5-9-2023

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Lauren M. Laifer

Cara C. Tomaso

Olivia D. Chang

Eric Phillips

Tiffany D. James

See next page for additional authors

Authors

Lauren M. Laifer, Cara C. Tomaso, Olivia D. Chang, Eric Phillips, Tiffany D. James, Jennifer Nelson, Kimberly Andrews Espy, W. Alex Mason, and Timothy D. Nelson

Received: 19 December 2022 | Accepted: 9 May 2023

DOI: 10.1002/jad.12195

RESEARCH ARTICLE

Foundation for PSA WILEY

Early executive control buffers risk for adolescent psychopathology during the COVID-19 pandemic

Lauren M. Laifer[1] | Cara C. Tomaso[1] | Olivia D. Chang[2,3] | Eric M. Phillips[1] | Tiffany D. James[4] | Jennifer Mize Nelson[1,4] | Kimberly Andrews Espy[5,6] | W. Alex Mason[7] | Timothy D. Nelson[1]

[1]Department of Psychology, University of Nebraska–Lincoln, Lincoln, Nebraska, USA

[2]Department of Psychology, University of Michigan, Ann Arbor, Michigan, USA

[3]School of Social Work, University of Michigan, Ann Arbor, Michigan, USA

[4]Office of Research and Economic Development, University of Nebraska–Lincoln, Lincoln, Nebraska, USA

[5]Department of Neuroscience, Developmental and Regenerative Biology, University of Texas at San Antonio, San Antonio, Texas, USA

[6]Department of Psychiatry and Behavioral Science, University of Texas Health Science Center at San Antonio, Long School of Medicine, San Antonio, Texas, USA

[7]Department of Child, Youth, & Family Studies, Nebraska Center for Research on Children, Youth, Families, and Schools, Lincoln, Nebraska, USA

Correspondence

Lauren M. Laifer, Department of Psychology, University of Nebraska–Lincoln, 238 Burnett Hall, Lincoln, NE, USA.
Email: llaifer@huskers.unl.edu

Funding information

Eunice Kennedy Shriver National Institute of Child Health and Human Development; National Institute of Diabetes and Digestive and Kidney Diseases; National Institute on Drug Abuse; National Institute of Mental Health; National Institute of General Medical Sciences; Nebraska Tobacco Settlement Biomedical Research Development Fund

Abstract

Background: The coronavirus disease 2019 (COVID-19) pandemic has had a global impact on youth mental health, and there is a critical need for research examining individual factors that contribute to increased psychopathology during the pandemic. The current study explored whether executive control (EC) abilities in early childhood interact with COVID-related stress to attenuate risk for adolescent psychopathology during the first 6 months of the pandemic.

Methods: Participants were 337 youth (49% female) living in a small midwestern city in the United States. Participants completed EC tasks when they were approximately 4.5 years old as part of a longitudinal study investigating cognitive development. At annual laboratory visits during adolescence and before the pandemic, participants (M_{age} = 14.57) reported on mental health symptoms. In July and August of 2020, participants (M_{age} = 16.57) reported on COVID-related stress and depression, anxiety, and trauma symptoms.

Results: COVID-related stress was associated with increased internalizing problems after controlling for prepandemic symptom levels. Further, the impact of COVID-related stress on adolescent internalizing problems was moderated by preschool EC, with higher levels of EC buffering the effects of COVID-related stress on adolescent internalizing problems.

Conclusions: Findings highlight the importance of promoting EC early in development, as well as screening for EC deficits and implementing targeted intervention strategies across the lifespan to help reduce the impact of stress on adolescent internalizing problems.

KEYWORDS

adolescence, executive function, protective factors, psychopathology, stress

1 | INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has contributed to soaring rates of mental health challenges in children, adolescents, and their families (American Academy of Pediatrics, 2021; Golberstein et al., 2020). Emerging research examining the psychological impact of COVID-19 suggests increased rates of child and adolescent internalizing symptoms (Nearchou et al., 2020; Panchal et al., 2021; Ravens-Sieberer et al., 2022; Robinson et al., 2022; Rogers et al., 2021). Given the adverse impact of the ongoing pandemic, there has been substantial interest in longitudinal research examining modifiable factors that can promote resilience in the face of global stressors and reduce risk for subsequent psychopathology (Brock & Laifer, 2020; Chen & Bonanno, 2020; Wade et al., 2020). Executive control (EC; also referred to as "executive function" or "cognitive control") is one promising factor. EC refers to a set of higher-order neurocognitive processes that not only underlie emotion regulation, but also help individuals adapt more effectively to challenges across the lifespan (Diamond, 2013; Zelazo, 2015, 2020). The current study sought to examine whether EC abilities in early childhood interact with COVID-related stress to attenuate risk for adolescent psychopathology during the first 6 months of the pandemic.

EC is typically conceptualized as three related abilities (Diamond, 2013). *Inhibitory control* involves suppressing or controlling one's attention, behavior, thoughts, and emotions in response to stimuli (e.g., ignoring a distraction). *Working memory* refers to the ability to temporarily store and manipulate information in the forefront of the mind. Finally, *flexible shifting* involves thinking about a stimulus in multiple ways (e.g., the ability to switch between changing task demands or to consider someone else's perspective). These neurocognitive skills work together and play fundamental roles in learning, goal-directed action, emotion regulation, and overall social functioning (Zelazo, 2020). The development of EC follows a protracted course and first emerges as a unitary construct in preschool (Clark et al., 2016) before gradually differentiating into three correlated but distinct subcomponents by adolescence (Best & Miller, 2010). Importantly, preschool has been characterized as a critical period during which EC is both rapidly developing and highly malleable (Carlson et al., 2013; Espy, 2016; Thompson & Steinbeis, 2020; Zelazo, 2020). The substantial growth in EC abilities across the preschool years parallels the maturation of the prefrontal cortex (Espy, 2016; Moriguchi & Hiraki, 2013; Tsujimoto, 2008), which plays a central role in higher-order neurocognitive processes. Further, EC development during preschool lays the foundation for subsequent abilities, with research demonstrating moderate stability in EC across development (Goh & Jeon, 2022; Miyake & Friedman, 2012; Nelson et al., 2022). Finally, individual differences in preschool EC predict a wide range of academic (De Franchis et al., 2017; Nelson, Nelson, et al., 2017), behavioral (Kidwell et al., 2017; Nelson, Kidwell, Nelson, et al., 2018), and health outcomes (Nelson, James, et al., 2017; Nelson, Kidwell, Hankey, et al., 2018). Thus, preschool EC has far-reaching implications for well-being across the lifespan.

Although cognitive training programs, on the whole, have failed to demonstrate far transfer (i.e., generalization of skills across loosely related domains; see Gobet & Sala, 2023 for a review), a large body of research demonstrates that EC can be enhanced in early childhood and across the preschool years (Muir et al., 2023). For instance, preschool EC can be improved through early intervention (i.e., cognitive scaffolding, Pauli-Pott et al., 2021; mindfulness programs, Thierry et al., 2016) and social–emotional curricula (Bierman & Torres, 2016), and preschool interventions demonstrate sustained benefits for children with early EC deficits (Sasser et al., 2017). Beyond more narrow training, the development of EC can be impacted by several environmental factors, including parenting behaviors (i.e., autonomy support and responsivity; Bernier et al., 2010; Meuwissen & Carlson, 2019) and household enrichment (i.e., learning materials, varied enrichment activities, and language/academic stimulation; Nelson et al., 2015). Financial stress is also negatively associated with preschool EC (Mason et al., 2020) via higher parental psychological distress (Vrantsidis et al., 2020); however, a recent randomized control study suggested that poverty reduction interventions can enhance infant brain functioning (Troller-Renfree et al., 2022) in ways that may be linked to higher cognitive skills across development. As such, early EC could be further enhanced through policy decisions that provide economic support for families with young children (National Academies of Sciences Engineering and Medicine, 2016).

1.1 | EC and risk for psychopathology

Extant research demonstrates a robust association between EC deficits and increased psychopathology, including depression and anxiety, among children and adolescents. Although most of this work has been cross-sectional (Cardenas-Iniguez et al., 2022; Romer & Pizzagalli, 2021; Snyder et al., 2019), recent longitudinal studies suggest that early EC deficits are a transdiagnostic risk factor for the development and maintenance of psychopathology (Caspi et al., 2020; Phillips et al., 2022; Yang et al., 2022). These findings are broadly consistent with the iterative reprocessing model (Zelazo, 2015), which posits that self-regulation involves the dynamic interplay between bottom-up (reactive) and top-down (reflexive) processes. EC skills are integral to top-down cognitive processes; thus, deficits in EC may contribute to greater emotion dysregulation and

subsequent psychopathology. Early EC deficits might also interfere with the ability to disengage from negative thoughts and anxiety-provoking cues, subsequently leading to increased negative emotionality (e.g., rumination, anxiety, depression; Nelson, Kidwell, Nelson, et al., 2018). Taken together, this work highlights the importance of early EC in long-term trajectories of mental health and well-being (Nelson et al., 2019) and supports the role of prevention and intervention efforts targeting EC skills *before the emergence of psychopathology* given the plasticity of EC early in development (Zelazo & Carlson, 2012).

Increasingly, researchers also recognize the role of EC in children's ability to adapt to stress and trauma (Chahal et al., 2021; Chen et al., 2020). Most children and adolescents experience some degree of psychological distress following trauma exposure, and EC facilitates top-down emotion regulation in this context. Thus, it follows that EC deficits in early childhood might be exacerbated by trauma exposure and contribute to the development and maintenance of internalizing psychopathology in children and adolescents (Connor et al., 2015). For instance, EC-related deficits in emotion regulation may contribute to greater difficulties inhibiting negative stimuli, disengaging from repetitive negative thinking, and successfully utilizing cognitive reappraisal (Demeyer et al., 2012; op den Kelder et al., 2017). Despite the association between trauma exposure and EC deficits (Lund et al., 2020; Op den Kelder et al., 2018), limited research has explored whether EC deficits *before trauma exposure* increase risk for internalizing problems among children and adolescents. Given growing recognition that EC deficits confer risk for child and adolescent psychopathology (Martel et al., 2017; Phillips et al., 2022), longitudinal research exploring whether early EC buffers the effect of stress and trauma exposure on internalizing problems is warranted.

Building on these findings and consistent with recent work highlighting the interplay between EC, stress, and psychopathology (Quinn & Shields, 2023), we posit that preschool EC represents a pre-existing protective factor that may buffer the effect of COVID-19 pandemic-related stress (Bridgland et al., 2021; Gruber et al., 2021; McLaughlin et al., 2022) on psychopathology. Children and adolescents may experience varying degrees of internalizing symptoms because of the pandemic, which will diminish over time for most individuals (Gruber et al., 2021), particularly those with strong foundational EC. On the other hand, for adolescents with poorer EC early in development, the stressful and potentially traumatic context created by the COVID-19 pandemic might exacerbate difficulties with attention (e.g., disengaging from COVID-related stimuli) and inhibition (e.g., inhibiting automatic fear responses), thereby contributing to the development of avoidant coping strategies and elevated levels of internalizing problems during the early months of the pandemic. Indeed, emerging research demonstrates that early pandemic-related stressors are prospectively associated with increases in youth internalizing symptoms during the first 6 months of the pandemic, particularly among adolescents (Rosen et al., 2021). Relatedly, adolescents reporting moderate to high COVID-related distress experienced significantly greater increases in internalizing symptoms during the first few months of the pandemic (Magson et al., 2021). Further, recent longitudinal studies exploring neural markers of EC demonstrate that deficits before the onset of COVID-19 are associated with increased adolescent psychopathology during the pandemic after controlling for prepandemic symptom levels (Chahal et al., 2021; Gupta et al., 2022). Taken together, this research suggests that EC and COVID-related stress play an important role in determining adolescent psychopathology amid the pandemic; however, to our knowledge, there are no studies examining how early EC interacts with pandemic-related stress to predict increases in adolescent psychopathology.

1.2 | The present study

Understanding the interplay between EC, COVID-related stress, and adolescent psychopathology during the pandemic is critical given that adolescents are at heightened risk for internalizing disorders (Rapee et al., 2019), which may be further exacerbated by significant pandemic-related social disruptions that have undermined adolescents' developmental needs for autonomy (Rogers et al., 2021). Research examining how poorer preschool EC relates to adolescents' abilities to adapt to the COVID-19 pandemic has the potential to inform screening priorities and the identification of individuals at greater risk of developing internalizing problems in the context of stress. Further, because EC in early childhood may be particularly malleable, findings may underscore the need or prevention and early intervention efforts that enhance top-down control and overall adaptation to stress across the lifespan. Thus, the overarching aim of the present study was to investigate whether preschool EC abilities buffer the effect of COVID-related stress on adolescent internalizing problems, as indicated by depression, anxiety, and posttraumatic stress disorder (PTSD) symptoms (see Figure 1). We predicted that preschool EC would moderate the association between COVID-related stress and adolescent internalizing problems during the first 6 months of the pandemic after controlling for prepandemic levels of psychopathology. Specifically, we hypothesized that adolescents who reported more COVID-related stress without sufficient EC to adapt to stress would experience higher levels of internalizing problems early in the pandemic.

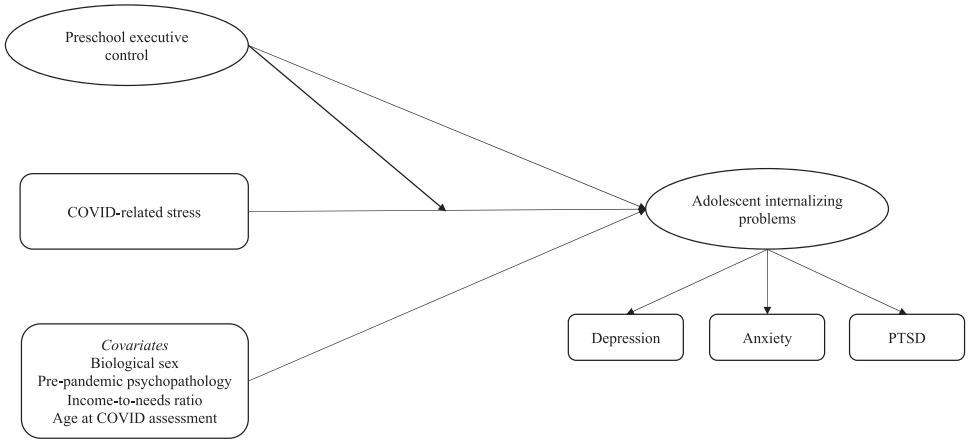

FIGURE 1 Conceptual model of the proposed interaction between COVID-related and preschool executive control predicting adolescent internalizing problems during the first 6 months of the coronavirus disease 2019 (COVID-19) pandemic.

2 | METHODS

2.1 | Participants and procedures

The sample included 337 youth who were enrolled in a larger longitudinal study investigating preschool cognitive development (49% assigned female at birth; 14.2% Hispanic; 70% White, 3.9% Black, 0.3% Asian American, 25.8% multiracial). Families were initially recruited through targeted community advertisements in a small midwestern city in the United States, and more than half of the sample (57.0%) met criteria for socioeconomic risk (e.g., met federal poverty guidelines, qualified for free/reduced school lunch, and/or received publicly subsidized health insurance when recruited). Children diagnosed with a developmental, behavioral, or language disorder before study entry could not enroll, but children remained eligible to participate if a developmental/behavioral (not language) disorder developed over the course of the study (see James et al., 2016 for a recruitment overview).

Data for the current study are drawn from assessments during the preschool and adolescent phases of the ongoing longitudinal study, as well as from a separate survey conducted during the early phase of the COVID-19 pandemic. The study employed a lagged cohort sequential design with planned missingness, and participants entered the study at different ages across preschool. At approximately 4.5 years old, participants ($n = 236$) completed EC tasks. At annual laboratory visits between ages 14 and 17 [$M_{age} = 14.57$ [$SD = 0.90$, $n = 226$]), participants completed prepandemic measures for most variables of interest. Participants also completed a series of questionnaires online approximately 4–5 months after the United States declared a state of emergency in response to COVID-19 (between July 21, 2020 and August 30, 2020; $M_{age} = 16.57$ [$SD = 1.13$, $n = 211$]). Participants aged into the adolescent phase at different times because of the lagged cohort sequential design during recruitment, resulting in different ages at the time of prepandemic assessments and the COVID-19 survey. On average, participants completed prepandemic measures 2.26 years ($SD = 0.72$, $n = 168$) before completing the COVID-19 survey. At all time points, parents or legal guardians gave informed, written consent allowing their children to participate in study procedures, which were approved by the Institutional Review Board at the University of Nebraska–Lincoln.

2.2 | Measures

2.2.1 | Preschool EC

Participants completed a developmentally appropriate, well-established battery of nine cognitive tasks. The battery assessed the three main components of EC; additional information about each task is included in Table 1. *Working memory* tasks included Nine Boxes (adapted from Diamond et al., 1997), Delayed Alternation (Espy et al., 1999), and Nebraska Barnyard (adapted from Noisy Book; Hughes et al., 1998). *Inhibitory control* tasks included Big–Little Stroop (adapted from Kochanska et al., 2000), Go/No-Go (adapted from Simpson & Riggs, 2006), Shape School (inhibition condition; Espy, 1997), and a modified Snack Delay task (adapted from Kochanska et al., 1996). *Flexible shifting* tasks included Shape School (switching condition; Espy, 1997) and Trail Making (switching condition; modified from Espy & Cwik, 2004). All tasks have excellent variability and good interrater reliability (where applicable) in the current sample (James et al., 2016). Earlier psychometric

TABLE 1 Descriptions of preschool executive control tasks.

Working memory	
Nine boxes	Nine boxes containing rewards are placed in front of the child. Boxes are rearranged between trials. The child must remember which boxes they have already searched to find the rewards in as few trials as possible.
Delayed alternation	A reward is hidden under one of two cups. The location of the reward alternates, and the child attempts to retrieve the award based on the location where they found it last.
Nebraska barnyard	Nine images of animal in colored boxes are arranged on the screen. The animals are removed, and the child must press the colored boxes in the order of the animal names read aloud by the examiner. Sequence length increases with each set of trials.
Inhibitory control	
Big–little stroop	The child views images of large shapes that contain images of smaller shapes and must name the smaller shape, which requires suppressing the name of the larger shape.
Go/no-go	Images of a fish or a shark appear on the screen. The child must press the button to "catch" the fish and inhibit pressing the button when a shark is shown.
Shape school—inhibit condition	Cartoon faces that are different shapes and colors appear on the screen. The child must say the color of the cartoon when the face is happy and inhibit naming the color when the face is sad.
Modified snack delay	The child is presented with a candy reward and told that they must remain still until the examiner rings a bell while the examiner engages in a standardized set of distracting behaviors.
Flexible shifting	
Shape school—switching condition	Cartoon faces that are different shapes and colors appear on the screen. The child must say the color when the cartoon is not wearing a hat and the shape when the cartoon is wearing a hat.
Trails—switching condition	The child must alternate between placing a stamp on the dog and bone images in order based on increasing image size.

work with this battery has shown that a unitary latent factor with all nine tasks included as factor loadings is preferred (Nelson et al., 2016) and was therefore used in the current study.

2.2.2 | Adolescent socioeconomic status (SES)

Participants' caregivers reported their total household income and family size at the prepandemic adolescent assessment. Income-to-needs ratio (i.e., total income divided by that year's poverty threshold for their family size) was calculated and used as a proxy variable for SES. To address extreme outliers, we Winsorized income-to-needs ratios at values that exceeded three standard deviations above or below the mean.

2.2.3 | COVID-related stress

Participants rated the extent to which COVID-19 had a positive or negative impact on their lives on a scale of 1 (*extremely negative*) to 7 (*extremely positive*). This item was reverse scored so that higher scores reflected higher levels of COVID-related stress.

2.2.4 | Adolescent psychopathology

To assess psychopathology during the first 6 months of the pandemic, participants were instructed to rate their symptoms following the United States declaring a national state of emergency on March 13, 2020, in response to COVID-19. Specifically, depression and anxiety symptoms were assessed using adapted versions of the Patient Health Questionnaire-8 (PHQ-8; Kroenke et al., 2009) and the Generalized Anxiety Disorder-7 (GAD-7; Spitzer et al., 2006), in which participants rated how often they had been bothered by each item since the COVID-19 crisis began (i.e., since mid-March) on a scale of 0 (*not at all)* to 3 (*nearly every day*). Items on each scale were summed, and total scores ranged from 0 to 24 on the PHQ-8 ($\alpha = .92$) and 0 to 21 on the GAD-7 ($\alpha = .91$). PTSD symptoms were measured using the 9-item pandemic-related traumatic stress scale (Blackwell et al., in press). Participants were asked to consider how often they were bothered by each item since

becoming aware of the COVID-19 pandemic on a scale of 1 (*not at all*)–5 (*very often*), and item scores were averaged ($\alpha = .86$).

Before the onset of the COVID-19 pandemic, participants completed the Youth Self-Report (YSR; Achenbach & Rescorla, 2001) as part of the adolescent phase of the larger longitudinal project. Participants rated the extent to which each item was true for them on a scale of 0 (*not true*)–2 (*very true or often true*). Subscale items were summed and converted to sex- and age-adjusted t-scores. The YSR internalizing problems subscale ($\alpha = .92$) was used as a prepandemic control in the present analyses.

2.3 | Data analytic approach

The model depicted in Figure 1 was tested in Mplus version 8.6 (Muthén & Muthén, 2017). Univariate statistics and bivariate correlations were examined for descriptive purposes and to screen for nonnormality. As expected with a lagged cohort sequential design, a subset of participants had missing EC data due to entering the study after age 4.5. Missing data and nonnormality were addressed with full information maximum likelihood estimation with robust standard errors (covariance coverage ranged from .46 to .70), which retains all participants and is preferred over more traditional approaches for handling missing data that introduce bias (e.g., pairwise deletion; Enders, 2010). The comparative fit index (CFI) and root mean square error of approximation (RMSEA) were computed to assess global model fit, with CFI values above 0.95 and RMSEA values below 0.06 interpreted as demonstrating good model fit (Bentler, 1990; Browne & Cudeck, 1992; Hu & Bentler, 1998).

2.3.1 | Measurement models

Substantial work demonstrates that EC is best represented as a unitary construct in preschool (Fuhs & Day, 2011; Wiebe et al., 2011; Willoughby et al., 2012), including with this specific battery (Espy, 2016). Thus, a unitary latent variable of EC was modeled with all nine tasks loading onto one factor. Consistent with past work using this battery, the residual error terms for the Shape School inhibition and switching conditions were allowed to covary, as they are from the same task. We also modeled a unitary latent variable of adolescent internalizing problems during the first 6 months of the pandemic with depression, anxiety, and PTSD symptoms as indicators. Both latent variables were standardized, such that the mean was 0 and the variance was 1.

2.3.2 | Moderation model

Study hypotheses were tested using latent moderated structural equation (LMS) models. LMS is advantageous over conventional moderator analyses as the estimates of interactions are less impacted by measurement error, reducing the likelihood of biased estimates (Maslowsky et al., 2015). We ran an LMS model to determine whether latent preschool EC moderated the association between manifest COVID-related stress and adolescent internalizing problems during the pandemic. As sex- and age-adjusted t-scores were not available for adolescent psychopathology during the pandemic, we included age and sex as covariates. We also controlled for income-to-needs ratio in adolescence given that individuals with lower SES have been disproportionately affected by health and social inequities exacerbated by the pandemic (e.g., Stark et al., 2020). Finally, we controlled for prepandemic adolescent psychopathology (measured before mid-March 2020) to determine the extent to which COVID-19 precipitated increases in internalizing problems.

Because Mplus does not provide conventional model fit indices for LMS models, we used a two-step procedure to determine model fit (Maslowsky et al., 2015). First, we ran the model without the latent interaction (model 0). Second, we ran the model with the latent interaction effect included (model 1). To evaluate whether adding the latent interaction significantly improved model fit, we used a loglikelihood ratio test to compare model 1 with model 0. Model 1 was retained only if both the loglikelihood ratio test was significant ($p < .05$) and the interaction term was significant. All analysis code is available from the corresponding author upon request.

2.3.3 | Transparency and openness

The present study's hypotheses and analyses were not preregistered. Consistent with Transparency and Openness Promotion Guidelines, all research materials (except raw participant data) and analysis code for the present study are available by

emailing the corresponding author. Although participants did not consent to the open sharing of their raw data, we have provided access to data in aggregate form (i.e., correlation matrix).

3 | RESULTS

Descriptive statistics and correlations are reported in Table 2. Two EC measures had nonnormal distributions: Big–Little Stroop (kurtosis = 5.78) and the inhibition condition of Shape School (kurtosis = 15.30). Trimming outliers that exceeded three standard deviations above/below the mean improved these values: Big–Little Stroop (kurtosis = 2.19) and Shape School—Inhibition (kurtosis = 5.99). As expected, there were large correlations between dimensions of adolescent psychopathology during the first 6 months of the pandemic (r ranging from .70 to .78), which exceeded the threshold for collinearity (Tabachnick & Fidell, 2012). There were also small correlations between COVID-related stress and adolescent psychopathology during the first 6 months of the pandemic (r ranging from .24 to .26). Sex was negatively correlated with adolescent psychopathology, with female participants endorsing higher levels of psychopathology (r ranging from −.38 to −.41) and COVID-related stress ($r = -.16$).

3.1 | Measurement models

Similar to previous findings with this sample (Nelson et al., 2016), model fit for the unitary latent factor for EC was good, CFI = 0.97, RMSEA = 0.03. Each task significantly loaded onto the latent factor, and standardized factor loadings ranged from 0.21 to 0.65 (see Table 3). The measurement model for adolescent internalizing problems was just identified. Depression, anxiety, and PTSD symptoms significantly loaded onto the latent factor, with standardized factor loadings between 0.82 and 0.92.

3.2 | Moderation model

Model 0 (without the interaction) demonstrated good global fit, $\chi^2(102, N = 337) = 124.33$, $p = .07$, CFI = 0.97, RMSEA = 0.03. The loglikelihood comparison test between model 0 and model 1 indicated that including the latent interaction improved model fit, $\chi^2(1) = 5.57$, $p = .018$. Thus, model 1 was retained. See Table 4 for a summary of model results. Adjusting for sex, age at the COVID assessment, income-to-needs ratio in adolescence, and prepandemic internalizing symptoms, COVID-related stress was significantly positively associated with internalizing symptoms ($b = 0.27$, 95% CI [0.079, 0.450], $\beta = .19$). Further, the latent interaction between COVID-related stress and preschool EC was significantly negatively associated with internalizing problems ($b = -0.26$, 95% CI [−0.504, −0.017], $\beta = -.19$), such that COVID-related stress was more positively associated with internalizing symptoms during the first 6 months of the pandemic at lower levels of preschool EC. A regions-of-significance analysis was conducted to determine whether there were points along the continuum of the moderator (preschool EC; standardized factor scores ranging from −2.412 to 1.747) at which the conditional effect of COVID-related stress on internalizing symptoms transitioned between statistically significant and not significant (Hayes, 2022). Results revealed that the effect of COVID-related stress on adolescent internalizing symptoms was present when scores of preschool EC were 0.31 or lower (48.31% of participants); the conditional effect at that point on the continuum was 0.15 (unstandardized), 95% CI [0.00205, 0.30955]. In contrast, the association between COVID-related stress and adolescent internalizing problems was nonsignificant at higher levels of preschool EC. A graphical depiction of the simple slopes is presented in Figure 2.

4 | DISCUSSION

The COVID-19 pandemic has had a profound impact on youth mental health. The present study adds to the growing body of longitudinal research examining how COVID-related stress contributes to adolescent psychopathology during the pandemic (Magson et al., 2021; Rogers et al., 2021; Rosen et al., 2021). Specifically, we investigated whether EC abilities in early childhood interact with COVID-related stress to buffer risk for adolescent psychopathology early in the pandemic. Consistent with emerging research, COVID-related stress uniquely predicted adolescent internalizing problems during the first 6 months of the pandemic after controlling for prepandemic symptom levels. Further, consistent with our hypothesis and recent longitudinal work exploring neural markers of EC before the pandemic (Chahal et al., 2021; Gupta et al., 2022), the effect of COVID-related stress on internalizing problems was stronger to the extent that preschool EC was lower. That is, the strength of the association between COVID-related stress and

TABLE 2 Descriptive statistics and bivariate correlations between study variables.

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Working memory																	
1. 9B	—																
2. DA	.04	—															
3. NB	**.16**	**.30**	—														
Inhibitory control																	
4. BL	**.13**	**.21**	**.36**	—													
5. GNG	.05	**.18**	**.24**	**.29**	—												
6. SS (Inhibition)	.03	**.19**	**.23**	**.14**	**.19**	—											
7. mSD	.10	**.34**	**.28**	.04	**.24**	**.24**	—										
Flexible shifting																	
8. SS (Switch)	**.16**	**.29**	**.42**	**.32**	**.31**	**.24**	**.23**	—									
9. Trails	.07	**.17**	**.21**	**.12**	**.16**	**.15**	**.13**	.25	—								
10. Prepandemic internalizing	−.09	−.04	−.06	**−.17**	**−.19**	**−.12**	**−.12**	**−.24**	-.06	—							
11. COVID-related stress	.04	−.10	**−.13**	−.04	.01	**−.18**	−.08	**−.14**	−.10	.13	—						
12. Adolescent depression symptoms	.02	−.06	.06	.08	.08	.09	−.04	−.01	−.02	**.41**	**.26**	—					
13. Adolescent anxiety symptoms	−.05	−.05	−.04	−.04	.01	.09	−.04	**−.17**	−.07	**.50**	**.25**	**.78**	—				
14. Adolescent PTSD symptoms	.04	−.02	.00	.00	.03	.01	−.07	−.07	−.10	**.40**	**.23**	**.70**	**.76**	—			
15. Sex	−.10	**−.15**	**−.11**	−.06	−.02	−.07	**−.19**	−.08	−.02	**−.12**	**−.16**	**−.38**	**−.42**	**−.41**	—		
16. Adolescent income-to-needs	−.02	.06	**.19**	**.16**	.09	**.17**	−.06	**.16**	.06	**−.11**	.06	−.05	.00	−.05	.08	—	
17. Age at COVID assessment	−.06	−.01	**.12**	.05	−.05	**.16**	**−.18**	.05	.05	.04	.09	.03	.06	.07	.01	**.35**	—
Mean	5.31	6.03	6.82	.84	2.27	.93	22.45	.74	.87	55.12	4.20	7.09	5.47	2.14	.49	2.18	16.57
Standard deviation	1.80	5.72	2.56	.21	.81	.17	9.36	.23	.11	11.39	1.18	6.08	5.09	.78	.50	1.54	1.13
Range	2–9	−5–16	1.67–13	0–1	−.69–3.12	0–1	0–45	0–1	.43–1	27–91	1–6	0–24	0–21	1–5	0–1	.19–7.84	14–18.58
n	236	236	236	235	236	235	235	234	223	233	208	211	211	211	337	230	211

Note: Significant correlations ($p < .05$) are bolded. Raw, nontransformed values for executive control tasks are presented. Sex was coded such that 0 = female and 1 = male.

Abbreviations: 9B, Nine Boxes; BL, Big–Little Stroop; DA, Delayed Alternation; GNG, Go/No-Go; mSD, modified Snack Delay; NB, Nebraska Barnyard; PTSD; posttraumatic stress disorder; SS, Shape School.

TABLE 3 Standardized factor loadings for preschool executive control.

Preschool executive control	Standardized Estimate	S.E.	*p* Value
Nine Boxes	0.21	0.07	.003
Delayed Alternation	0.48	0.07	<.001
Nebraska Barnyard	0.65	0.06	<.001
Big–Little Stroop	0.48	0.06	<.001
Go/No-Go	0.46	0.06	<.001
Shape School (Inhibition)	0.39	0.07	<.001
Modified Snack Delay	0.42	0.08	<.001
Shape School (Switch)	0.65	0.06	<.001
Trails	0.34	0.06	<.001

TABLE 4 Summary of results.

	Unstandardized estimate	95% CI	Standardized estimate
Outcome with predictors and control variables			
Adolescent internalizing symptoms, $R^2 = 0.482$			
Preschool EC	0.03	[−0.230, 0.297]	0.02
COVID stress	**0.27**	**[0.079, 0.450]**	**0.19**
Preschool EC × COVID stress	**−0.26**	**[−0.504, −0.017]**	**−0.19**
Prepandemic internalizing symptoms	0.05	[0.035, 0.072]	0.44
Sex	−1.03	[−1.390, −0.669]	−0.37
Adolescent income-to-needs ratio	0.06	[−0.076, 0.193]	0.07
Age at COVID assessment	0.01	[−0.155, 0.175]	0.01
Covaried predictors			
Preschool EC—COVID stress	−0.21	[−0.388, −0.033]	−0.21

Note: Model results after controlling for sex, adolescent income-to-needs ratio, age at COVID assessment, and prepandemic internalizing symptoms. CIs were calculated to determine significance of effects. If a CI did not contain zero, the effect was significant. Significant main and interaction effects are bolded.

Abbreviation: CI, confidence interval; EC, executive control.

internalizing problems significantly weakened and became statistically nonsignificant as preschool EC increased. Interestingly, at low levels of COVID-related stress, adolescents with lower preschool EC reported lower levels of internalizing symptoms than adolescents with higher preschool EC. Thus, it is possible that lower preschool EC reflects differential susceptibility to both positive and negative environments rather than vulnerability to adverse experiences (Belsky & Pluess, 2009; Ellis et al., 2011). However, given that adolescents with higher preschool EC reported average levels of internalizing problems, these findings should be interpreted with caution. Future research exploring the interaction between EC and stress within a differential susceptibility framework is warranted.

There are several pathways through which EC difficulties in early childhood might confer risk for internalizing symptoms in the wake of the COVID-19 pandemic. For instance, pandemic-related stress may exacerbate deficits in attentional control, such that adolescents who had lower EC early in development may engage in more rumination and experience greater difficulty redirecting attention away from COVID-related stimuli. In addition, stress resulting from the COVID-19 pandemic may interact with pre-existing self-regulation difficulties and contribute to increased avoidant coping strategies (e.g., disengaging from digital social connection) that inadvertently increase distress. On the other hand, strong foundational EC might enable more positive coping strategies (e.g., relaxation, exercise, spending time in nature or with loved ones) that mitigate the impact of COVID-related stress on adolescent mental health.

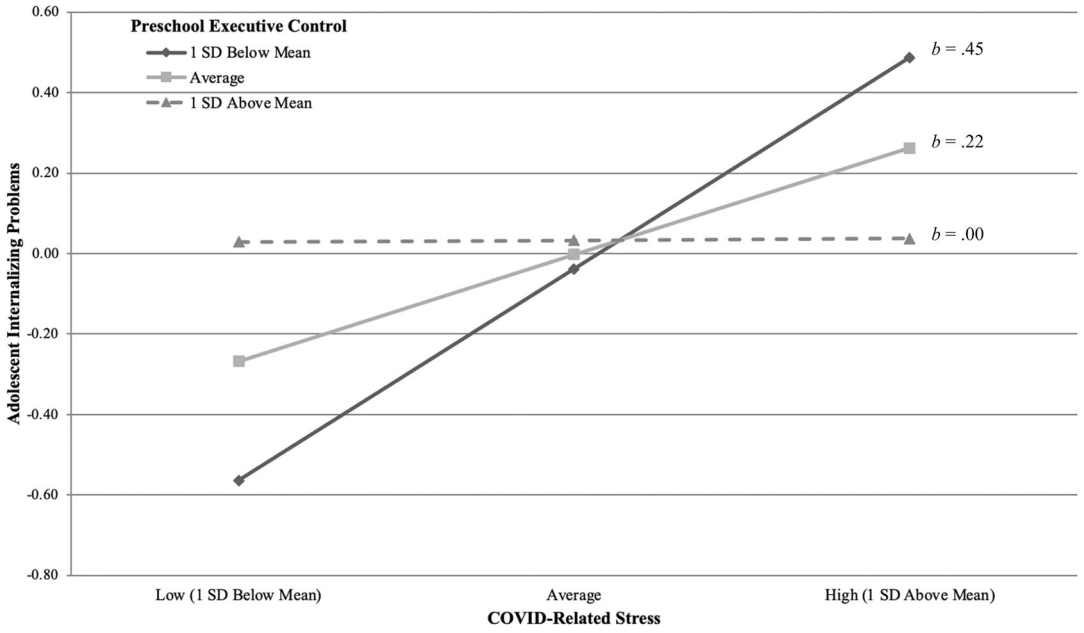

FIGURE 2 Conditional effects of COVID-related stress on adolescent internalizing problems during the COVID-19 pandemic at high (1 *SD* above the mean), average, and low (1 *SD* below the mean) levels of preschool executive control. Significant effects are represented by solid lines, and nonsignificant effects are represented by dashed lines. Slope coefficients are unstandardized.

4.1 | Theoretical and empirical implications

The present study has several theoretical and empirical implications. Findings highlight the importance of early prevention efforts targeting EC (e.g., computerized training, social and emotional learning curricula; Diamond, 2013) to promote top-down emotion regulation and to reduce risk for psychopathology across the lifespan. Indeed, given that EC is modifiable early in development (Zelazo, 2020; Zelazo & Carlson, 2012) and has long-lasting mental health consequences (e.g., Caspi et al., 2020), screening for relative EC deficits and implementing remediation strategies as early as preschool has the potential to mitigate the impact of stress on psychological well-being. Further, given the malleability and protracted development of EC, there may be additional opportunities to promote EC during adolescence. For instance, targeted intervention efforts to improve EC abilities among adolescents with internalizing problems (e.g., mindfulness training; Diamond & Lee, 2011) could enhance existing evidence-based treatments. Alternatively, rather than directly targeting EC, training adolescents with lower EC in compensatory strategies (e.g., goal management) to help reduce the effects of stress may mitigate risk for mental health difficulties amidst the COVID-19 pandemic (Snyder et al., 2015, 2019).

Several limitations of the present study should also be noted. First, the sample was comprised of adolescents in a small midwestern city, and most participants identified as White. Given the well-documented racial, ethnic, and socioeconomic disparities in physical (Magesh et al., 2021) and mental health difficulties related to the pandemic (Thomeer et al., 2022), research exploring the impact of early EC and COVID-related stress on mental health among more racially diverse groups of adolescents is warranted. Nonetheless, participants in the present study were oversampled for sociodemographic risk, which is a notable strength given the disproportionate impact of COVID on individuals with lower SES (Khanijahani et al., 2021). Second, COVID-related stress and adolescent psychopathology during the pandemic were measured concurrently; thus, it is possible that higher levels of COVID-related stress could be attributed to increased adolescent psychopathology. Finally, our measure of COVID-related stress was comprised of a single item with unknown reliability. However, this is consistent with other research on the impact of COVID-19 on adolescent mental health (Temple et al., 2022), as well as existing research supporting the validity of single-item measures of stress (Elo et al., 2003; Vinstrup et al., 2021). Relatedly, our measure of COVID-related stress did not assess objective levels of stress, but rather the perceived impact of the COVID-19 pandemic. Although the negative impact of COVID-19 on an individual may be correlated with specific stressors related to infection and disruptions to daily routines, we were unable to explore this possibility in the present study. Future research should explore the impact of perceived and objective stress on adolescent mental health using a validated measure of COVID-19 stressors (i.e., the COVID-19 Stressors Scale, Tambling et al., 2021).

Limitations notwithstanding, the present study makes meaningful contributions to the growing body of research examining risk factors for adolescent internalizing problems during the COVID-19 pandemic. Research on child and adolescent mental health amidst the pandemic has largely been conducted cross-sectionally. Thus, the inclusion of measures

assessing prepandemic mental health symptoms and the incorporation of measures from key developmental periods spanning nearly a decade, including the rich measurement of early EC with developmentally appropriate performance-based tasks, represent significant methodological strengths. Further, the present study adds to the growing literature of research examining the role of early EC deficits in future risk for internalizing problems in children and adolescents following exposure to adversity. Future research should expand on our findings by examining specific mechanisms (e.g., rumination, expressive suppression, disengagement from emotional stimuli) through which early EC interacts with COVID-related stress to contribute to adolescent internalizing problems beyond the acute phase of the pandemic. An improved understanding of the mechanisms through which early EC contributes to adolescent internalizing psychopathology in the context of stress and trauma exposure has the potential to inform novel prevention and intervention efforts and support psychosocial functioning across the lifespan.

ACKNOWLEDGMENTS

This work was supported by grants from the National Institute of Diabetes and Digestive and Kidney Diseases (F31DK122636, R01DK116693), the National Institute on Drug Abuse (R01DA041738), the National Institute of Mental Health (R01MH065668), the National Institute of General Medical Sciences (P20GM130461), and the National Institute of Child Health and Human Development (F31HD107948) of the National Institutes of Health. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. This project was also made possible by funding from the *Nebraska Tobacco Settlement Biomedical Research Development Fund*.

CONFLICT OF INTEREST STATEMENT

The authors declared they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

All analysis code for the present study is available by emailing the corresponding author. Participants did not consent to the open sharing of their raw data; however, we have provided access to data in aggregate form (i.e., correlation matrix) in the manuscript.

ETHICS STATEMENT

All study procedures were approved by the University of Nebraska–Lincoln Institutional Review Board (Protocol 7197).

ORCID

Lauren M. Laifer http://orcid.org/0000-0001-5473-7882
Cara C. Tomaso https://orcid.org/0000-0003-0641-3319
Kimberly Andrews Espy https://orcid.org/0000-0003-3933-1053
Timothy D. Nelson https://orcid.org/0000-0003-1831-9135

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How to cite this article: Laifer, L. M., Tomaso, C. C., Chang, O. D., Phillips, E. M., James, T. D., Nelson, J. M., Espy, K. A., Alex Mason, W., & Nelson, T. D. (2023). Early executive control buffers risk for adolescent psychopathology during the COVID-19 pandemic. *Journal of Adolescence*, 1–15. https://doi.org/10.1002/jad.12195