in model chi-square were assessed relative to changes in model degrees of freedom. Second, invariance in the structural paths from executive control and foundational cognitive abilities to adolescent outcomes was tested. In testing the invariance of the structural model, paths from all other covariates to adolescent outcomes and covariances among adolescent behavioral outcomes were constrained to equality across groups. Again, change in fit was assessed, although since these models used the WLSMV estimator to handle the binary outcome of substance use initiation, the chi-square difference test based on model parameter derivatives was employed (Muthén and Muthén 2017). A statistical significance criterion of $p < 0.05$ was used.

Results

Single Group Models

The initial CFA model fit the data well, (χ^2(df) = 189.93 (134), p = 0.001, RMSEA = 0.037; CFI = 0.95). The overall associations among model variables and descriptive statistics are shown in Table 1. Almost all (99%) adolescents reported at least some externalizing and internalizing problems, and only 20% reported no instances of getting into trouble in school. Over a quarter (28%) reported initiating substance use.

Table 1. Correlations among model variables from the confirmatory factor analysis model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Executive control											
(2) Foundational cognitive abilities	0.00										
(3) Sex (0 = female, 1 = male)	−0.19*	−0.06									
(4) Family income to needs	−0.07	0.39***	0.09								
(5) Mother's educational attainment	0.06	0.46***	−0.03	0.55***							
(6) Age at last assessment	−0.25*	0.36***	−0.08	0.41***	0.33***						
(7) Family history of alcohol problems	0.06	−0.10	0.02	−0.22***	−0.22***	−0.08					
(8) Externalizing problems	−0.28*	−0.12	0.09	−0.16*	−0.19**	−0.04	0.21**				
(9) Internalizing problems	−0.15	−0.01	−0.34***	−0.13	−0.04	−0.03	0.15*	0.54***			
(10) Trouble in school	−0.32**	−0.17*	0.19**	−0.22***	−0.22***	−0.14*	0.19**	0.53***	0.12		
(11) Substance use initiation	−0.12	−0.09	0.05	−0.12	−0.07	0.06	0.22**	0.38***	0.17*	0.34***	
M	0	0	0.49	0.00	0.00	15.37	0.33	11.16	14.69	3.41	0.28
SD	1	1	0.50	1.00	1.00	0.64	0.47	7.20	9.91	4.40	0.45

*p < 0.05, **p < 0.01, ***p < 0.001

Correlations among all the adolescent outcomes were positive and statistically significant. Foundational cognitive abilities was significantly and negatively associated with getting in trouble in school. Executive control was negatively associated with all adolescent outcomes, although the associations with internalizing problems and substance use initiation were not statistically significant. Age was negatively associated with both foundational cognitive abilities and executive control as well as with measures of SES. This is likely due to the oversampling of economically disadvantaged families at the end of the preschool phase of data collection; children recruited at the end of this phase were younger during the adolescent phase of data collection. Foundational cognitive abilities had statistically significant negative associations with family SES, as found in prior studies (e.g., Clark et al. 2016; Mason et al. 2020). Executive control was lower among male children.

Fit of the structural model was acceptable (χ^2(df) = 204.99 (134), p < 0.001, RMSEA = 0.041; CFI = 0.92). Estimates for the structural model are shown in Figure 1 as well as in Table A (see supplementary material). Controlling for foundational cognitive abilities and the covariates, the executive control factor had statistically significant and negative unique

associations with externalizing problems (β = −0.26, p = 0.014) and getting in trouble in school (β = −0.28, p = 0.001). Executive control had nonsignificant negative associations with internalizing problems (β = −0.19, p = 0.051) and substance use initiation (β = −0.14, p = 0.333). Foundational cognitive abilities had small negative and nonsignificant associations with all of the adolescent outcomes. Both externalizing problems and substance use initiation were significantly predicted by family history of alcohol problems, and internalizing problems were uniquely associated with sex, with girls reporting more internalizing problems than boys. Girls, on the other hand, reported less getting into trouble in school. Residual variation in substance use initiation was positively associated with all of the other adolescent outcomes, although the association with internalizing problems was not statistically significant.

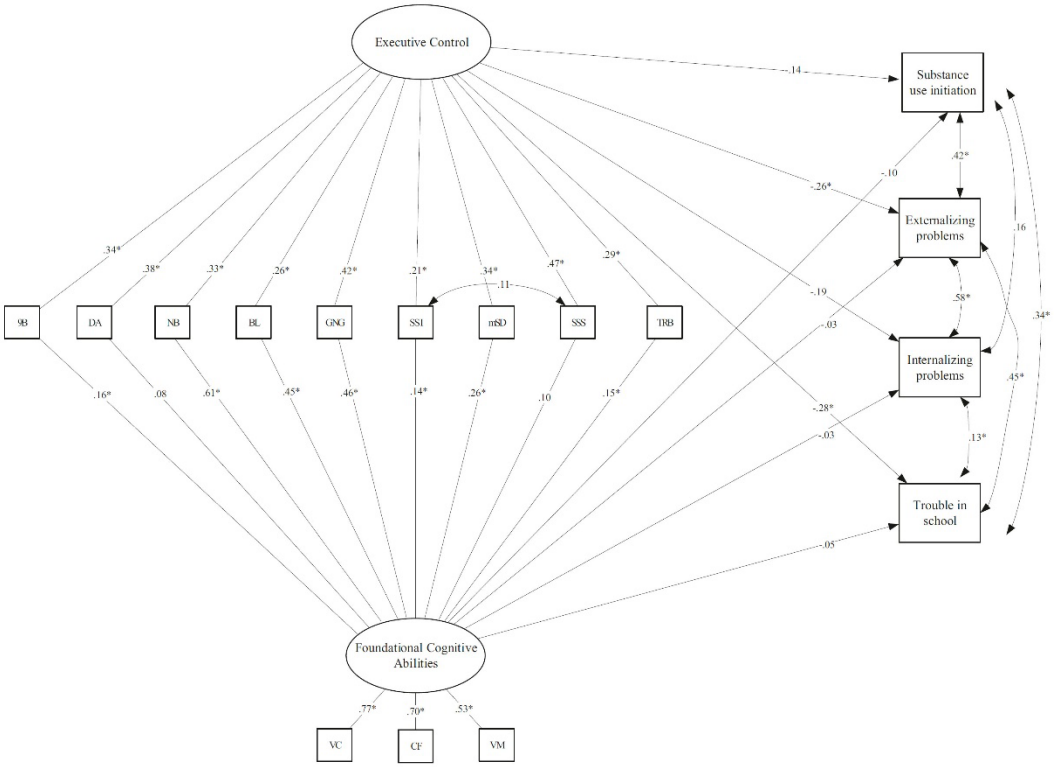

Figure 1. Bi-factor model of executive control and foundation cognitive abilities predicting early adolescent behavioral outcomes. Standardized coefficients are shown. Standard errors, exact p values, paths from sociodemographic covariates, and covariances among predictors reported in online supplementary Table A. *$p < 0.05$

Multiple Group Models

Multiple group tests of invariance by sex in the bi-factor measurement model for executive control and foundational cognitive abilities revealed a good fit for the configural invariance model (χ^2(df) = 112.70 (88), p = 0.039, RMSEA = 0.042; CFI = 0.96), indicating the pattern of specification of latent factors to indicators functioned well and similarly for boys and

girls. There was minimal decrement in fit when metric invariance constraints of equality in factor loadings were imposed ($\delta\chi^2(\delta df) = 16.73$ (19), $p = 0.608$), which suggests that the patterns of correlations among indicators within constructs were similar across sex. There was a decrement in fit from between the metric and scalar invariance model ($\delta\chi^2(\delta df) = 25.32$ (10), $p = 0.005$), pointing to a difference in pattern of intercepts among indicators. This difference is relevant when comparing means of the constructs by sex. Our primary research questions concerned potential differences in relationships between the executive control and foundational cognitive abilities constructs and adolescent behaviors, however, and the difference in fit between the scalar and configural invariance models was nonsignificant ($\delta\chi^2(\delta df) = 39.51$ (29), $p = 0.092$). Based on this, the scalar invariance model was retained in the test of invariance in the structural model.

Multiple group analyses testing the invariance of structural paths from executive control and foundational cognitive abilities to adolescent outcomes also did not provide strong evidence of differences by sex. The difference in fit between models in which those structural paths were constrained and unconstrained across groups (while all other paths were constrained to equality) was nonsignificant $\delta\chi^2$ ($\delta df) = 11.06$ (8), $p = 0.198$), and the fit of the constrained model was adequate ($\chi^2(df) = 349.28$ (301), $p = 0.029$, RMSEA = 0.038; CFI = 0.91).

Sensitivity Analyses

Two alternative specifications of the single group structural model were used in sensitivity analyses. First, the measure of getting into trouble in school included an item regarding not handing homework in on time, which is a minor form of noncompliance and could be considered an indication of academic performance rather than rule following. This item was removed from the trouble in school measure and the model was re-run. The path from executive control to getting into trouble in school remained of similar magnitude ($\beta = -0.29$, $p < 0.001$). The one difference in results was that the path from executive control to internalizing problems, although similar in magnitude to the estimate from the original specification ($\beta = -0.19$), had a p-value of 0.047, slightly below the 0.05 cutoff. A second respecification of the single group structural model involved using the original measures but estimating the model with the Maximum Likelihood Robust estimator. This allowed for the use of full information maximum likelihood missing data estimation in the structural model and accounted for the nonnormal distribution of substance use initiation with robust standard errors. Again, the direction of all paths from executive control to adolescent behavioral outcomes remained the same, the magnitudes of standardized coefficients for these paths were similar to the estimates with WLSMV, and the path from executive control to internalizing problems had a p-value slightly below 0.05. Complete results from these sensitivity analyses are available on request from the first author.

Discussion

The degree to which executive control in preschool, a period of rapid development and executive control organization, has unique versus shared associations with substance use initiation, externalizing problems (both within and outside of the school context), and

internalizing problems in early adolescence, is uncertain. This study found that preschool executive control, measured as a unitary latent variable indicated by scores on performance-based tasks administered in a laboratory setting and accounting for foundational cognitive abilities, was negatively associated with adolescent self-report of problem behavior outcomes at ages 14–16 years. The associations with externalizing problems and getting into trouble in school were statistically significant, while associations with internalizing problems and substance use initiation were not. The results add to prior research (e.g., Moffitt et al. 2011, Sitnick et al. 2017), including work from earlier phases of this ongoing longitudinal project (Mason et al. 2020; Nelson et al. 2018; Nelson et al. 2019), by pointing to deficits in early childhood executive control as an antecedent of early adolescent risk behaviors. Executive control is a possible target for intervention, since research has indicated that interventions can improve executive control (Diamond and Lee 2011).

Prior work from earlier phases of this ongoing longitudinal project (Nelson et al. 2018) found associations between preschool executive control and internalizing and externalizing behaviors in middle childhood, although the pattern of statistically significant relationships differed across studies. In the earlier study, the association between executive control and internalizing problems was statistically significant and the association with externalizing was not; here, the opposite was the case. One notable difference between the current and the prior study is that the earlier study used a parent-report measure of externalizing behaviors in middle childhood, while the current study used selfreported measures of externalizing and internalizing behaviors in adolescence. In both studies, however, the directions and magnitudes (as reflected in the standardized path coefficients) of the associations were similar. An additional component of the current study was examining adolescents' reports of getting in trouble in school. This measure captures information on a context-dependent manifestation of noncompliant or disruptive behaviors that result in reactions from teachers and other school staff in the school setting. Together these findings point to early childhood executive control as a salient risk factor for externalizing behaviors in early adolescence for which adolescents get into trouble.

Research suggests that the asynchronous maturation of brain systems during adolescence, in which systems associated with emotion and reward salience develop sooner than those associated with cognitive control, partially explains vulnerability for the types of risky and problem behaviors that often emerge during the adolescent years (Squeglia et al. 2017). Externalizing problems, in particular, likely reflect rule breaking behaviors resulting from preferences for immediate reward over consideration of longer-term consequences and delayed gratification associated with prosocial alternatives. Even while cognitive control systems in the brain continue to mature for all adolescents, those who developed stronger executive control abilities in early childhood likely derive protective benefits against externalizing problems in early adolescence due to stable proficiencies in working memory, inhibitory control, and flexible shifting. To further investigate this possibility, future research is needed to examine dynamic changes in the growth and structure of executive control over childhood and into adolescence in relation to the emergence of adolescent risky and problem behaviors.

The association between executive control and substance use initiation was negative, but small and not statistically significant. Substance use was correlated with other

adolescent problems, although more strongly with externalizing problems than internalizing problems. The findings are consistent with substance use being related to other early adolescent behavior problems but did not provide strong evidence of a relationship between substance use initiation and executive control. Substance initiation is governed, in part, by substance availability, which varies substantially for early adolescents. It is possible that the abilities reflected in executive control will play a stronger role with respect to more frequent and harmful levels of substance use later in adolescence, when access to substances is widespread and decisions to use increasingly reflect cognitive control processes. The data from the current project do not yet cover later adolescence when more frequent and disordered substance use becomes more prevalent.

The findings suggest promise for early interventions that improve executive control and, in turn, may reduce externalizing behavior problems and prevent young adolescents from falling into a pattern of disruptive or rule-breaking behavior that results in negative sanctions in the school environment as well as other social domains. Numerous studies have found evidence for the efficacy of interventions focusing on executive control (for a review, see Diamond & Lee 2011). For example, studies have reported improvements in childhood executive control when using computerized or noncomputerized games, aerobic exercise, martial arts, and mindfulness practices. School-based strategies involving supplemental curricula or instructional practices also have shown evidence of positive effects. For instance, one randomized trial found a school-based intervention, which involved supplemental curricula focusing on emotion regulation with 7- to 9-year-old children, led to executive control improvements that partially accounted for reductions in externalizing and internalizing behavior problems compared to a control group at a 1-year follow-up assessment (Riggs et al. 2006). The current results suggest that it might be effective to start this type of intervention even earlier in child development, during preschool, as a way to promote early pathways leading away from subsequent problem behaviors.

Because there are sex differences in adolescent behavioral problems between boys and girls, particularly with respect to depression, this study explored whether the relationships between cognitive processes in early childhood and adolescent behavioral outcomes differed by sex. Although sex was a predictor of internalizing problems, with girls reporting more internalizing problems than boys, the associations between executive control and internalizing problems were not significantly different between boys and girls. It should be noted, however, that estimates of moderation effects are less precise than estimates of main effects. The results are consistent with early childhood cognitive processes being a similar indicator of risk for both boys and girls, but the findings do not allow for a strong inference about equality of this relationship.

Other limitations of this study include using a sample recruited from one city in the Midwestern US and sample attrition, with the effective sample size being 208 for the YSR outcomes and 229 for substance use initiation and getting in trouble in school. The effective sample size lessens the precision of estimates of associations, some of which, although small (e.g., $r < 0.2$), may still have clinical importance. The sensitivity analyses also point to the limitations of organizing the presentation of findings with regard to the $p < 0.05$ criterion for statistical significance, since slight differences in estimates can push p-values above or below the 0.05 cutoff. The substance use initiation measure is limited by the fact

that some participants who did participate in the adolescent phase of data collection were only age 14 or 15 years at their last survey time point. Further, the measure of substance use initiation was limited to marijuana, alcohol, smokeless tobacco, and cigarettes. Few individuals in the sample reported use of other illicit substances, such as cocaine or non-prescribed narcotics, and none reported using other illicit drugs while not having used marijuana, alcohol, or tobacco. Future research on this project, however, will be devoted to additional specific substances, such as electronic cigarettes, which represent a new and evolving form of substance use for adolescents.

Conclusion

Preschool is a critical period of executive control organization with potential long-term consequences for development, but the unique versus shared associations of preschool executive control with early adolescent problem behaviors, including substance use initiation, externalizing problems (both within and outside of the school context), and internalizing problems, are understudied. Prior research on executive control and related constructs (e.g., hyperactivity, impulsivity) in early childhood has often relied on parent- or teacher-report measures or clinical diagnoses. The current study extended the developing line of research on executive control, a potentially modifiable factor in child development, by using performance-based measures of early childhood cognitive processes and a measurement model that partials out variation in task performance attributable to foundational cognitive abilities. The results from bi-factor structural equation modeling showed that deficits in early childhood executive control factor in the etiology of a variety of problem behaviors in early adolescence, a period of increased risk for the emergence of such behaviors, with particularly strong associations with externalizing problems. Deficits in executive control are also antecedents of the related phenomenon of adolescents getting in trouble in the school setting. Thus, this study extends our understanding of the emergence of adolescent problem behaviors by indicating that how children perform on lab-administered tests of executive control when they are 5 years old may foreshadow their involvement in such behaviors at 14–16 years of age. The findings imply that intervening to improve children's executive control during preschool may help direct them away from problem behaviors during the formative years of adolescence.

Authors' Contributions – C.B.F. helped develop the conceptual framework and hypotheses for the study, conducted the statistical analyses, and wrote the initial draft of the paper; A.L.S. assisted in writing of the paper and in the management of data used in the analyses. M.V. assisted in the review of prior research and the writing of the paper; I.P. assisted in the analysis of data, the review of prior research, and the writing of the paper; T.D.N. is a Principal Investigator on the National Institute on Drug Abuse project and helped conceive the primary research aims of the project and the design of data collection; he also assisted with the writing of the paper; J.M.N. helped with conceptualization of the aims of the project and the design of data collection; she also assisted in the writing of the paper; T.D.J. oversaw collection and management of data for the project and conducted analyses that were the basis of the measurement of executive control and foundational cognitive abilities; she also assisted with writing of the paper; K.A.E. was the Principal Investigator of the parent National Institute of Mental Health project and designed the data collection and foundational analyses on which

this study is built; W.A.M. is a Principal Investigator for the current National Institute on Drug Abuse project, helped conceptualize the aims of that grant and this particular study, and assisted in the drafting of the paper. All authors have read and approved the final version of this manuscript.

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Conflict of Interest – The authors declare they have no conflict of interest.

Ethical Approval – All procedures in this study complied with ethical standards of the University of Nebraska–Lincoln Institutional Review Board.

Informed Consent – Informed consent was obtained from all adult participants, and assent was obtained from all child participants.

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Author Notes

Charles B. Fleming is a research scientist at the Center for the Study of Healthy and Risk Behaviors in the Department of Psychiatry and Behavioral Sciences, University of Washington. His research focuses on the etiology of adolescent and young adult problem and risky behaviors and testing of preventive interventions.

Amy L. Stevens is a research supervisor at the Boys Town Child and Family Translational Research Center. Her research involves child and adolescent development and evaluation of preventive and treatment interventions for adolescents.

Marla Vivero is a graduate student in the Department of Psychology at the University of Nebraska–Lincoln. Her research focuses on child and adolescent psychology.

Irina Patwardhan is a Research Scientist at the Boys Town Child and Family Translational Research Center. Her research focuses on development of executive function and longitudinal data analyses.

Timothy D. Nelson is a professor in the Department of Psychology at the University of Nebraska–Lincoln and faculty affiliate at the Center for Brain, Biology and Behavior at the University of Nebraska–Lincoln. His research interests are in pediatric psychology and pediatric neuroscience.

Jennifer Mize Nelson is a research associate professor in the Department of Psychology at the University of Nebraska–Lincoln; faculty affiliate at the Center for Brain, Biology and Behavior at the University of Nebraska–Lincoln; and director of Research Strategy and Infrastructure in the Office of Research and Economic Development at the University of Nebraska–Lincoln. Her research involves the examination of the development and amelioration of mental health problems in childhood and adolescence.

Tiffany D. James is the assistant director of Data Infrastructure and Analysis in the Office of Research and Economic Development at the University of Nebraska–Lincoln. Her research is on assessment of pediatric and adolescent cognitive processes and development.

Kimberly Andrews Espy is a professor in the Department of Psychology at the University of Texas at San Antonio and in the Long School of Medicine in the Department of Department of Psychiatry and Behavioral Science at the University of Texas at San Antonio. Her research is in pediatric neuroscience.

W. Alex Mason is a professor at the University of Tennessee Health Science Center in the Department of Preventive Medicine. His areas of research include child, adolescent, and young adult neurocognitive and psychosocial development and preventive intervention development and evaluation.

Supplementary material

Table A. *Standardized structural path estimates from bi-factor model of executive control and foundation cognitive abilities predicting early adolescent behavioral outcomes.*

Path	*β*	*SE*	*p* =
Directional paths			
EC → Substance use initiation	–0.14	0.14	.333
EC → Externalizing problems	–0.26	0.10	.014
EC → Internalizing problems	–0.19	0.10	.051
EC → Trouble in school	–0.28	0.09	.001
FCA → Substance use initiation	–0.10	0.14	.453
FCA → Externalizing problems	–0.03	0.10	.750
FCA → Internalizing problems	–0.03	0.10	.728
FCA → Trouble in school	–0.05	0.09	.556
Male → Substance use initiation	0.02	0.09	.835
Male → Externalizing problems	0.05	0.07	.419
Male → Internalizing problems	–0.36	0.06	.000
Male → Trouble in school	0.14	0.06	.019
Family income-to-needs → Substance use initiation	–0.16	0.12	.167
Family income-to-needs → Externalizing problems	–0.07	0.09	.444
Family income-to-needs → Internalizing problems	–0.11	0.07	.142
Family income-to-needs → Trouble in school	–0.14	0.09	.146
Mother's educational attainment → Substance use initiation	0.06	0.12	.611
Mother's educational attainment → Externalizing problems	–0.08	0.10	.396
Mother's educational attainment → Internalizing problems	0.06	0.09	.486
Mother's educational attainment → Trouble in school	–0.03	0.08	.748
Age at last assessment → Substance use initiation	0.16	0.13	.220
Age at last assessment → Externalizing problems	-0.03	0.09	.693
Age at last assessment → Internalizing problems	0.00	0.08	.983
Age at last assessment → Trouble in school	–0.13	0.08	.099
Family history of alcohol problems → Substance use initiation	0.27	0.08	.001

Path	β	*SE*	p =
Family history of alcohol problems → Externalizing problems	0.19	0.07	.003
Family history of alcohol problems → Internalizing problems	0.12	0.07	.091
Family history of alcohol problems → Trouble in school	0.15	0.06	.015
Covariances			
EC with			
Male	–0.20	0.08	.009
Family income-to-needs	–0.10	0.07	.148
Mother's educational attainment	0.00	0.08	.976
Age at last assessment	–0.25	0.10	.008
Family history of alcohol problems	0.08	0.08	.326
FCA with			
Male	–0.06	0.06	.330
Family income-to-needs	0.39	0.06	< .001
Mother's educational attainment	0.47	0.06	< .001
Age at last assessment	0.38	0.08	< .001
Family history of alcohol problems	–0.10	0.06	.120
Family income-to-needs with			
Male	0.08	0.06	.132
Mother's educational attainment with			
Male	–0.03	0.06	.610
Family income-to-needs	0.55	0.03	< .001
Age at last assessment with			
Male	0.09	0.07	.159
Family income-to-needs	0.41	0.06	< .001
Mother's educational attainment	0.32	0.06	< .001
Family history of alcohol problems with			
Male	0.02	0.06	.783
Family income-to-needs	–0.22	0.05	< .001
Mother's educational attainment	–0.22	0.06	< .001
Age at last assessment	–0.08	0.06	.194

Note: EC = executive control, FCA = foundational cognitive abilities, β = standardized coefficient, *SE* = standard error