Title
The Effects of Stress on Executive Function Performance in Children

Author
Deer, LillyBelle

Publication Date
2021

Peer reviewed|Thesis/dissertation

The Effects of Stress on Executive Function Performance in Children

By

LILLYBELLE KU'ULEI DEER
DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Psychology

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

Approved:

____
Camelia Hostinar

____
Paul Hastings

____
Yuko Munakata

Committee in Charge

2021

ACKNOWLEDGEMENTS

Throughout the writing of this dissertation I have received a great deal of support and assistance.

First, I am deeply indebted to my advisor, Dr. Camelia Hostinar, whose guidance, detailed feedback, and unwavering encouragement were invaluable throughout the dissertation process and my graduate career. Cam, your belief in my ideas and abilities helped me to persevere through this process in periods where I did not have much belief in myself. Your patience, probing questions, and attention to detail strengthened my ideas, methodology, and writing. Your kindness and unparalleled support have made my experience as a PhD student great. I am proud every day to be your graduate student and feel so incredibly lucky to have worked with you for these past five years.

I would like to express my deepest appreciation to my other two dissertation committee members, Dr. Paul Hastings and Dr. Yuko Munakata, for their insightful comments and suggestions, which have greatly strengthened this project. Paul, your guidance through this project and throughout my graduate career have strengthened my ideas and work, and your support has been invaluable. Yuko, your insightful questions and suggestions significantly improved this work, and I am extremely grateful to have had your guidance.

I am also very grateful to Dr. Ross Thompson for his unwavering support throughout my graduate career and critical feedback on my dissertation proposal and to Dr. Daniel Choe, for his significant feedback on my dissertation proposal, which strengthened this project.

This work was done in close collaboration with Nicholas V. Alen, and Anna M. Parenteau, whose support, kindness, and constructive feedback were essential to this project and to my graduate career. I have learned so much from both of you. Several undergraduate students in the Social Environment and Stress lab were essential to the completion of this project and I would like to thank Jency Umana Linares and Katie Wyant in particular for their coding of the executive function variables in the Social Support Study. I would also like to thank the families who participated in the Avon Longitudinal Study of Parents and Children (ALSPAC), the Social Support Study, and the COVID-19 Executive Function study, without whom none of this would be possible.

I also want to thank my partner, Marc Blumberg, for his incredible depth of support, patience, and love throughout my graduate career and especially through the dissertation process. I am also extremely grateful for the support of my family, their encouragement and excitement about my work has made this process all the better. I also am extremely appreciative of the support and comfort that my three dogs, Dot, Doug, and Milo, have offered throughout my graduate studies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Executive function (EF) is an umbrella term for a collection of important cognitive skills, including working memory, cognitive flexibility, and inhibitory control. These skills are important for both short-term and long-term outcomes such as peer relations, mental and physical health, and academic achievement. Numerous factors influence performance on each of these skills, one of which is experiencing stress. However, how different stressors impact EF across the life span, and how stress-induced impacts on EF are related to other outcomes, is not fully understood. For example, while there is a large body of literature examining the effects of acute stress on adult EF, the literature on this relation in childhood is sparse.

The aim of the following studies was to examine how different stressors impact EF and how this process relates to other outcomes, such as academic achievement and mental health. First, longitudinal analyses of the mediating role of executive function in middle childhood (age 7-11) in the relation between early-life family income (age 0-5) and academic achievement in late adolescence (16-18) were examined. These analyses indicated that executive function serves as a mediator in this relation. Second, the effects of an acute experimental stressor on EF performance in 9-11-year-old children were examined, as well as the potential moderating roles of child characteristics such as physiological reactivity and emotional and behavioral problems. There was no overall effect of stress on EF performance but there was a moderating effect of parasympathetic nervous system reactivity in the relation between stress condition and inhibitory control performance. Lastly, the association between COVID-19-related economic stress and both EF and mental health in 9-17-year-old children and their parents was examined. There were no effects of either parental job loss or family financial stress on EF, but family financial stress

did predict worse mental health in parents. These findings highlight the complex interplay between stress, EF, and other related outcomes such as mental health.

CHAPTER 1

STUDY 1: THE ROLE OF CHILDHOOD EXECUTIVE FUNCTION IN EXPLAINING INCOME DISPARITIES IN LONG-TERM ACADEMIC ACHIEVEMENT

LillyBelle K. Deer, Paul D. Hastings, & Camelia E. Hostinar

Please cite this article as:

Deer, L. K., Hastings, P. D., & Hostinar, C. E. (2020). The role of childhood executive function in explaining income disparities in long-term academic achievement. *Child Development*, *91*(5), e1046-e1063. https://doi.org/10.1111/cdev.13383

Children growing up in economically disadvantaged contexts are at risk of underperforming academically, as shown by decades of evidence in developmental psychology, sociology, education and economics (Blair & Raver, 2015; Duncan & Murnane, 2011; Noble & Farah, 2013; Reardon, 2011). Research examining the developmental pathways through which family economic circumstances affect children's academic outcomes, such as the amount of schooling they complete and their long-term academic aspirations (e.g., pursuing university admission), is important for informing targeted efforts to promote academic success in students from economically disadvantaged households. Many relevant pathways have been examined, including studies on the mediating role of family characteristics (Aikens & Barbarin, 2008; Yeung, Linver, & Brooks-Gunn, 2002) or the school environment (McLoyd, 1998; Sirin, 2005).

There are likely to be multiple mechanisms and processes linking economic hardship with academic outcomes, some of which may be more amenable to intervention than others. The present study was conducted to evaluate a critical factor within the child, executive function, which is both important for academic achievement (Blair & Raver, 2015; Raver, 2012) and is malleable through certain interventions (Blair & Raver, 2014; Diamond & Lee, 2011). Specifically, the current study capitalized on the unique and comprehensive data from the Avon Longitudinal Study of Parents and Children (ALSPAC, also known as "Children of the 90s"; Boyd et al., 2013; Fraser et al., 2013) to test the role of children's executive function in explaining the association between family income in the first years of life and high school academic achievement.

Income-based Disparities in Academic Achievement

Income-based disparities in academic achievement emerge early in life and have been noted across the globe (Duncan, Magnuson, & Votruba-Drzal, 2017; Sirin, 2005). For instance, children from low-income families already show deficits in a number of academic proficiencies by kindergarten (Duncan et al., 2017). This pattern persists into later childhood and adolescence (Duncan et al., 2017). By adulthood, those from low-income backgrounds complete less schooling overall (Duncan, Yeung, Brooks-Gunn, & Smith, 1998; Duncan, Ziol-Guest, & Kalil, 2010). Additionally, children from low-income communities are less likely to participate in extracurricular activities (Fredricks & Simpkins, 2012), which have been shown to improve academic achievement in low-income populations (Morris, 2015). Overall, income-based disparities in academic achievement are concerning, because education provides one of the most important mechanisms for improving one's socioeconomic conditions, especially in today's global economy (Autor, 2014). Because the academic achievement gap between low-income youth and their financially better-off peers often translates into a gap in adult earnings and overall socioeconomic status, limited education contributes to the transmission of socioeconomic disadvantage to the next generation (Duncan et al., 1998; Duncan et al., 2010). To break this vicious cycle, we need more research that can clarify the pathways between early-life family income and young adult academic achievement in order to suggest possible targets for intervention.

The Role of Executive Function in Academic Achievement

Executive function is an umbrella term for a collection of "attention-regulation skills that make it possible to sustain attention, keep goals and information in mind, refrain from responding immediately, resist distraction, tolerate frustration, consider the consequences of different behaviors, reflect on past experiences, and plan for the future" (Zelazo, Blair, & Willoughby, 2016, p. 1). Executive function reflects activity in prefrontal neural systems that allow children to exercise increasing levels of cognitive control over their responses to environmental stimuli across development (Munakata, Snyder, & Chatham, 2012). In adults, executive function has been modeled as three separable but correlated factors reflecting inhibition, working memory and updating, and mental set shifting (Miyake et al., 2000). There is less consensus on the latent structure of executive function in middle-to-late childhood. Some researchers have found that a single executive function factor fit their data best (e.g., Brydges, Reid, Fox, & Anderson, 2012), others have identified two or three factors resembling those identified in adults by Miyake et al. (e.g., Demetriou & Spanoudis, 2015; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003). In addition, some studies have suggested qualitative differentiations of executive function by age (e.g., 8 years old versus 10 years old, Brydges, Fox, Reid, & Anderson, 2014), whereas others have shown differentiation by measurement strategy, with objective cognitive tasks capturing unique variance and predicting academic achievement more strongly compared to executive function ratings by teachers and parents (Dekker, Ziermans, Spruijt, & Swaab, 2017). Given these mixed findings and the assessment of multiple facets of executive function at different ages by different informants in the current study, we used exploratory factor analysis to select the best measurement model in a data-driven way.

It is important to focus on executive function during this developmental period because previous research has indicated that executive function skills are malleable in childhood. A number of interventions have been effective in improving executive function abilities across early and middle childhood (reviewed in Diamond & Lee, 2011). This may be especially true for children who have experienced adversity, as one study found that intervening to improve executive function during kindergarten was particularly beneficial for children in schools with high rates of poverty (Blair & Raver, 2014).

Accumulating evidence suggests that children need more than just content knowledge to perform well in school, and that executive function skills are also essential for succeeding in an academic environment (Blair & Raver, 2015; Diamond, 2010). Importantly, these skills are associated with successful academic outcomes independently of general cognitive ability as indexed by IQ (Blair & Razza, 2007; Bull & Lee, 2014; Checa & Rueda, 2011).

When examining which cognitive skills best explain and predict economic disparities in academic achievement, some studies have suggested that executive function plays a prominent role (Hackman & Farah, 2009; Noble, Norman, & Farah, 2005). Prevailing theory suggests that chronic exposure to poverty-related stressors (e.g., neighborhood violence, family chaos, racial discrimination, noise and pollution) leads to alterations in the neurobiological systems that support executive function, shifting children from a more “reflective” to a more “reactive” pattern of responding that is adaptive in their environment (Blair, 2010; Blair & Raver, 2016; Hackman & Farah, 2009; Ursache & Noble, 2016). This behavioral pattern leads children from homes with low financial resources to be seen by their parents or teachers as less competent in various aspects of self-regulation (Brody, Flor, & Gibson, 1999; Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005), and to exhibit poorer performance on task-based measures of inhibitory control, working memory, and attention shifting (Blair et al., 2011; Evans & English, 2002; Farah et al., 2006; Noble, McCandliss, & Farah, 2007; Raver, Blair, & Willoughby, 2013; Sarsour et al., 2011). These effects appear to be enduring, as shown in a longitudinal study that linked childhood poverty exposure to impairments in young adult working memory (Evans & Schamberg, 2009). Importantly, there is encouraging evidence that intervening to improve executive function skills can improve academic achievement for children from high-poverty schools and thereby reduce the achievement gap (Blair & Raver, 2014). Such studies point to the importance of executive function in the relation between early-life economic conditions and later academic achievement. However, few studies have examined the long-term associations of low family income and low childhood executive function with academic achievement in late adolescence. This study aims to address this gap.

This study focused on executive function during middle childhood because these skills become consolidated during middle childhood and adolescence (reviewed in Anderson, 2002). Prior research has devoted much less attention to executive function in middle childhood relative to early childhood and adolescence, despite the likely importance of executive function during middle childhood for school performance. Additionally, this is an important developmental period when children begin to learn to manage their own behavior with less supervision from adults, suggesting that individual differences in executive function measured at this stage may be meaningful in predicting long-term outcomes.

The Role of Early-life Conditions

There is evidence that chronic exposure to poverty is more detrimental to children's cognitive and social development than transitory exposure (NICHD Early Child Care Research Network, 2005). In addition, some have argued that even when exposure is transitory, certain developmental periods are more vulnerable to the negative effects of low income with respect to specific outcomes. For instance, there is some evidence from the United States that low family income from birth to age five is a stronger predictor of low academic achievement compared to low family income during later developmental stages (Duncan et al., 1998; Johnson & Schoeni, 2011). The first few years of life might be a period of vulnerability to stress exposure because neural regions important for inhibiting the stress response (e.g., the hippocampus) develop during this period (Lupien, McEwen, Gunnar, & Heim, 2009). For these reasons, we hypothesized that early-life family income would show associations with long-term academic achievement, even when adjusting for later family income.

Hypotheses

The present project aimed to examine the association between early-life family income (birth to age five) and late-adolescence academic achievement (16-18 years), as well as to test the mediating role of executive function in middle-to-late childhood (7-11 years). These ages were chosen based on prior literature suggesting that birth to age five may be a period of sensitivity to economic hardship, that academic achievement around the end of high school is critical in determining one's future socioeconomic standing, and that middle childhood is an important period of consolidation for executive function abilities. Specifically, we aimed to examine the following three hypotheses: (1) lower early-life family income would be associated with lower levels of academic achievement in late adolescence; (2) executive function skills would act as statistical mediators of the association between early-life family income and academic achievement in late adolescence; and (3) this mediation effect would remain significant even after adjusting for a comprehensive panel of covariates including verbal IQ, sex, family income at later time points (ages 8 and 18), two executive function-like measures from toddlerhood, parental education, and extracurricular activities in late childhood (age 11). These covariates were selected because they account for the temporal ordering of exposure to low income (income at ages 8 and 18), prior executive function development (toddlerhood measures), and a number of other factors that might influence the predicted associations (verbal IQ, sex, parental education, and extracurricular activities).

Method

Sample

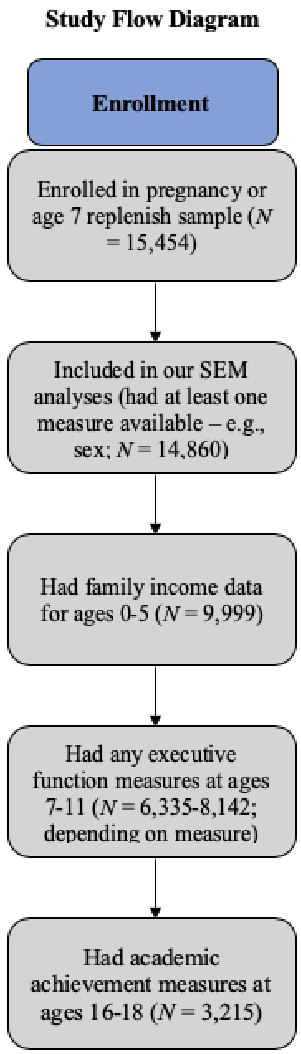
The sample in this study consists of participants from the Avon Longitudinal Study of Parents and Children who had data available on any of our measures of interest. ALSPAC is an ongoing birth cohort study that aims to follow more than 14,000 participants from birth into adulthood to understand the role of environmental and genetic factors in shaping a wide range of developmental and health outcomes. Mothers were recruited if they had an expected delivery date between April 1, 1991 and December 31, 1992 and lived in the former county of Avon in the United Kingdom. Their recruitment resulted in an initial sample of 14,541 pregnant mothers, resulting in 14,676 fetuses, 14,062 of whom were alive at birth and 13,988 children who were alive at one year of age. When the oldest children were approximately 7 years of age, an attempt was made to bolster the initial sample with eligible cases who had failed to join the study originally, resulting in a total sample size of 15,454. Of this sample, 14,901 were alive at age one. This rich dataset includes many waves of data collection, including questionnaires completed by children, parents, and teachers; administrative records; observational data; clinical assessments; and biological samples. Please note that the study website contains details of all the data that are available through a fully searchable data dictionary and variable search tool: http://www.bristol.ac.uk/alspac/researchers/our-data/. For further information regarding sample enrollment, participant characteristics, and general study methodology, we refer the reader to publications from the ALSPAC team that have profiled this cohort (Boyd et al., 2013; Fraser et al., 2013; Golding, Pembrey, Jones, & Team, 2001). Ethical approval for the study was obtained from the ALSPAC Ethics and Law Committee and the Local Research Ethics Committees. Informed consent for the use of the data collected via questionnaires and clinics was obtained from participants following the recommendations of the ALSPAC Ethics and Law Committee at the time.

Our most inclusive structural equation model used data from N = 14,860, which was the total number of participants that contributed data to at least one of our measures of interest (please see Table 1.1 for descriptive statistics on this sample and Figure 1.1 for a flow chart of participation numbers). Please note that the sample was 96.1% Caucasian and there were no significant associations with ethnicity in these analyses or changes in our results when this variable was included, thus we report the more parsimonious models that do not include the ethnicity variable.

Table 1.1. Sample characteristics. Family income at ages 0-5 and age 8 were ordinal variables ranging from 1 to 5 and representing weekly income in pounds: 1 = < 100; 2 = 100-199; 3 = 200-299; 4 = 300-399; 5 = > 400. Family income at age 18 was an ordinal variable ranging from 1 to 10 representing monthly income in pounds, which was rescaled to the same 1-5 range representing weekly income as the family income variables for ages 0-5 and 8. Parental education was an ordinal variable ranging from 1-13 with the following levels: 1 = No educational qualifications, 2 = Has CSE/GCSE (D, E, F, G); 3 = Has O-level/GCSE (A, B, C); 4 = Has A-levels; 5 = Has vocational qualification; 6 = Has done apprenticeship; 7 = Is a state enrolled nurse; 8 = Is a state registered nurse; 9 = Has City & Guilds intermediate technical qualification; 10 = Has City & Guilds final technical qualification; 11 = Has City & Guilds full technical qualification; 12 = Has a teaching qualification; and 13 = Has a university degree. Academic achievement was an ordinal variable ranging from 0-4 with the following levels: 0 = did not complete any academic milestones; 1 = only completed the AS exams; 2 = completed both AS and A2 exams, and did not apply to university; 3 = completed the exams and applied to university, but was not admitted, 4 = completed the exams, applied for and gained university admission. Please see Method section for additional details on how we computed and scaled each variable.

	N	Minimum	Maximum	*M*	*SD*
Family income – Age 0-5	9999	1.00	5.00	3.37	1.22
Teacher – Age 8 attention	6339	.00	20.00	15.18	5.46
Teacher – Age 8 activity	6335	.00	18.00	16.07	3.73
Teacher – Age 11 attention	7573	.00	20.00	16.02	5.08
Teacher – Age 11 activity	7563	.00	18.00	16.11	3.72
Parent – Age 8 attention	8132	.00	18.00	15.50	3.72
Parent – Age 8 activity	8142	.00	18.00	15.53	3.65
Sky Search – Age 8	7299	1.00	19.00	8.71	2.39
Dual Attention – Age 8	7050	1.00	19.00	7.57	3.78
Opposite Worlds – Age 8	7201	1.00	19.00	18.24	1.70
Counting Span – Age 10	7006	.00	5.00	3.42	.85
Sky Search – Age 11	7118	1.00	17.00	9.12	2.43
Dual Attention – Age 11	6987	1.00	19.00	7.76	2.33
Opposite Worlds – Age 11	6796	1.00	19.00	18.44	1.36
Academic achievement	3215	.00	4.00	2.57	1.55
Persistence score	10306	.00	35.00	18.73	4.89
Distractibility score	10313	.00	40.00	24.54	4.68
Family income – Age 8	7107	1.00	5.00	4.09	1.11
Family income – Age 18	3490	1.00	10.00	6.72	2.77
Parental education – Age 8	7195	1.00	13.00	8.11	4.08
Verbal IQ	7378	46.00	155.00	106.96	16.80
Extracurricular activities	6359	.00	7.00	3.07	1.29
Sex (% female)	14854			46.7	
Ethnicity (% Caucasian)	14854			96.1	
Academic achievement	Level 0	Level 1	Level 2	Level 3	Level 4
% of sample in each category	16.9	13.1	10.4	14.9	44.7

Figure 1.1. Flow chart with participant numbers for the main variables of interest.



Measures

Early-life family income. Total family weekly income was assessed through maternal self-report at two time points before the child turned five years old: when the child was 33 months and 47 months of age (r = .80). These were averaged to yield one value due to our interest in estimating children's aggregate exposure to low income.

Academic achievement. Four measures were available and used to exemplify offspring's academic achievement when they were 16-18 years old: (1) completion of AS qualification exams, (2) completion of A2 level qualification exams, (3) whether they applied to university, and (4) whether they were accepted into university. These measures were assessed through self-report by the study participants when they were 18 years old. The AS and A2 are both exams taken at the end of secondary education in the United Kingdom. These measures build on each other, as follows: one has to have taken the AS level exams in order to take A2 level exams, and one has to have taken these examinations before they can apply and be accepted into university. Given the interdependence (and multicollinearity) between these variables (mean r = .51), we constructed one continuous hierarchical index of academic achievement that had five levels: 0, for those who did not complete any of these academic milestones; 1 for those who only completed their AS exams; 2 for those who completed both AS and A2 exams, but did not apply to university; 3 for those who completed their AS and A2 levels and applied to university, but did not gain admission; and 4 if they passed their AS and A2 levels, applied for and gained university admission.

Executive function. Executive function was assessed at multiple time points and through multiple informants between ages 7 and 11. Thirteen measures of executive function from three different informants served as indicators for the latent variables. Executive function was assessed in the clinic using three subtests of the Test of Everyday Attention for Children (TEACh; Manly, Robertson, Anderson, & Nimmo-Smith, 1998) when the study children were 8 and 11 years old and by the Counting Span Task (Case, Kurland, & Goldberg, 1982) when the study children were 10 years old, by parent report when the children were 8 years old, and by teacher report during school years when the children were 7 or 8 years old, and when they were 10 or 11 years old. The three subtests of the TEACh used in these analyses were the Opposite Worlds, Sky Search, and Dual Attention tasks. The Opposite Worlds task is similar to the Stroop task and was used to measure cognitive inhibition (age 8: *M* = 18.24, *SD* = 1.70; age 11: *M* = 18.44, *SD* = 1.36). The Sky Search task assesses a child's ability to focus on relevant stimuli and measures selective attention (age 8: *M* = 8.71, *SD* = 2.39; age 11: *M* = 9.11, *SD* = 2.43). The Dual Attention task builds on the Sky Search task and measures the ability to divide attention, as it requires children to multi-task (age 8: *M* = 7.57, *SD* = 3.78; age 11: *M* = 7.75, *SD* = 2.33). These measures all have good test-retest reliability (Sky Search *r* = .90, Dual attention *r* = .81, Opposite Worlds *r* = .92; Manly et al., 2001). The Counting Span Task (Case et al., 1982) measures children's working memory abilities. Children can earn a score up to 5 based on the number of sets they can correctly recall. Each child's teacher and parent reported the child's activity and attention abilities using the Attention and Activity subscales of the Development and Well-Being (DAWBA, Goodman, Ford, Richards, Gatward, & Meltzer, 2000) assessment. These scales were included in order to capture behavioral aspects of inhibitory control. For example, teachers assessed students on statements like "Finds it hard to wait his/her turn", and parents rated their children with questions like "Does she often blurt out an answer before he/she has heard the question properly?" The Attention scale was a weighted composite of ten items and the Activity score was a weighted composite of nine items (all Cronbach's α > .91).

Covariates. Our most complex model included a comprehensive panel of potentially confounding covariates. Temperament in toddlerhood, family income when the study child was 8 and 18 years old, parental education when the study child was 8 years old, sex, verbal IQ, and extracurricular activities in middle-to-late childhood were used as covariates in this final model. The ALSPAC data set does not have information regarding early executive function skills (ages 0-5), but we included two indices of children's persistence and distractibility as measured by the Carey Infant Temperament Scale (Carey & McDevitt, 1978) as the closest executive function-like measures available. These scales were assessed via parent report when the study children were 24 months of age (both α = .71). High values on the distractibility measure indicate that the children were rated by their parents as more distractible and high values on the persistence measure indicate that children were rated by their parents as having high levels of persistence (note: we reverse-coded the persistence variable from the ALSPAC dataset, which originally indicated lower persistence for higher values). Family income at ages 8 and 18 was indexed through parental report of weekly and monthly income, respectively. Parental education level at age 8 was assessed through maternal report. The highest level achieved by the mother or the father was used. Sex recorded on the child's birth certificate was used as the sex variable in the present analyses. Verbal IQ was estimated using the most widely-used cognitive ability test for children worldwide, the Wechsler Intelligence Scale for Children (WISC-III^{UK}, Wechsler, Golombok, & Rust, 1992) and was measured when the study child was 8 years old. There were five verbal IQ subtests: information, similarities, arithmetic, vocabulary, and comprehension. Lastly, extracurricular activities were assessed through parent-report when the child was 11 years of age. Parents were asked whether their child participated in seven activities including: sports, swimming, languages, music, singing, religion, and other groups like Scouts. The number of activities that the child participated in was used to create a measure of extracurricular involvement.

Data Analysis Plan

Structural equation models were used to allow the inclusion of both latent and observed variables. Analyses were conducted using the **R** statistical programming language, version 3.4.0 (R Core Team, 2017) and SPSS Version 25. The exploratory factor analysis and missing data imputation were conducted using SPSS. Structural equation models were estimated using the lavaan package in **R**, version 0.6-1 (Rosseel, 2012). To account for the missing data in the sample, we used Full-Information Maximum Likelihood (FIML) estimation, which introduces the least amount of bias compared to listwise deletion of participants with missing data and other available methodologies of correcting for missing data (Enders & Bandalos, 2001). To best model non-normal data, we used maximum likelihood with robust corrections using the MLR estimator (Yuan & Bentler, 2000). Figures and text both report the standardized paths from these models.

We aimed to examine two models that tested the mediating role of childhood executive function for the link between early-life family income and late adolescent academic achievement under increasingly complex assumptions. Given the lack of consensus regarding the structure of executive functions in childhood, we first conducted an exploratory factor analysis with the 13 indicators of executive function abilities measured between the ages of 8 and 11. These analyses indicated four factors, corresponding to a teacher ratings factor, a parent ratings factor, a task-based factor tapping primarily into Lower-Order executive function skills (e.g., selective attention, inhibitory control), and a task-based factor that captured multiple facets of higher-order executive function skills (e.g., divided attention, working memory). We defined each factor based on the common practice of allocating the measures loading .30 or higher on that factor in the exploratory factor analysis (Osborne, Costello, & Thomas Kellow, 2008; see highlighted cells in Table 1.3 for loadings). We then conducted a confirmatory factor analysis (Model 1, Figure 1.2) that assessed the fit of a 4-factor model suggested by the exploratory factor analysis, such that measures were set to load on a factor if they had a loading of .30 or higher on that same factor in the exploratory factor analysis. Next, we tested two structural models to evaluate our main hypotheses. We started with the most basic model that tested the mediating role of executive function in the relation between early-life family income and later academic achievement, without the inclusion of any covariates (Model 2, Figure 1.3). Our second model added the two temperament variables, family income at age 8 and 18, parental education at age 8, sex, verbal IQ, and extracurricular activities at age 11 as covariates in order to account for other potential influences on executive function and academic achievement (Model 3, Figure 1.4). We chose these covariates a priori based on previous literature linking them to executive function or academic achievement. The mediating effect of task-based executive function was significant irrespective of whether these covariates were entered one at a time or simultaneously as a block. The addition of covariates was implemented by adding paths from each of these covariates to the executive function latent factor and the academic achievement measure. The paths from the covariates to the main variables of interest are not shown in the figures due to space constraints, but are discussed in the main text. The first two hypotheses are tested in model 2 and the third hypothesis is tested in model 3.

In all of the above models, several indices of model fit were considered jointly to assess the models based on current recommendations for best practice. The chi-square test of model fit is often significant in large samples such as this one, so we relied more heavily on the following indicators of good fit: a root mean square error of approximation (RMSEA) below .05 for good fit and below .08 for acceptable fit; the comparative fit index (CFI) and Tucker-Lewis index (TLI) being at least .90 for acceptable fit and at least .95 for good fit, and the standardized root-mean-square residual (SRMR) being below .05 for good fit and below .08 for acceptable fit (Hu & Bentler, 1999).

Missing Data

To test whether data were missing completely at random, we conducted Little's MCAR test. The test was significant ($p < .001$), indicating that the data were not missing completely at random. A previous paper from ALSPAC reported that attrition over time was dependent on several variables in the dataset such that participants who remained in the study were more likely to be female, have higher educational attainment, and were less likely to be eligible for free school meals (Boyd et al., 2012). Missing pattern analyses with the sample from the current analyses confirmed these results. For instance, academic achievement data were more likely to be available at age 16-18 if participants were female, had higher family income at age 0-5, and higher levels of parental education. In the current analyses, we used FIML to account for missing data in SEM, as this allows all participants to provide information from some variables even if they have missing data on other variables. Additionally, we re-tested our models with five complete datasets generated via multiple imputation (Fully Conditional Specification method), as can be seen in the Supplemental Material. Results were identical or stronger with the imputed data (see Supplemental Figures 1.5, 1.6, and 1.7).

Results

Table 1.1 displays sample characteristics. Table 1.2 displays bivariate correlations between the major variables.

Table 1.2. Correlations between the major variables. In the table, 1 = family income age 0-5, 2 = teacher report of age 8 attention, 3 = teacher report of age 8 activity, 4 = teacher report of age 11 attention, 5 = teacher report of age 11 activity, 6 = parent report of age 8 attention, 7 = parent report of age 8 activity, 8 = Sky search task age 8, 9 = Dual attention task age 8, 10 = Opposite worlds age 8, 11 = Counting span age 10, 12 = Sky search age 11, 13 = Dual attention age 11, 14 = Opposite worlds age 11, 15 = Academic achievement, 16 = Persistence score, 17 = Distractibility score, 18 = Family income age 8, 19 = Family income age 18, 20 = Parental education age 8, 21 = Verbal IQ, 22 = Extracurricular activities, 23 = Sex.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.
1.	-																						
2.	.15**	-																					
3.	.09**	.65**	-																				
4.	.14**	.57**	.47**	-																			
5.	.10**	.42**	.56**	.69**	-																		
6.	.06**	.46**	.35**	.38**	.28**	-																	
7.	.10**	.36**	.42**	.32**	.33**	.72**	-																
8.	.03**	.12**	.04*	.09**	.01	.09**	.04**	-															
9.	.09**	.11**	.04*	.10**	.01	.10**	.07**	.04**	-														
10.	.11**	.21**	.11**	.21**	.08**	.18**	.10**	.24**	.21**	-													
11.	.15**	.21**	.09**	.19**	.07**	.13**	.07**	.11**	.17**	.21**	-												
12.	.06**	.20**	.11**	.17**	.08**	.18**	.09**	.28**	.10**	.22**	.12**	-											
13.	.06**	.17**	.11**	.18**	.13**	.13**	.10**	.06**	.17**	.13**	.13**	-.03*	-										
14.	.09**	.26**	.14**	.21**	.10**	.18**	.10**	.18**	.17**	.48**	.22**	.27**	.16**	-									
15.	.27**	.25**	.16**	.20**	.11**	.13**	.10**	.03	.09**	.14**	.16**	.03	.08**	.11**	-								
16.	.001	.05**	.05**	.10**	.06**	.16**	.16**	.04**	.05**	.02	.03*	.05**	.03**	.02	.01	-							
17.	.04**	.01	.001	.03*	.04**	.01	.01	-.03*	-.02	-.02	-.001	-.02	-.02	.01	.03	-.15**	-						
18.	.66**	.11**	.07**	.09**	.08**	.07**	.12**	.02	.09**	.08**	.13**	.03*	.05**	.06**	.26**	-.01	.05**	-					
19.	.51**	.13**	.06*	.08**	.05*	.07**	.11**	-.01	.07**	.08**	.14**	.03	.06**	.09**	.26**	.03	.02	.53**	-				
20.	.37**	.06**	.04*	.09**	.06**	.04**	.07**	.04**	.08**	.05**	.11**	.01	.03*	.06**	.24**	.02	.01	.33**	.30**	-			
21.	.27**	.33**	.17**	.30**	.12**	.20**	.14**	.14**	.23**	.26**	.32**	.13**	.13**	.21**	.37**	.08**	-.02	.22**	.21**	.26**	-		
22.	.17**	.06**	.06**	.08**	.04*	.06**	.07**	.04**	.05**	.08**	.12**	.04**	.07**	.10**	.17**	.04**	.02	.16**	.14**	.20**	.16**	-	
23.	.01	.26**	.27**	.30**	.28**	.16**	.14**	-.03**	-.12**	-.02	.03*	.20**	.17**	.10**	.01	.06**	.02*	-.01	.01	.01	-.04*	.12**	-

**Correlation is significant at the .01 level (2-tailed)

*Correlation is significant at the .05 level (2-tailed)

As expected, there were significant associations among all our measures of executive function. The academic achievement index was significantly and positively associated with the measure of early-life family income. In bivariate correlations (see Table 1.2), this academic index exhibited associations of comparable size with family income at ages 0-5, age 8, and 18. When examining the associations among executive function measures and early-life income, the Opposite Worlds task (a measure of cognitive inhibition), Counting Span (a measure of working memory), and the teacher-reported measure of behavioral inhibition showed the strongest associations with indices of early-life income.

Exploratory Factor Analysis

The exploratory factor analysis for the executive function measures identified four distinct factors with eigenvalues greater than 1. The minimum criteria used for deciding whether an individual measure loaded on a factor was that it had a primary factor loading of at least .3 (Osborne et al., 2008; Table 1.3).

Table 1.3. Factor loadings for the four executive function latent factors. We conducted an exploratory factor analysis to reduce the 13 observed executive function (EF) measures using Principal Components Analysis with a Promax rotation (note that the same pattern of results was obtained with a Varimax rotation). We retained all factors having eigenvalues greater than 1. Factor loadings are shown for each measure and the four factors. We defined each factor based on the common practice of allocating measures loading at .30 or higher (see highlighted cells; Osborne, Costello, & Kellow, 2008). Because the tasks loaded on two separate factors, we labeled one as "Lower-Order EF Tasks" for easier differentiation in text because the Sky Search tasks loaded strongly and almost exclusively on this factor and it is primarily an attention task.

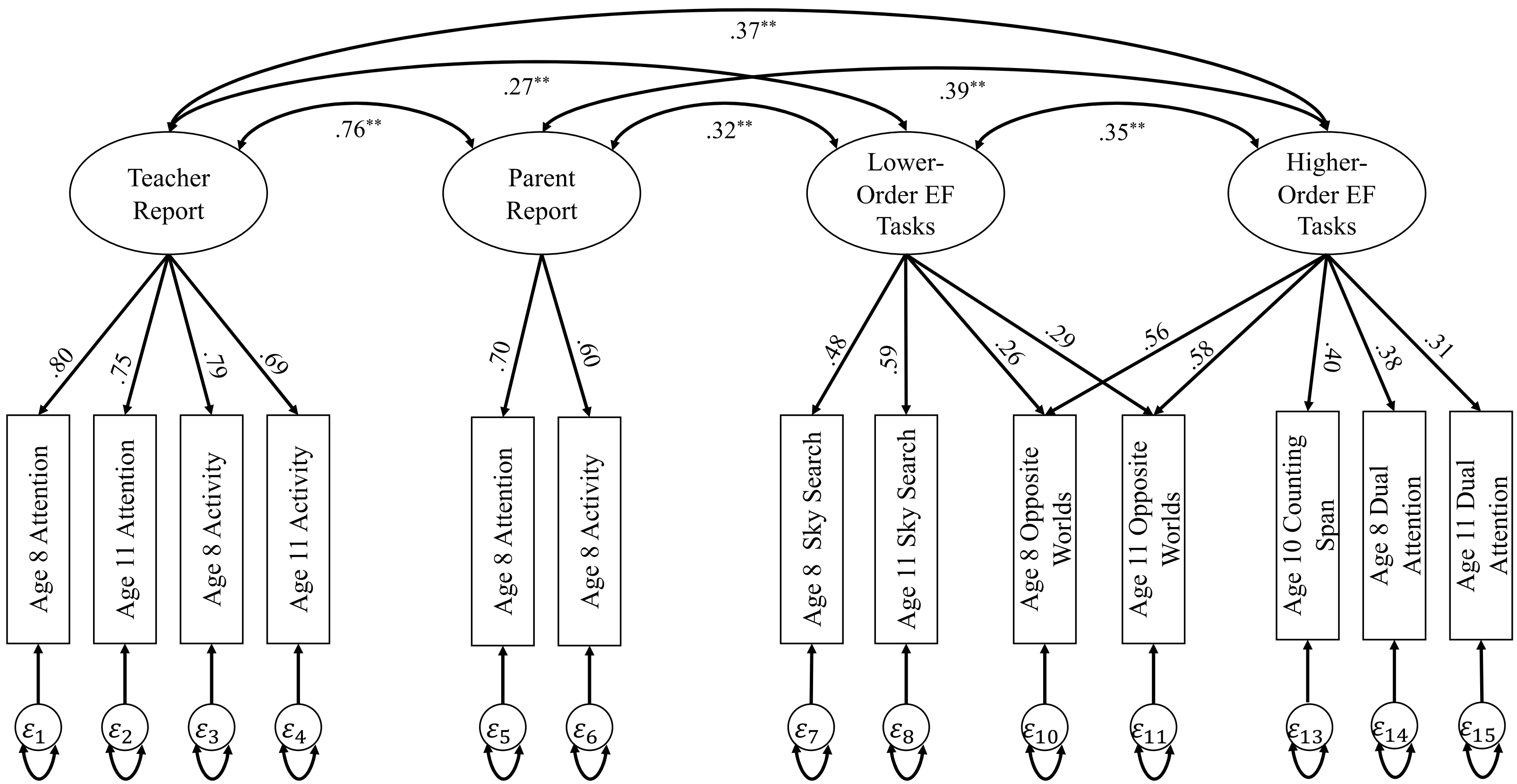
	Teacher Report Factor *(Eigenvalue 3.56)*	*Lower-Order EF Factor* *(Eigenvalue 1.71)*	*Parent Report Tasks* *(Eigenvalue 1.20)*	*Higher-Order EF Tasks* *(Eigenvalue 1.13)*
Teacher – Age 8 Attention	**.68**	.11	.13	.07
Teacher – Age 11 Attention	**.84**	.03	-.01	.02
Teacher – Age 8 Activity	**.81**	-.04	.06	-.05
Teacher – Age 11 Activity	**.90**	-.09	-.09	-.09
Parent – Age 8 Attention	.00	.06	**.90**	.04
Parent – Age 8 Activity	.04	-.04	**.90**	.01
Sky Search – Age 8	-.08	**.71**	.03	-.04
Sky Search – Age 11	-.02	**.80**	.08	-.22
Dual Attention – Age 8	-.22	-.07	.10	**.73**
Dual Attention – Age 11	.13	-.25	.02	**.64**
Opposite Worlds – Age 8	.03	**.36**	-.05	**.40**
Opposite Worlds – Age 11	.10	**.55**	-.11	**.26**
Counting Span – Age 10	.04	.20	-.06	**.51**

This analysis indicated a separation of the measures by informant and facet of executive function, but not age of measurement. The eigenvalues indicated that there was one factor defined most strongly by the teacher ratings, a second defined by the parent ratings, a third factor defined most strongly by the Sky Search tasks at both time points and the Opposite Worlds task at both time points (for ease of discussion we are labeling this factor the Lower-Order EF tasks factor given that these tasks index lower-order executive function tasks like selective attention and inhibitory control, while also recognizing that this may recruit other facets of executive function), and a final factor consisting of the Dual Attention task at both time points (measures of set shifting), the Opposite Worlds task at both time points (measures of inhibition), and the Counting Span task at age 10 (a measure of working memory). We refer to these factors from here on respectively as: Teacher Report factor, Parent Report factor, Lower-Order EF tasks factor, and Higher-Order EF tasks factor.

Confirmatory Factor Analysis

Model 1. The CFA for the measurement model of executive function indicated excellent model fit (see Figure 1.2): χ^2 (50) = 845.05, $p < .001$, *RMSEA* = .04, *CFI* = .96, *TLI* = .94, *SRMR* = .04.

Figure 1.2. Model 1 was a confirmatory factor analysis for the executive function latent factors. $^{**}p < .01$ (2-tailed). Standardized coefficients are shown on each path in this model and all subsequent models.



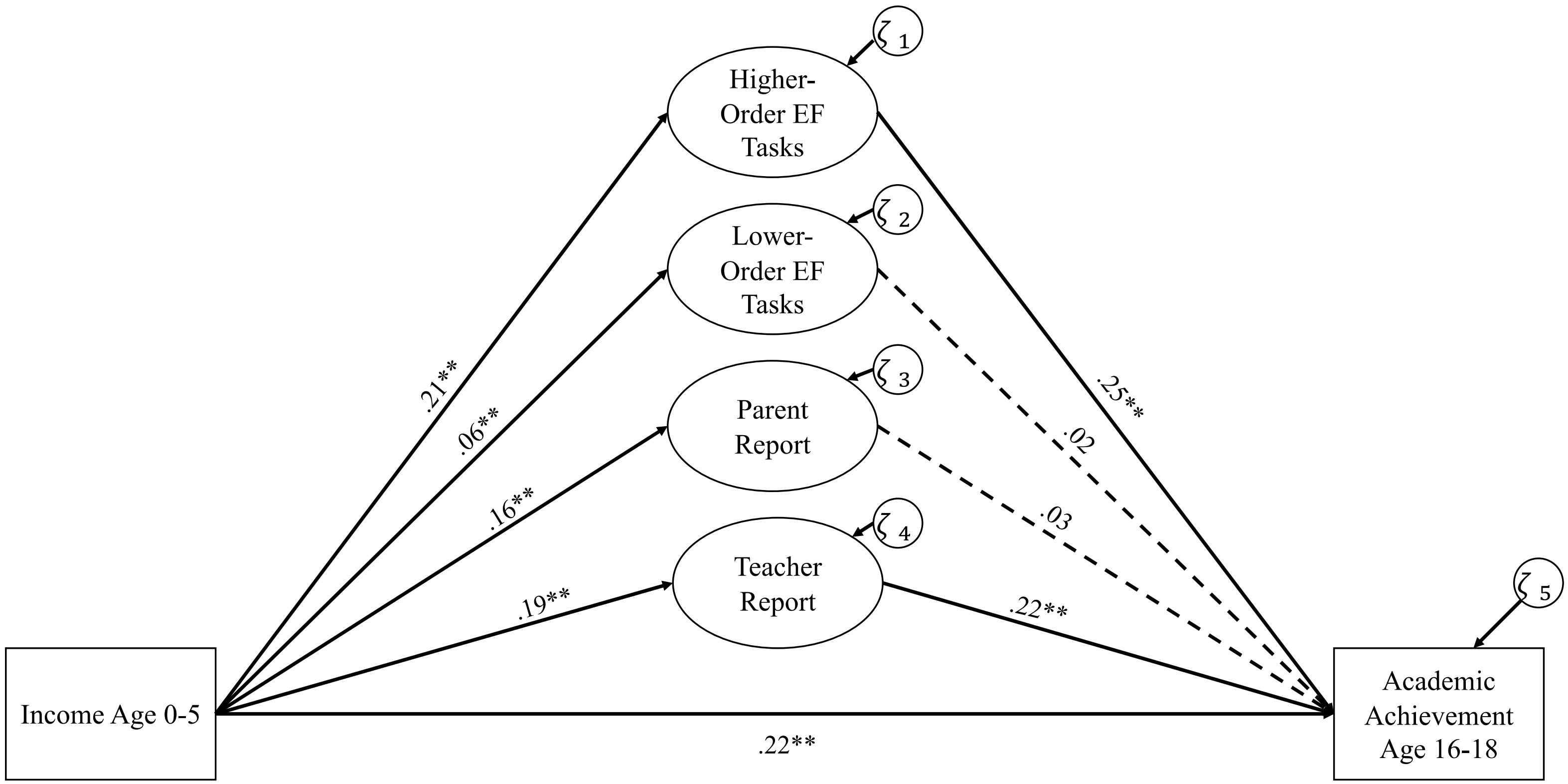
X^2 (df = 50) = 845.05, $p < .001$, *RMSEA* = .04, *CFI* = .96, *TLI* = .94, *SRMR* = .04

The Teacher Report factor was well defined by the teachers' report of the child's attention abilities at age 8 and age 11 and of the child's activity levels at age 8 and 11 (the standardized loadings were all significant at $p < .001$: .80, .75, .79, and .69, respectively). The two parent reported measures loaded strongly on the Parent Report factor (the standardized paths were both significant at $p < .001$: .70, and .60, respectively). As suggested by the high modification indices for the first model we tested, we allowed the teacher reported measures to co-vary with each other, the parent report measures to co-vary with each other, and the teacher and parent measures at age 8 to co-vary. Four measures loaded on the Lower-Order EF tasks factor: the Sky Search and Opposite Worlds subtests of the TEACh at both age 8 and 11 (the standardized paths were all significant at $p < .001$: .48, .60, .26, and .29, respectively). Lastly, five measures loaded on the Higher-Order EF tasks factor: the Dual Attention and Opposite Worlds subtests of the TEACh at age 8 and age 11, and the Counting Span task measured at age 10 (the standardized paths were all significant at $p < .001$: .38, .31, .56, .58, and .40, respectively).

Structural Model Testing

Model 2. We began by testing the mediating pathways from early-life income to later academic achievement via the four executive function factors. This was a basic model, without additional covariates (see Figure 1.3 for complete details).

Figure 1.3. Model 2 tested the structural model including mediation by the four executive function factors, without covariates. $^{**}p < .01$ (2-tailed).

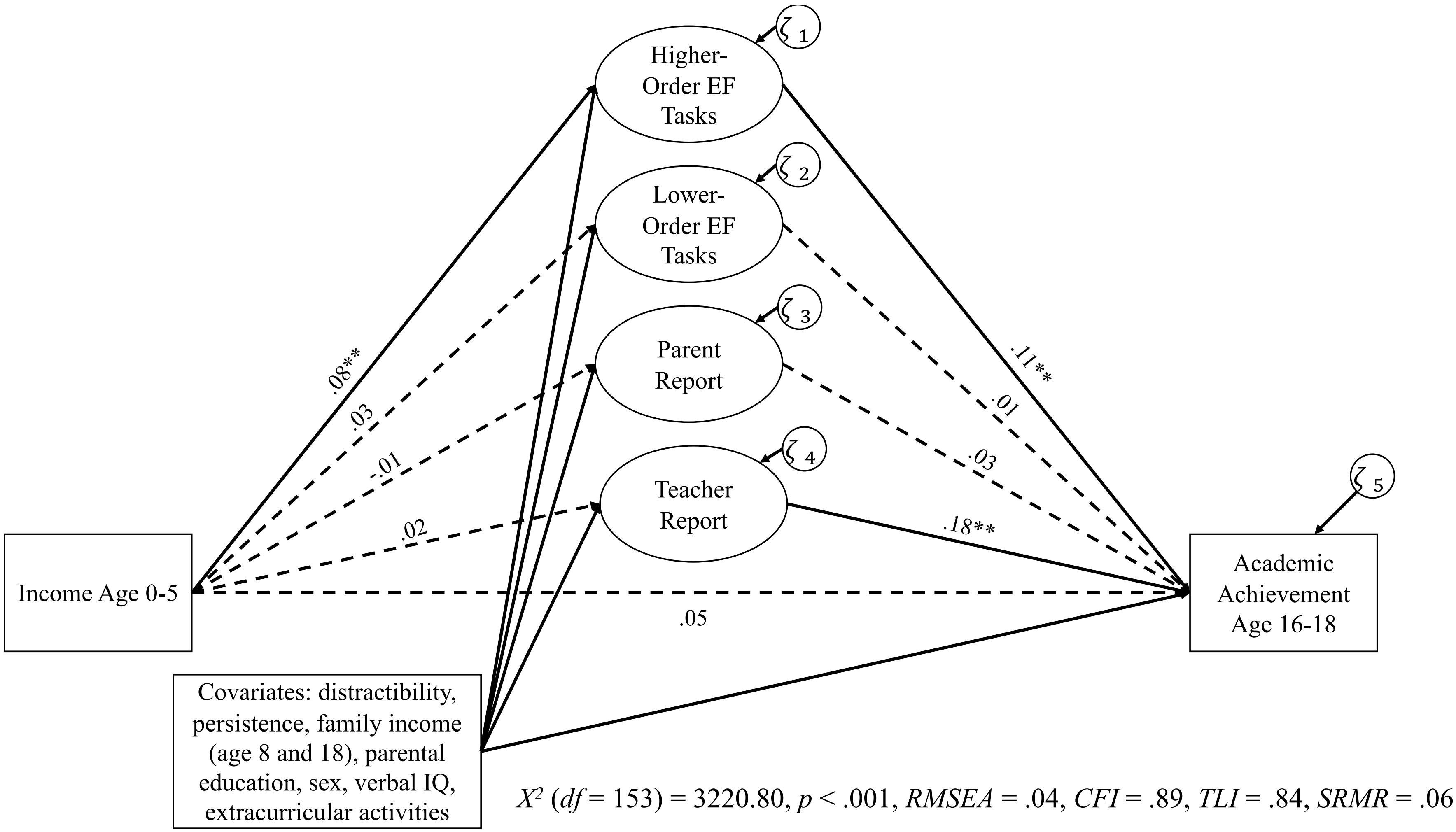


X^2 (df = 74) = 2388.81, $p < .001$, $RMSEA$ = .05, CFI = .88, TLI = .84, $SRMR$ = .12

Consistent with our first hypothesis, higher early-life income predicted better academic achievement in late adolescence (β = .22, *SE* = .07, $p < .001$). There was a significant positive direct path from early-life income to the Higher-Order EF tasks factor (β = .21, *SE* = .03, $p < .001$), the Lower-Order EF tasks factor (β = .06, *SE* = .02, $p = .004$), the Parent Report factor (β = .16, *SE* = .04, $p < .001$), and the Teacher Report factor (β = .19, *SE* = .02, $p < .001$). There were also significant positive paths from the Higher-Order EF tasks factor to academic achievement (β = .25, *SE* = .04, $p < .001$) and from the Teacher Report factor to academic achievement (β = .22, *SE* = .02, $p < .001$), with paths from the Lower-Order EF tasks factor and Parent Report to academic achievement not significant (*p*'s > .05). There were significant mediating pathways through both the Higher-Order EF tasks (indirect effect: β = .05, *SE* = .01, $p < .001$) and the Teacher Report factors (indirect effect: β = .04, *SE* = .01, $p < .001$).

Model 3. The final model included all of the covariates (the two temperament variables, family income at age 8 and 18, parental education at age 8, sex, verbal IQ, and extracurricular activities at age 11, see Figure 1.4 for details).

Figure 1.4. Model 3 revealed that the mediation pathway from age 0-5 income to academic achievement via the Higher-Order EF Tasks factor retained explanatory power after accounting for our panel of covariates (paths involving covariates not shown to improve readability but path statistics are included in text). ECAs = extracurricular activities. **p < .01.



We explored this model as a robustness check to test whether our central mediation model retained explanatory power after accounting for a number of potentially confounding variables. In this model, there was only a significant positive direct path from early-life income to the Higher-Order EF tasks factor ($\beta = .08$, $SE = .04$, $p = .001$), with the paths from early-life income to the other three executive function factors being non-significant ($p > .05$). As in the previous model, there was a significant positive direct path from the Higher-Order EF tasks factor to academic achievement ($\beta = .11$, $SE = .04$, $p = .005$) and from the Teacher Report to academic achievement ($\beta = .18$, $SE = .02$, $p < .001$), but not from the other two factors to academic achievement (p's $> .05$). Overall, there was only one significant mediating pathway through the Higher-Order EF tasks factor ($\beta = .01$, $SE = .01$, $p = .03$), but not any of the others (p's $> .05$).

There were a number of significant paths involving the covariates, as follows. Persistence and distractibility in toddlerhood were related to both Teacher Report ($\beta = .06$, $SE = .01$, $p < .001$, and $\beta = .03$, $SE = .01$, $p = .02$, respectively) and Parent Report ($\beta = .16$, $SE = .01$, $p < .001$, and $\beta = .03$, $SE = .01$, $p = .02$, respectively), such that children who had high levels of persistence and distractibility were rated as having better executive function abilities later on. Higher family income at age 8 was a significant predictor of higher executive function abilities as reported by teachers ($\beta = .08$, $SE = .06$, $p = .002$) and parents ($\beta = .08$, $SE = .06$, $p < .001$), as well as higher academic achievement in late adolescence ($\beta = .06$, $SE = .04$, $p = .04$). Higher family income at age 18 was also significantly related to higher academic achievement ($\beta = .10$, $SE = .02$, $p = .001$). Higher parental education measured in middle childhood was linked to higher academic achievement ($\beta = .08$, $SE = .01$, $p < .001$). Higher verbal IQ ability predicted higher teacher ratings ($\beta = .37$, $SE = .003$, $p < .001$) and parent ratings ($\beta = .23$, $SE = .003$, $p < .001$) of executive function, stronger performance on the Lower-Order EF tasks ($\beta = .19$, $SE =$

.002, $p < .001$) and Higher-Order EF tasks ($\beta = .46$, $SE = .003$, $p < .001$), as well as higher academic achievement ($\beta = .20$, $SE = .002$, $p < .001$). Female participants were rated as having higher executive function abilities by their teachers ($\beta = .38$, $SE = .08$, $p < .001$) and parents ($\beta = .18$, $SE = .07$, $p < .001$), and performed better on the Lower-Order EF tasks ($\beta = .16$, $SE = .08$, $p < .001$). There were no significant effects of sex on the Higher-Order EF tasks factor ($\beta = -.03$, $SE = .07$, $p = .18$) or academic achievement ($\beta = -.02$, $SE = .07$, $p = .42$). Lastly, participating in more extracurricular activities was associated with better performance on the Higher-Order EF tasks ($\beta = .10$, $SE = .03$, $p < .001$) and higher academic achievement ($\beta = .06$, $SE = .02$, $p = .001$), but was not associated with any of the other executive function factors (p's $> .28$).

Discussion

Economic disparities in academic achievement exist worldwide and perpetuate inequality from one generation to the next (Duncan et al., 2017; Sirin, 2005). Much of the existing research on pathways from low family income to low academic achievement has focused on the role of family, school, or neighborhood characteristics. The present study aimed to add to this important literature by focusing on a pathway involving executive function, a within-child process that is sensitive to disruption under economic hardship (Blair & Raver, 2015; Raver, 2012), but which is also amenable to interventions (Blair & Raver, 2014; Diamond & Lee, 2011).

As hypothesized, lower early-life family income predicted lower academic achievement in adolescence. This observation is consistent with prior literature on the achievement gap between low-income children and their better-off counterparts (Duncan et al., 2017; Sirin, 2005). Although some studies have shown concurrent associations between socioeconomic status and university admission outcomes (Sackett et al., 2012), the present study adds novel evidence by showing that family income many years prior is associated with long-term academic achievement around the time of university admission. The large sample size in the current study afforded us the unique opportunity to test whether early-life family income continued to predict academic outcomes via executive function when we statistically adjusted for family income at ages 8 and 18, and it did. This finding suggests a potentially important and independent role of early experience in setting up the foundation for later academic achievement.

We also found support for our second and third hypotheses. Namely, the link between early-life income and academic achievement was significantly mediated through the Higher-Order EF tasks factor in all model specifications (with and without covariates, with covariates entered as a block or one at a time, and with mediation models conducted with FIML or with imputed data). In addition, the Teacher Report of executive function factor mediated in models without covariates and in the imputed datasets (see Supplemental Table 1.4). The Parent Report and Lower-Order EF tasks only mediated in the imputed datasets without covariates (Supplemental Figure S1.2). Overall, these results are consistent with prior findings that cognitive testing and teacher report, but not parent report, were predictive of academic success in 6-8-year-old children (Dekker et al., 2017), and that cognitive tests were stronger predictors than teacher report (Dekker et al., 2017). Cognitive tests may have more predictive power due to their objective nature, whereas teacher report may be stronger than parent report in predicting academic achievement because it reflects skills evidenced within the academic context. Parents' ratings may be anchored more closely to family dynamics and involve comparison of the child's behavior to that of other family members, which may be less informative of the child's potential for future academic achievement.

Overall, the mediating role of task-based executive function is consistent with previous studies, which found a similar mediating path through executive functions over the preschool years (Fitzpatrick, McKinnon, Blair, & Willoughby, 2014) and over short time periods during childhood (Lawson & Farah, 2017). This study extends these findings to a much longer time span from early childhood to middle-to-late childhood and late adolescence. This report did not examine potential mediators between early-life family income and executive function, but prevailing theory suggests important roles for stress neurobiology and the quality of parent-child interactions (Blair, 2010; Blair & Raver, 2016; Hackman & Farah, 2009; Ursache & Noble, 2016).

Furthermore, the current study added evidence that executive function skills are important predictors of academic success. To provide just a few examples that might explain these associations, executive function allows children to shift and maintain attention as needed during a lesson, remember classroom rules, inhibit inappropriate impulses, hold and manipulate items in working memory to aid reasoning, and use planning to solve problems effectively. It is increasingly recognized that these behaviors and abilities are equally important in education as content knowledge, if not more important (Blair & Raver, 2015). Nevertheless, it must be noted that our analyses suggested partial, not full mediation of lower early-life income predicting academic achievement in late adolescence via executive function, as a direct path between low early-life family income and academic achievement persisted after accounting for the role of executive function in our basic model without covariates. It should not be surprising that full mediation was not observed; there are likely to be multiple mediating mechanisms in addition to executive function by which family income influences academic achievement. Previous studies have highlighted the mediating role of family, school, and neighborhood processes (Aikens & Barbarin, 2008; McLoyd, 1998; Sirin, 2005; Yeung et al., 2002), and more research is necessary to elucidate these pathways and their relative importance.

Accounting for Covariates

The large sample size in the ALSPAC Study allowed us the unique opportunity to statistically adjust for a number of variables that might confound the associations of interest: early-life distractibility and persistence, family income at ages 8 and 18 years, parental education at age 8, sex, verbal IQ, and extracurricular activities in middle-to-late childhood. We discuss findings related to each covariate in turn.

In order to infer that early-life family income contributes to the development of executive function in middle-to-late childhood, it would be important to statistically adjust for executive function in early childhood. Towards this goal, our models regressed executive function in middle-to-late childhood on two proxy measures of early-life executive function skills assessed at age two, the Distractibility and Persistence scales from the Carey Infant Temperament Questionnaire (Carey & DeVitt, 1978). Both the Distractibility and Persistence scales were significant predictors of later executive function as reported by the teacher and parent, and early-life income continued to predict executive function as reported by the teacher and captured by the EF tasks after partialing out the effect of these two variables. This analysis provides some hints about the potential contribution of low family income to the development of executive function, but this finding should be interpreted with caution given the correlational study design and the limitation that this early measure was a weaker assessment of executive function than the age 7-11 measures.

Higher family income measured when the child was 8 years old and 18 years old was also related to higher academic achievement. This is not surprising, given that financial circumstances in late childhood and adolescence may constrain youth’s decision to continue schooling and orient them towards seeking employment rather than pursuing a university education if they come from families who are struggling financially. Once these two covariates were added into the model, the role of early-life income was weakened because both of these variables were strongly correlated to the early-life income measure. Nevertheless, the indirect path from early-life income to academic achievement via executive function tasks remained significant, suggesting a foundational role for early-life income in predicting later academic achievement. This finding is consistent with some prior evidence from national datasets in the United States highlighting the role of early-life income above the role of subsequent family income (Duncan et al., 1998; Johnson & Schoeni, 2011).

As expected, parental education at age 8 was positively related to later academic achievement. The logic behind the inclusion of this covariate was two-fold. First, we wanted to examine whether family income would retain its predictive power after we account for this other important facet of socioeconomic status. This is useful to examine in order to inform future interventions, which may focus on improving family finances, parental education, or both. Secondly, parents' educational attainment shapes offspring academic aspirations through pathways such as parental beliefs, expectations, and modeling of desirable goals (Davis-Kean, 2005; Eccles, 2005), which would be different pathways to explaining our outcomes than our hypothesis that executive function is directly involved in and a facilitator of academic performance. Analyses indicated that, even after accounting for parental education, income continued to predict academic achievement and executive function remained a predictor of academic achievement.

Interestingly, sex was related to three aspects of executive function but not academic achievement. In the current study, female participants demonstrated better executive function abilities as reported by their parents and teachers and performed better on the Lower-Order EF tasks relative to male participants. This is consistent with previous research, which has indicated a sex effect favoring females in executive function, particularly in studies of young children (reviewed in Zelazo, Carlson, & Kesek, 2008). However, females did not differ from males on our academic achievement composite, which included performance on end-of-high school qualification exams and university application or admission outcomes. The fact that the female advantage in aspects of executive function did not translate into higher academic achievement is intriguing. This result may dovetail with meta-analytic evidence suggesting that females receive higher school marks than males on almost any subject, but this advantage disappears when examining national achievement tests (Voyer & Voyer, 2014). Perhaps females' higher executive function skills in the classroom allow them to perform better in daily school contexts and when being evaluated by their teachers who observe other aspects of competence, such as behavioral self-regulation. However, this advantage may diminish in the context of standardized national exams, which are often one-time tests that both males and females try to prepare well for. The fact that the female advantage not only disappears but is reversed in some standardized achievement tests such as mathematics tests (Voyer & Voyer, 2014) also suggests that female performance might suffer in these circumstances due to stereotype threat, which is perhaps reducing the scholastic advantage they otherwise exhibit when school marks are considered.

As expected, verbal IQ at age 8 was related to all four executive function factors and later academic achievement, such that participants who had higher verbal IQ exhibited better executive function and better later academic achievement. This is in line with an extensive body of prior research (e.g., Arffa, 2007; Roth et al., 2015). Verbal IQ was also significantly associated with early-life family income (see Table 1.2), such that participants with higher family income scored higher on this test. This finding is consistent with prior longitudinal research in the United Kingdom indicating that children of lower socioeconomic status already exhibit lower IQ compared to high-socioeconomic status children by the time they are two years old, and these differences widen over time (von Stumm & Plomin, 2015). Nevertheless, executive function explained variability in academic achievement even after accounting for the association of verbal IQ with both executive function and academic achievement.

Participation in extracurricular activities (sports, swimming, languages, music, singing, religion, and other groups like Scouts) exhibited positive associations with both of the task-based Higher- and Lower-Order EF factors as well as later academic achievement, consistent with prior research on the positive developmental outcomes associated with participating in such activities (Farb & Matjasko, 2012). We included this covariate to reflect the potential influence of the broader social context that school-aged children encounter and because extracurricular activities are associated with both income and academic achievement (Morris, 2015). We found that early family income retained significant associations with task-based executive function and academic achievement even after accounting for the role of these enriching social activities.

Limitations, Strengths, and Conclusions

The present study was not without limitations. First, although the long-term prospective longitudinal design was a major strength because it allowed us to link early-life experiences to long-term outcomes, it also resulted in significant attrition in our outcome measure (only 3,215 participants, representing 21% of the original sample, completed the academic assessment at age 16-18). This is a significant limitation of this study. Although not uncommon among studies that span such long time periods, this high attrition rate left the sample less representative and of higher socioeconomic status than the initial sample (Boyd et al., 2012), limiting generalizability. Furthermore, we believe that this likely resulted in an underestimation of the true magnitude of the effects, since many of the low-income participants from the initial sample were lost to follow-up and this restricted the range of income observed in the final sample. This interpretation is supported by results from the imputed data, which were stronger and showed mediation by all four executive function factors with complete, imputed datasets (see Supplemental Figure 1.6). Thus, our analyses should be interpreted as evidence that the pathways we tested matter for the target outcomes and as potential hints about the lower bound of the possible effect sizes, rather than as exact point estimates for the true effects in the population.

A second limitation is that the self-report nature of the academic achievement data may introduce some bias. We believe that memory biases are mitigated by the fact that these data were collected very close in time to the relevant qualification exams and university application deadlines. Furthermore, subjectivity biases were mitigated by the concrete and unambiguous nature of the questions (whether they passed certain qualification exams or not, applied for university admission or not, and gained university admission or not).

Finally, another limitation is that this study is correlational, thus we cannot definitively ascertain causality. We statistically controlled for early-life distractibility and persistence at age 2 as proxy measures of early executive function, thus revealing that early-life family income continued to predict executive function in middle-to-late childhood, consistent with our hypothesis about a potential contribution of early family income to the development of executive function from age 2 to ages 7-11. A measure of academic achievement at ages 7-11 was not available to conduct similar adjustment for prior levels of academic achievement. Ultimately, the correlational design in this study precludes stronger causal inferences about the role of family income in shaping child executive function given that we cannot rule out alternative explanations (e.g., the contribution of genetics to both parent and child executive function, which could impact parental earnings and contribute to the association we observed). Other studies with experimental and quasi-experimental designs (e.g., cash transfer programs, laboratory experiments that induce resource scarcity mindsets) suggest that a causal effect is theoretically plausible, as these studies demonstrate that resource scarcity leads to a pattern of decision-making that favors smaller short-term gains over greater long-term benefits (Haushofer & Fehr, 2014), which would be reflected in low executive function skills as assessed with various tasks.

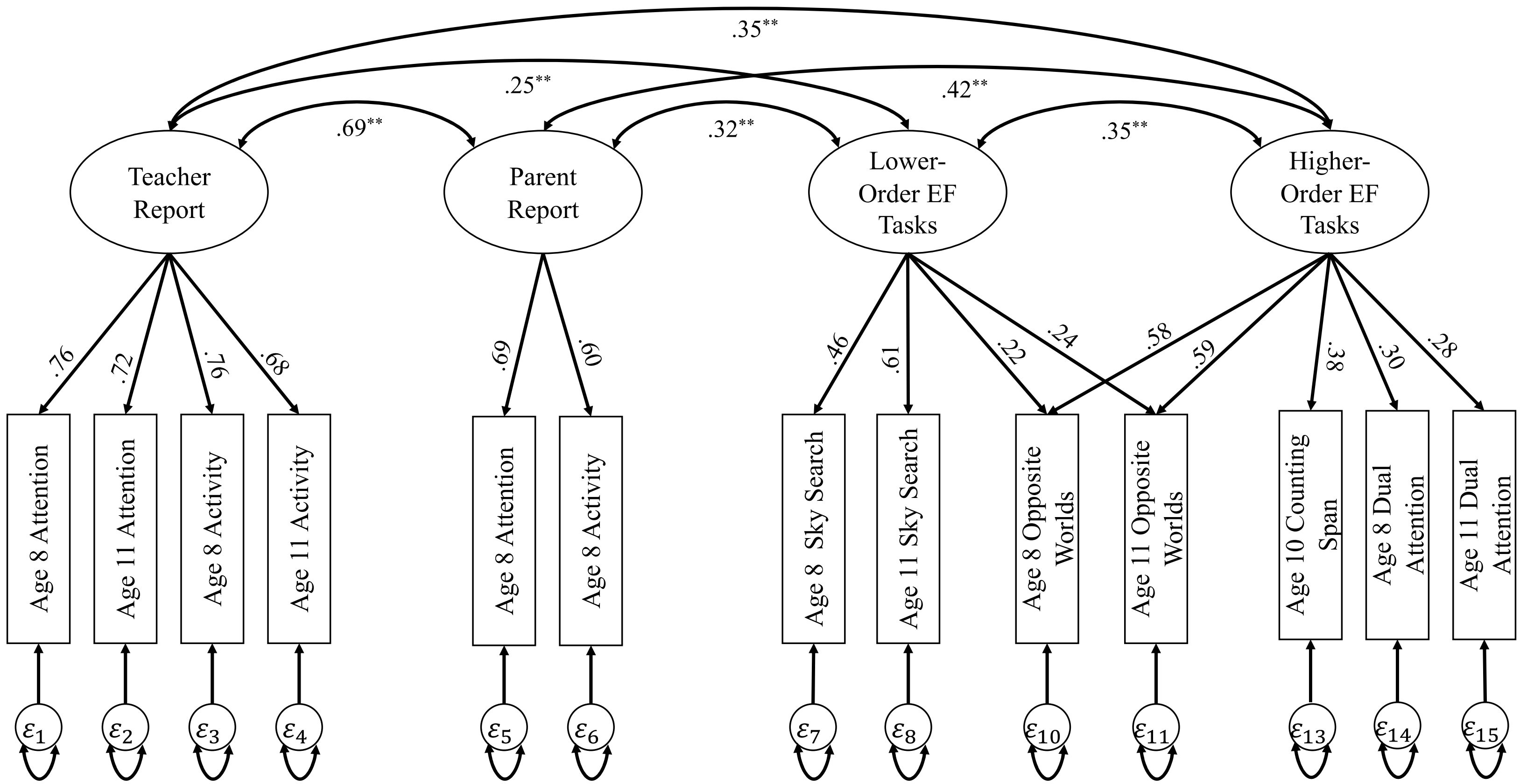
Despite these limitations, the current study also had a number of methodological strengths. The long developmental time span covered and large sample size were unique assets of this study that allowed us an expanded window for observing associations with early-life family income independently of later income. Furthermore, the thorough assessment of executive function through multiple indices and across multiple waves of data collection strengthens confidence in our findings. The availability of both task-based measures of executive function as well as parent and teacher reports limited the contribution of reporting biases by allowing us to parse measurement variance out through latent factor modeling.

In conclusion, this study supports the role of executive function in middle-to-late childhood as a foundation for long-term academic success, and a possible mediator between early-life family income and academic achievement. These findings support the value of intervention programs that aim to improve executive function to reduce income-based disparities in academic achievement. Indeed, evidence exists that boosting executive function in the preschool years may help close the achievement gap between poor children and their better-off peers (Blair & Raver, 2014). Our study also highlights executive function between the ages of 7 and 11 as another possible target, with potentially far-reaching benefits for academic achievement.

Supplemental Table 1.4. Exploratory factor analysis with 13 observed executive function measures and all missing data imputed returned the same results as our primary analyses: four factors with eigenvalues > 1. Factors were extracted using Principal Components Analysis with a Promax rotation (note that the same pattern of results was obtained using a Varimax rotation). Factor loadings are shown for each measure and the four factors. We defined each factor based on the common practice of the measures loadings at .30 or higher (see highlighted cells; Osborne, Costello, & Kellow, 2008).

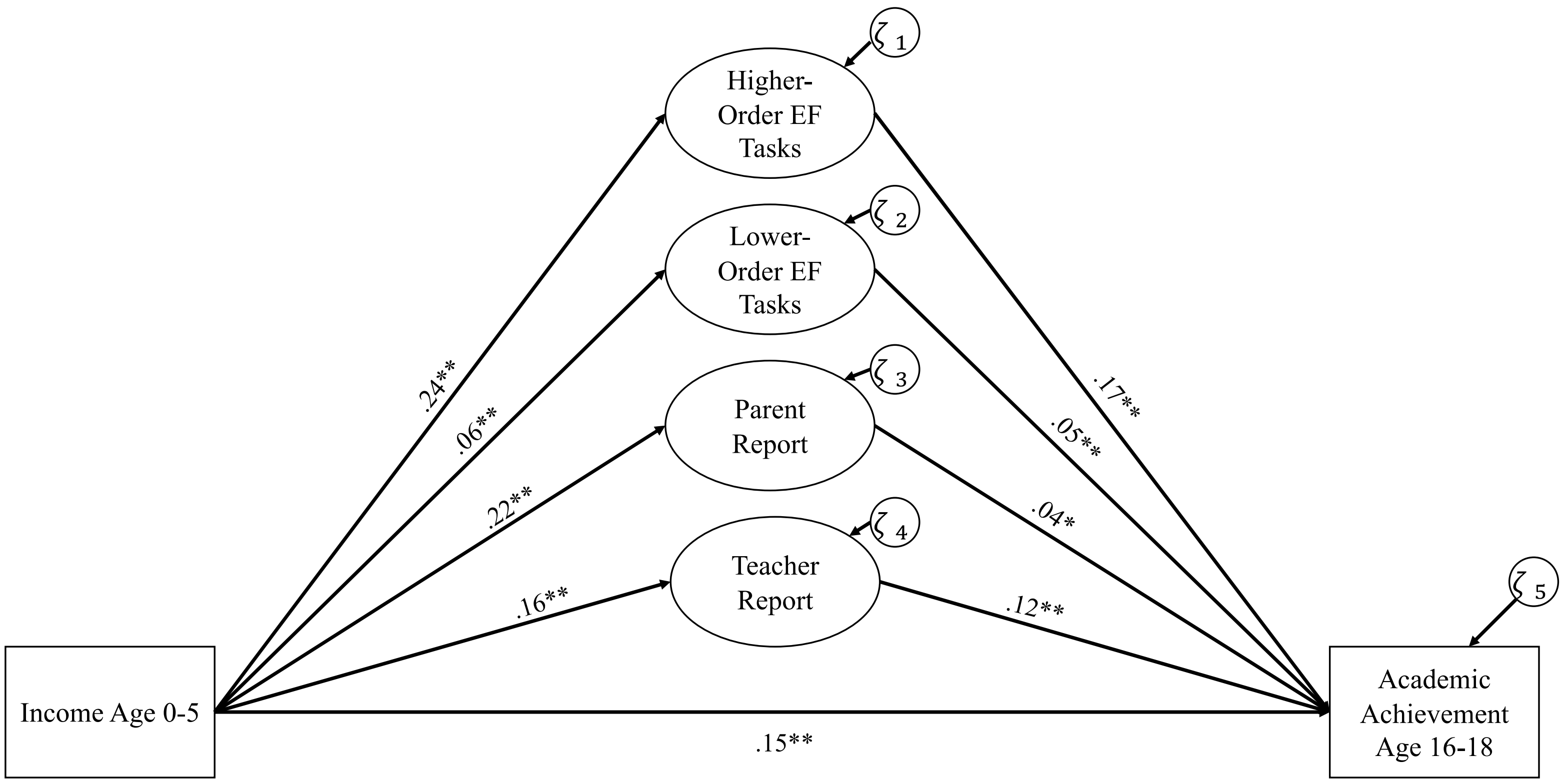
Observed Measures	*Teacher Report Factor* *(Eigenvalue 3.70)*	*Lower-Order EF Tasks* *(Eigenvalue 1.75)*	*Parent Report Factor* *(Eigenvalue 1.16)*	*Higher-Order EF Tasks* *(Eigenvalue 1.10)*
Teacher – Age 8 Attention	**.66**	.08	.12	.09
Teacher – Age 11 Attention	**.75**	-.05	.15	-.09
Teacher – Age 8 Activity	**.84**	.05	-.09	.08
Teacher – Age 11 Activity	**.91**	-.08	-.08	-.07
Parent – Age 8 Attention	.00	.05	**.90**	.03
Parent – Age 8 Activity	.03	-.07	**.94**	-.05
Sky Search – Age 8	-.07	**.74**	-.02	-.16
Sky Search – Age 11	.06	**.79**	-.01	-.20
Dual Attention – Age 8	-.15	-.12	.05	**.69**
Dual Attention – Age 11	.07	-.32	-.02	**.73**
Opposite Worlds – Age 8	-.05	**.48**	.04	**.41**
Opposite Worlds – Age 11	.03	**.47**	.02	**.40**
Counting Span – Age 10	.11	.12	-.09	**.50**

Supplemental Figure 1.5. Confirmatory Factor Analysis (CFA) with imputed data



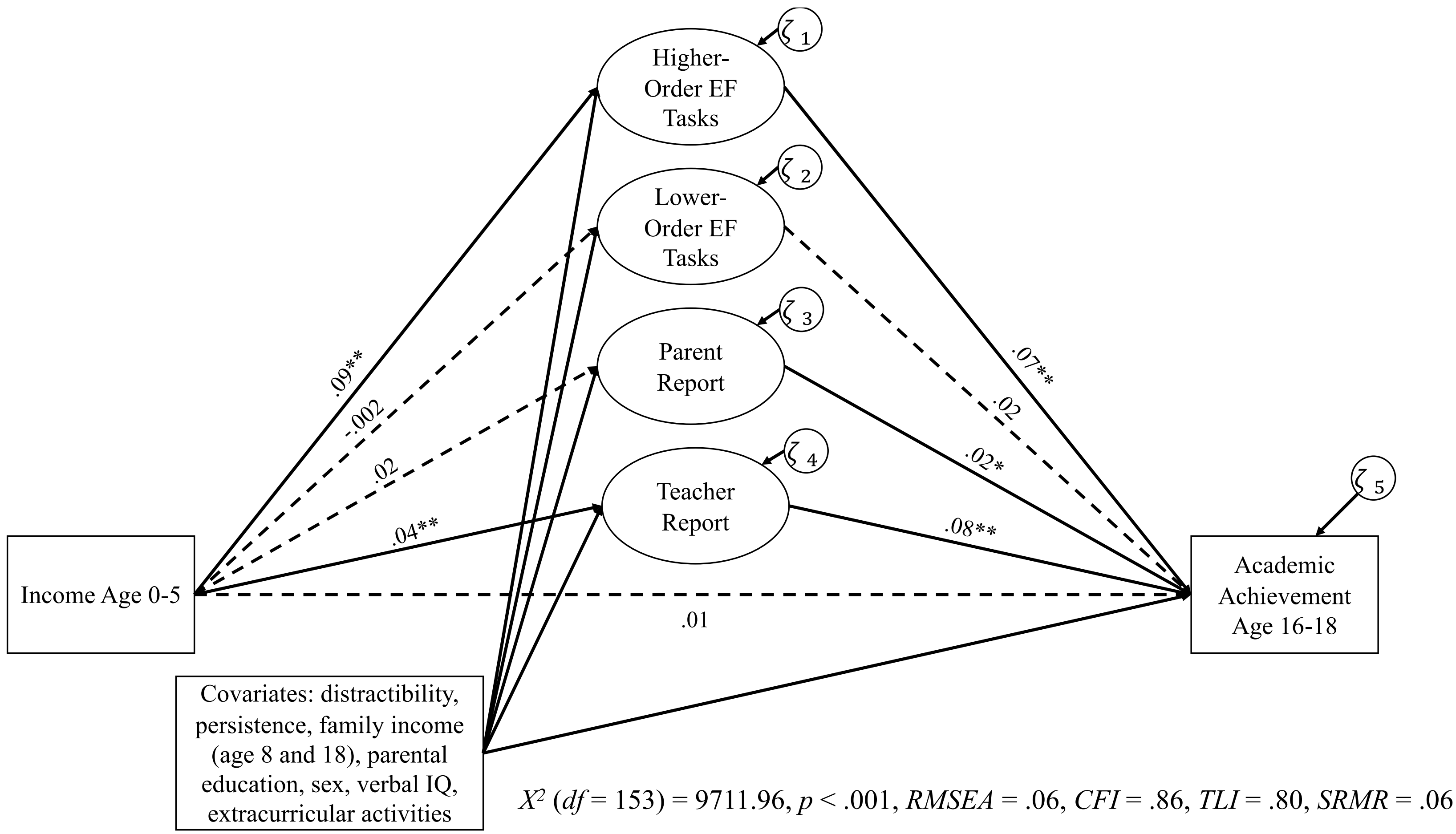
X^2 (df = 50) = 2758.30, p < .001, *RMSEA* = .06, *CFI* = .95, *TLI* = .92, *SRMR* = .04

Supplemental Figure 1.6. Mediation model without covariates (imputed data). All four executive function factors significantly mediated the relation between income age 0-5 and academic achievement (indirect effects for Higher-Order EF Tasks: β = .04, *SE* = .004, *p* < .001; for Lower-Order EF Tasks: β = .003, *SE* = .001, *p* = .001; for Parent Report: β = .009, *SE* = .005, *p* = .04; for Teacher Report: β = .02, *SE* = .002, *p* < .001).



X^2 (*df* = 74) = 7389.82, *p* < .001, *RMSEA* = .09, *CFI* = .85, *TLI* = .80, *SRMR* = .11

Supplemental Figure 1.7. Mediation model with covariates (imputed data). Higher-Order EF Tasks and Teacher Report factors significantly mediated the relation between income age 0-5 and academic achievement (indirect effects for Higher-Order EF Tasks: β = .006, *SE* = .002, $p < .001$; for Lower-Order EF Tasks: β = -.000, *SE* = .000, $p = .90$; for Parent Report: β = .000, *SE* = .000, $p = .15$; for Teacher Report: β = .004, *SE* = .001, $p < .001$).



CHAPTER 2

STUDY 2: THE EFFECTS OF ACUTE STRESS AND PARENT SUPPORT ON EXECUTIVE FUNCTION: AN EXPERIMENTAL STUDY

Executive function (EF) is an umbrella term for a collection of skills that make it possible for us to keep goals and information in mind, maintain attention, remain focused on a task despite distractions, decide on the best course of action, reflect on the past and plan for the future (Zelazo et al., 2016). EF includes at least three core facets: working memory, cognitive flexibility, and inhibitory control (Diamond, 2013; Miyake & Friedman, 2012). Working memory comprises the ability to hold information in mind as well as update and integrate those contents if new information arises. Cognitive flexibility comprises the ability to shift between rules and ways of thinking. Inhibitory control involves the overriding of a prepotent thought or response in order to stay on task or respond in an appropriate way. Within these three core facets of EF, research indicates that there may also be both “hot” and “cold” EF, the difference between the two being emotion and motivation (Zelazo & Carlson, 2012). When motivation and emotion are high, “hot” EF is recruited, while when motivation and emotion are low, “cold” EF is recruited. The three core facets are what high-order EF such as planning, problem-solving and reasoning are based upon. These processes are important for getting along with peers (e.g., Holmes et al., 2016; Nakamichi, 2017) and parents (Merz et al., 2017), as well as academic performance (Cortés Pascual et al., 2019; Wang & Zhou, 2020). Additionally, EF is important for long-term outcomes such as mental and physical health, academic outcomes, marital harmony, and involvement with the justice system (Diamond, 2013).

The importance of EF for all of these short and long-term outcomes makes it imperative that the factors that influence it are understood. Stress is thought to impact many brain regions and networks that overlap with those recruited by EF, namely the prefrontal cortex (PFC; reviewed in Arnsten, 2009). Although the effects of stress on brain regions such as the prefrontal cortex are stronger when individuals experience chronic stress, there are also measurable effects of acute stress. Stressors that are social-evaluative and unpredictable in nature are particularly potent activators of neurobiological stress-response systems (Dickerson & Kemeny, 2004). Children face a variety of these social-evaluative and unpredictable stressors daily, ranging from evaluation in the classroom to conflict with a classmate or a family member. These types of stressors may have an impact on EF performance.

Stress and Executive Function

Accumulating evidence suggests that the experience of stress can acutely influence cognitive processes such as EF (for review, see Lawson et al., 2018; Op den Kelder et al., 2018; Shields et al., 2016a). However, the majority of this research has focused on the effects of acute stress on EF performance in adults. In comparison to the literature on the effects of acute stressors on EF in childhood, the adult literature is much more expansive. Shields and colleagues (2016a) conducted a meta-analysis of 51 studies that evaluated the effect of acute stressors such as the Trier Social Stress Test (TSST) and the Socially Evaluative Cold Pressor Test (SECPT) on EF performance in adults. Of the 51 studies, 34 assessed working memory, 21 assessed inhibitory control, and 6 assessed cognitive flexibility. They found that adults who had experienced an acute stressor exhibited both impaired working memory and cognitive flexibility, but they did not find an overall effect of acute stress on inhibitory control (Shields et al., 2016a). They found that the type of inhibitory control may matter, such that response inhibition, or the suppression of a prepotent response, was enhanced following stress, while cognitive inhibition, or selectively attending to or ignoring information, was impaired following stress (Shields et al., 2016a). Although this distinction between response inhibition and cognitive inhibition has been challenged (Roos et al., 2017b), this evidence suggests the impact of acute stress on inhibitory control may vary by task type.

The literature examining the relation between experiencing chronic stressors and EF performance is also quite expansive and consistent. Two relevant meta-analyses that assessed the relation between experiencing chronic stressors such as low socioeconomic status (Lawson et al., 2018) and trauma (Op den Kelder et al., 2018) and EF performance in childhood found that experiencing these chronic stressors was related to lower performance across all EF domains. Taken together, the extant literature indicates that there appear to be effects of both acute and chronic stress on EF performance, but there is much more to be learned about the effects of acute stress in children.

The literature assessing the effect of acute stressors on EF in children is sparse and the findings are mixed. To date, there are just four studies of the effects of experiencing acute stressors on EF in children and adolescents (de Veld et al., 2014; Mücke et al., 2020; Quesada et al., 2012; Tsai et al., 2021). Three of these previous studies have assessed the impact of experiencing an acute stressor on working memory performance in children (de Veld et al., 2014; Quesada et al., 2012; Tsai et al., 2021), and another assessed the impact on inhibitory control in adolescents (Mücke et al., 2020). All of these studies examined how the experience of an acute social-evaluative stressor, the Trier Social Stress Test (TSST) impacted EF performance. Quesada and colleagues (2012) found no effect of experiencing the TSST on working memory of 8-10-year-old children in comparison to children in a no-stress comparison condition, while de Veld and colleagues (2014) found for 9-11-year-old children, that children who experienced the TSST exhibited worse performance on working memory tasks following the TSST in comparison to their performance on the tasks a week earlier, without the TSST. Tsai and colleagues (2021) examined the effects of experiencing the TSST on working memory performance in 8-15-year-olds and examined differences in processes involved in working memory based on age and activation of physiological systems. They found that older children exhibited better accuracy and fewer false alarms on the task, but since all participants experienced the TSST, this study could not examine the effects of the acute stressor itself (Tsai et al., 2021). Mücke and colleagues (2020) examined the effects of experiencing the TSST on inhibitory control in 16-20-year-old adolescents, finding no effect compared to baseline. To date, there is no published work looking at the effects of acute stressors on cognitive flexibility performance in children.

The Role of Parental Support

If acute stress impacts EF performance, it is also important to examine factors that might buffer children from these impacts. Social support from parents can buffer children’s physiological stress response during and after experiencing a stressor (Gunnar et al., 2015; Hostinar et al., 2015; Parenteau et al., 2021; Seltzer et al., 2010). Although social support has not yet been examined as a buffer against the effects of stress on EF performance, there is a literature that assesses the relation between the quality of the parent-child relationship and child EF performance. Research indicates that children exhibit better EF performance if they have a secure attachment style (e.g., Bernier et al., 2012; 2015; Lind et al., 2017; Merz et al., 2017), and if their parents exhibit high levels of support (e.g., Moilanen et al., 2010; Spruijt et al., 2018; Vandenbroucke et al., 2017), positive parenting (e.g., Amicarelli et al., 2018; Roskam et al., 2014), and parental involvement (e.g., Roskam et al., 2014; Sosic-Vasic et al., 2017). This literature points to the possibility that support from a parent might serve as a significant buffer for children against the effects of acute stress.

Potential Moderators of the Relation Between Stress and EF

Stressors, particularly social-evaluative stressors, are potent activators of stress neurobiological systems like the hypothalamic-pituitary-adrenal (HPA) axis and the autonomic nervous system (Dickerson & Kemeny, 2004). The parasympathetic nervous system (PNS) is essential in moderating arousal in response to stressors and is also linked to cognitive performance (Thayer et al., 2009; Yim et al., 2015). However, the literature assessing the role of the PNS in explaining the effects of acute stress on EF is quite sparse. Roos and colleagues (2017a) found that higher PNS reactivity was a protective factor for participants, such that participants who had high PNS reactivity did not exhibit the impaired inhibitory control performance that those with lower PNS reactivity did. While this relation has not been tested in children, other research has found that during EF tasks, moderate PNS reactivity, rather than high or low, is linked to optimal EF performance (Marcovitch et al., 2010). The other branch of the autonomic nervous system, the sympathetic nervous system (SNS), has also been examined as a potential moderator of the stress-EF relation, focusing on working memory. Two studies have examined SNS reactivity as an explanation of the stress-EF relation in childhood through salivary alpha-amylase (sAA; de Veld et al., 2014; Tsai et al., 2021). De Veld and colleagues (2014) found no association between sAA reactivity to the TSST and working memory performance, while Tsai and colleagues (2021) found that higher sAA reactivity to the TSST predicted better working memory performance.

Similarly, cortisol, the end product of the HPA axis, can disrupt typical prefrontal cortical function (e.g., Porcelli et al., 2008; Vogel et al., 2016), which is essential for EF (Arnsten, 2009). However, the literature examining the effect of cortisol on EF performance is inconsistent. Schwabe and colleagues (2013) found that when cortisol was pharmacologically blocked, the effects of acute stress on EF were non-significant, indicating that cortisol may be involved in the pathway by which acute stress impacts EF. Other studies that measure circulating cortisol have found that higher cortisol was related to better EF (de Veld et al., 2014; Gabrys et al., 2019; Wünsch et al., 2019), or had no effect on EF (Human et al., 2018; Shields et al., 2016b).

In addition to these biological processes, child mental health may also play an important role in the relation between experiencing a stressor and EF performance. Previous work has found that children who have both internalizing (e.g., Mullin et al., 2018; Wang & Zhou, 2020) and externalizing (e.g., Mullin et al., 2018; Schoemaker et al., 2013) problems exhibit worse EF in comparison to children who do not. Therefore, it is possible that pre-existing child emotional and behavioral problems may influence how the experience of stress impacts EF performance.

The Present Study

In order to address these gaps in the literature, the current study tested the relation between the experience of acute stress and EF performance in 9-11-year-old children. We hypothesized that children exposed to the Trier Social Stress Test-Modified (TSST-M) would exhibit worse EF than children who did not experience the TSST-M. We also hypothesized that children who received social support from parents prior to the TSST-M would be buffered from the effects of experiencing the TSST-M and would exhibit better performance than children who did not experience parental support and similar performance to children who did not experience the TSST-M. Lastly, we examined the exploratory hypotheses that child characteristics such as PNS and SNS reactivity, cortisol reactivity, and child behavioral and emotional problems would moderate the relation between experiencing the TSST-M and EF performance.

Methods

Participants

Participants included 181 children, aged 9-11 years old and their parents who lived in the Sacramento-Davis area. Participants were recruited through the University of California, Davis Participant Pool system (*n* = 170) and Facebook advertisements (*n* = 11). Sample demographic information can be found in Table 2.1. Participants were 9 to 11 years old (*M* = 9.91 years, *SD* = 0.56 years; 50.6% male and 49.4% female at birth; current gender identification: 48.3% male, 50% female, and 1.7% other). Participants were screened to participate via a phone interview with a parent. Exclusion criteria included having a developmental disorder, chronic health condition, a speech or language disorder that would prohibit study activities, and currently taking psychotropic or steroid medication. In addition, parents were asked if their child had been ill in the past two weeks, and if so, study visits were scheduled two weeks after their child's symptoms subsided.

Demographic information was obtained via parent report. The racial/ethnic distribution for the 180 participants who provided this information was as follows: 64.2% of children were White, 5.6% were Asian, 4.5% were Hispanic/Latino, 1.1% were Native American, 0.6% were Black/African American, and 24.0% were more than one race/ethnicity. In addition, one participant declined to answer. Mean total annual household income was $126,498 (*SD* =

$56,266), ranging from $12,500 to more than $200,000. Highest parental education level was the highest education level among the participant's parents that culminated in the obtainment of a degree, and was coded as a 6-level ordinal variable for the 178 participants who provided this information, such that: 0 = *less than high school* (0.6%), 1 = *high school diploma or GED* (7.9%), 2 = *two-year or vocational degree* (11.3%), 3 = *four-year degree* (34.5%), 4 = *master's degree* = 4 (29.9%), 5 = *doctoral level degree* (15.8%). Three participants declined to answer.

Procedure

Participants attended a laboratory visit accompanied by a parent or legal guardian. All visits occurred in the afternoon, with a start time between the hours of 1:30 pm and 2:30 pm. After informed consent and assent were obtained from the parent and child respectively, the first saliva sample was collected (10 minutes after arrival). Saliva samples were collected at 8 time points, every 20 minutes, for the remainder of the laboratory visit. Participants were randomly assigned to one of three experimental conditions (see description below). Following recruitment of 130 participants, careful monitoring of age bins and gender was implemented to ensure that the three conditions were balanced by gender and have nearly identical age distributions. This study was approved by the Institutional Review Board of the University of California-Davis and the State of California Committee for the Protection of Human Subjects.

Trier Social Stress Test – Modified (TSST-M). The TSST-M is a modified version of the Trier Social Stress Test acute social stressor for adults (Kirschbaum, Pirke, & Hellhammer, 1993). The TSST-M was specifically designed to elicit a mild stress response in children in this age range (Yim et al., 2010). The TSST-M procedure consisted of the following steps: participants were told that they had ten minutes to prepare a speech that would be evaluated by judges and recorded on camera to be later analyzed. For the topic of the speech, participants were asked to imagine that they are in a new classroom and a teacher has asked them to introduce themselves to the class (for details on this protocol, please see Yim et al., 2010). After the ten-minute preparation period, participants were escorted to a novel room where there were two judges in white lab coats and a video camera (the judges were research assistants who remained hidden to participants prior to this point). The video camera was turned on in front of the participant and once the experimenter left the room, a judge asked the participant to begin their speech. The participant then engaged in a five-minute speech followed by a five-minute arithmetic subtraction task. Children were asked to continuously subtract from 758 by 7s and if they were unable to do that, were asked to subtract from 304 by 3s. Judges refrained from showing facial affect or providing feedback to the child during the process, aside from informing them that they had more time if they paused during the speech, and informing them when they gave an incorrect answer during the arithmetic task. Following the TSST-M or a control task, the participants completed four EF tasks (described in greater detail below), a donation task (described in Alen et al., 2021), and additional questionnaires, and provided four subsequent saliva samples every 20 minutes. At the very end of the laboratory visit, participants and their parents were debriefed regarding the nature of the TSST-M, explaining why the judges had to remain neutral. The experimenter assured the child that they did a commendable job on the study tasks.

Experimental conditions. Participants were randomly assigned to one of three experimental conditions: alone, parent, and control. Participants in the alone and parent condition underwent the TSST-M (described above). Participants in the alone condition spent the 10-minute preparatory period alone while participants in the parent condition spent the preparatory period with their parent, who was instructed to help their child in whichever way felt most natural. The participants in the control condition were told that they were in the “calm comparison group” and that instead of doing the speech, they would talk with the experimenter about their favorite book or movie and then play a game. They were asked to spend the 10-minute preparation period with their parent, thinking about their favorite book or movie and writing down some ideas to discuss. Following this 10-minute period, participants were taken to a novel room where they engaged in five minutes of friendly conversation about the chosen book or movie with the experimenter, which would match the speaking demands of the TSST-M but exclude the elements of social evaluation, as there were no judges present and the conversation was not video-recorded. Next, to match the cognitive demands of the mental arithmetic component of the TSST-M, the participants were asked to play a Sudoku game for five minutes; a game in which participants were asked to fill in the blank spaces of a number puzzle; each row, column and 3x3 block had to be filled with numbers 1-9 (level played was ‘Easy’). If the participant was unfamiliar with the game, it was explained to them. Participants were told that their performance on the Sudoku was not important and were given access to a sheet with hints and answers on it. The experimenter spent time tidying up the room during this part of the task, to prevent the participant from feeling watched and evaluated on their performance. Following the TSST-M or control condition, participants provided a saliva sample with the experimenter and then began the EF tasks (described below).

Measures

Working memory. Working memory was measured using the Memory for Sentences task (Sattler, 1988; Thorndike et al., 1986). The Memory for Sentences task involves an experimenter reciting a sentence for participants to immediately repeat, with sentences increasing in complexity as the task goes on. The task started with a different sentence depending on the child's age. Participants were acclimated to the task by completing three practice sentences that were less complex than those for their age-level. Once the child demonstrated understanding of the task through successful practice trials, the experimenter read the first sentence specified for the child's age. If the child incorrectly repeated the first sentences, the experimenter administered an easier sentence for younger children. The task continued until two consecutive sentences were repeated incorrectly by the participant. If the child appeared to be struggling, the experimenter used encouraging words such as, "That was a hard one!" or "That was a great try", as words of motivation (Thorndike et al., 1986). To end the task on a positive note, the experimenter read a few easy sentences in earlier sections prior to moving on to the next task (Thorndike et al., 1986). Children's score on this task was recorded as the number of the highest item administered minus the total number of items failed. Higher scores on this task indicate better working memory performance.

Cognitive flexibility. Cognitive flexibility was measured using the Trail Making task (Reitan & Wolfson, 1985). This task consisted of two parts, A and B. In part A, participants were asked to draw a line to connect numbers 1-25 in ascending order. In part B, participants were asked to connect numbers and letters (1-13) and (A-L) alternating between numbers and letters (Reitan & Wolfson, 1985). Following an example from the experimenter, the child's proceeded to complete both parts while being timed. The child was advised to not lift up the pen or pencil to accomplish the task as quickly as possible. If an error was made throughout the process the experimenter pointed it out and allowed the child to correct it (Reitan & Wilson, 1985). Part A of the Trail Making Task signifies the participants' performance on processing speed; part B signifies the participants cognitive flexibility performance. A ratio was calculated by dividing the time taken on part B by the time taken on part A. Higher scores indicate poorer cognitive flexibility performance. This ratio was positively skewed so the score was transformed with the log-10 transformation. Lower transformed scores on this task indicate better cognitive flexibility performance.

Inhibitory control. Inhibitory control was measured using the Day/Night task (Gerstadt et al., 1994; Lagattuta et al., 2011). This task was posed to participants as an “opposite game”. The task involved a picture of a moon and a sun, presented to them on a computer screen. Participants were instructed to say “night” when they saw a sun and “day” when they saw a moon (Lagattuta et al., 2011). Participants were given the chance to practice 4 trials in random order before starting the task (Lagattuta et al., 2011). The experimenter ensured that the random order included at least one consecutive repetition of “day” or “night” to encourage the development of a prepotent response (e.g., day-day-night; Lagattuta et al., 2011). If a child made errors during the practice, the experimenter explained the rules and started the practice trials again until the child got four trials correct in a row (Lagattuta et al., 2011). The experimenter then started a timer and asked the child to start the task, which consisted of 20 moon and sun images displayed as a Microsoft PowerPoint slideshow. Upon a child providing a response (“day” or “night”), the experimenter advanced to the next slide by pressing a button on the computer. The performance variable on this task was computed as the total number of trials correct. This score was positively skewed so the score was transformed with the exponential transformation and Z-scored. Higher transformed scores on this task indicate better inhibitory control performance.

Emotional inhibitory control. Emotional inhibitory control was measured via the Happy/Sad task, which uses the same procedure as the Day/Night task but uses emotional stimuli (i.e., “happy” and “sad” faces instead of moon/sun stimuli). Participants were presented with a cartoon portraying happy (smiling) and sad (frowning) faces. Similar to the Day/Night task, they were instructed to say “sad” when they saw a happy face and to say “happy” when they saw a sad face (Lagattuta et al., 2011). The addition of the emotional component makes this a measure of “hot” inhibitory control. The task consisted of 20 happy and sad faces. The emotional inhibitory control task was coded as the total number of trials correct. This score was positively skewed so the score was transformed with the exponential transformation and Z-scored. Higher transformed scores on this task indicate better emotional inhibitory control performance.

EF task coding. The working memory and cognitive flexibility tasks were recorded in the moment by the experimenter and examined for accuracy using video recordings while the inhibitory control and emotional inhibitory control tasks were coded using the video recordings. The video recordings were examined by two research assistants, KW (n = 71) and JU (n = 103). LD reviewed 10 of each research assistant’s coding for accuracy. Six participants have missing data due to participant refusal (n = 2) and experimenter error (n = 4).

Respiratory sinus arrhythmia (RSA) change. Respiratory Sinus Arrhythmia (RSA) was utilized as a marker of parasympathetic activity, where higher RSA reflects greater parasympathetic modulation of cardiac activity (Laborde, Mosley, & Thayer, 2017). RSA was collected with a MindWare ambulatory electrocardiogram (ECG; MindWare, Westerville, OH), using three silver electrodes with a 7% chloride wet gel attached to the child’s chest (1 on the upper left and 1 on the upper right portion of the chest, and 1 on the lower left ribcage). RSA data were collected during a resting 5-minute baseline period, and during the TSST-M as part of a larger ECG data collection procedure. Current analyses focused on the change in RSA from a baseline period to during the TSST-M. During baseline, participants were instructed to not engage in any activity, to refrain from speaking to their parent, and to attempt to relax for the five-minute duration. During the TSST-M, participants were standing in front of a panel of two judges and engaging in the speech and math tasks.

Interbeat interval (IBI) data were calculated using an automated algorithm in the MindWare Biolab acquisition software. A high-frequency band pass filter set at .24 – 1.04 Hz was used to correspond to the average breathing rate of this age range (Quigley & Stifter, 2006). Sampling rate was set at 500 Hz. R-peaks were inspected and cleaned for artifacts by trained researchers using MindWare Heart Rate Variability software. Arrhythmias (e.g., ectopic beats, sinus pauses) were corrected using the MindWare mid-beat function, which averages the IBI interval and minimizes the influence of artifacts. RSA was calculated, using a Fast Fourier transformation algorithm, in 60-second epochs (Berntson et al., 1997). A 60-second epoch was considered usable when it met two criteria: (1) at least 30-seconds of clean, continuous data were available, and (2) less than 10% of R-peaks were estimated (e.g., using the mid-beat function). Manual inspection of peak breathing rate within each 60-second epoch ensured that participant breathing rate did not fall outside of the high-frequency band pass filter range. RSA during the individual 60-second epochs were then averaged together, producing a mean baseline RSA value and a mean TSST-M RSA value. Fourteen participants were missing RSA data for the following reasons: excessive, un-cleanable noise (n = 2), participant request to remove ECG electrodes (n = 3), participant declining to participate in the task (n = 4), and ECG technical malfunction (n = 5). This resulted in RSA data being available for: baseline (n = 173), and TSST-M (n = 166). RSA change was calculated by subtracting RSA during the TSST from RSA at baseline, such that positive values indicate RSA suppression while negative values indicate RSA augmentation.

Pre-ejection period (PEP) change. Pre-ejection period (PEP) was utilized as a marker of sympathetic activity, where longer PEP reflects less SNS modulation of cardiac activity (Berntson et al., 2004). PEP is the length of time between the electrical depolarization of the left ventricle and the beginning of ventricular ejection and has been widely used as a non-invasive index of sympathetic modulation of the heart (Bagley & El-Sheikh, 2014; Forouzanfar et al., 2018), and has been previously validated using pharmacological blockade (Berntson et al., 1994; Cacioppo et al., 1994; Mezzacappa et al., 1999; Schächinger et al., 2001; Winzer et al., 1999).

PEP was calculated from cardiac impedance data measured concurrently to ECG data collection using a MindWare ambulatory device (MindWare, Westerville, OH). Four silver electrodes with a 7% chloride wet gel were attached to the child's chest and back in standard configuration (Sherwood et al., 1990), including two on the chest (one at the top of the sternum and one at the xiphisternal junction) and two on the back (one over the C4 vertebrae and one over the thoracic spine). The impedance signal was used to derive dZ/dt, the first derivative of the change in thoracic impedance. PEP was defined as the amount of time in milliseconds between the Q-wave of the ECG signal and B-notch of the dZ/dt signal (Berntson et al., 2004). For the identification of the B-notch we employed a two-stage approach recommended by Lozano and colleagues (2007). When impedance data provided a clear signal with a visible B-notch, an algorithm was utilized that identified the B-notch as the peak of the second derivative of the dZ/dt; when impedance data did not provide a clear visible B-notch, the B-notch was estimated using a percentage of the R-peak to Z-peak interval (RZ interval) in milliseconds plus a constant, set at 4 milliseconds: B-notch = 0.55*RZ interval + 4 (Lozano et a., 2007). Due to the small percentage of participants that showed a clear visible B-notch (<3%), all PEP values were calculated using the second method for consistency. Current analyses focused on the change in

PEP from a baseline period to during the TSSST-M. Twenty-nine participants were missing PEP data for the following reasons: excessive, un-cleanable noise (n = 9), signal error (n = 8), participant request to remove ECG electrodes (n = 3), participant declining to participate in the task (n = 4), and ECG technical malfunction (n = 5). This resulted in PEP data being available for: baseline (n = 158), and TSST-M (n = 151). PEP change was calculated by subtracting PEP during the TSST from PEP at baseline, such that positive values indicate PEP shortening while negative values indicate PEP lengthening.

Cortisol reactivity. Saliva samples were collected via the passive drool method every 20 minutes beginning 10 minutes after arrival at the laboratory until 60 minutes after the end of the TSST-M, for a total of eight samples (10, 30, 50, 70, 90, 110, 130, and 150 minutes from arrival). Saliva was stored in micro centrifuge tubes in a secure −80°C freezer until being shipped for assay. Samples were assayed at the Salimetrics' SalivaLab (Carlsbad, CA) using the Salimetrics Salivary Cortisol Assay Kit (Cat. No. 1-3002), without modifications to the manufacturer's protocol. Samples were assayed in duplicate and averaged. Intra-assay coefficient of variation (CV) was excellent (4.6%), as was the inter-assay CV (6%). Complete salivary cortisol data were available for 179 participants, as one participant ended the study visit after completing the second saliva sample and another did not provide any cortisol samples.

In the present study, cortisol reactivity was indexed by change in cortisol from Sample 4 (taken directly before administration of the TSST-M or control condition) to Sample 6 (taken 20 minutes following the TSST-M or control condition). Sample 4 included three outliers (above 4 *SD* from the mean); Sample 6 included two outliers. Outliers were winsorized to the highest value within 4 *SD* from the mean. After winsorizing, all cortisol values were log-transformed to correct for positive skew. Cortisol reactivity was then calculated by subtracting Sample 4 from

Sample 6, such that higher values represent greater increases in salivary cortisol from Sample 4 to Sample 6.

Behavioral and emotional problems (CBCL Total). Child behavioral and emotional problems were measured via parent-report, using the Child Behavior Checklist for 6-18-year-olds (CBCL; Achenbach & Rescorla, 2001). The CBCL includes items that may reflect a behavioral or emotional problem in children ("*Unhappy, sad, or depressed*", "*Gets in many fights*"), which parents rate from 0 to 2 (0 = not true, 1 = somewhat or sometimes true, or 2 = very true or often true). Items are then counted and summarized into subscales (Anxious/depressed, withdrawn/depressed, somatic complaints, social problems, thought problems, attention problems, rule-breaking behavior, aggressive behavior, other problems), which are then computed into 3 final scales: Internalizing, Externalizing, and Total Problems Score (Achenbach, 2019). The present study used the Total Problems score, which captures the eight subscales described. The CBCL has been administered across multiple samples in various cultures (Achenbach, 2019), and features clinical cut-offs and ranges for each of the subscales as well as the Total Score. In our study population (ages 9-11 years old), total scores above 49 are deemed clinically significant and scores between 39-48 fall in the "borderline clinical range". This variable was positively skewed and had possible values of zero so the score was reflected and transformed with the square root transformation to normalize its distribution.

Data Analysis

Statistical analyses were conducted using SPSS version 27. Due to the small amount of missingness (less than 5% on primary variables), listwise deletion was used. As a manipulation check to assess whether the TSST-M activated a stress response, an analysis of variance

(ANOVA) with condition as a fixed effect and cortisol reactivity as the dependent variable was conducted.

To test our first and second hypotheses that there are differences in EF performance by condition, a multivariate analysis of covariance (MANCOVA) with condition as a fixed effect, controlling for participant age and sex (multivariate analyses of variance without covariates are also presented) was conducted. To test our exploratory hypotheses that child characteristics may moderate the effect of condition on EF performance, a series of regressions was conducted. First, the moderating effects of RSA change on performance on each EF task were examined by conducting a series of regressions with condition, RSA change, the interaction between condition and RSA change, baseline RSA, age, and sex. Second, the moderating effects of PEP change on performance on each EF task were examined by conducting a series of regressions with condition, PEP change, the interaction between condition and PEP change, baseline PEP, age, and sex. Third, the moderating effects of cortisol reactivity were examined by conducting a series of regressions with condition, cortisol reactivity, the interaction between condition and cortisol reactivity, baseline cortisol, age, and sex. Lastly, the moderating effects of child emotional and behavioral problems on performance on each EF task were examined by conducting a series of regressions with condition, child emotional and behavioral problems, the interaction between condition and child emotional and behavioral problems, age, and sex. A Bonferroni correction of $p < .0125$ was used for multiple comparisons.

Results

Descriptive statistics for main study variables and bivariate correlations in the full sample controlling for condition appear in Table 2.1. There was a significant correlation between sex and RSA baseline ($r = .244$, $p = .017$), PEP change ($r = -.204$, $p = .047$), and cortisol reactivity (r

= -.247, p = .012), such that male participants had higher RSA at baseline, less PEP shortening in response to the TSST (i.e., less increase in sympathetic activity), and lower cortisol reactivity than female participants. There was also a significant correlation between child age and performance on cognitive flexibility (r = -.222, p = .030), such that older children performed better on this task. PEP change and emotional inhibitory control performance were significantly correlated (r = .229, p = .026), such that children who exhibited PEP shortening during the TSST performed better on this emotional inhibitory control task. Lastly, all three physiological reactivity measures were significantly correlated with its respective baseline measure. Baseline RSA was significantly correlated with RSA change (r = .377, $p < .001$), such that children with higher baseline exhibited more RSA suppression. Baseline PEP was significantly correlated with PEP change (r = .496, $p < .001$), such that children with higher baseline PEP exhibited more PEP shortening. Baseline cortisol was significantly and inversely correlated with cortisol reactivity (r = -.330, p = .001), such that children with higher baseline cortisol exhibited lower cortisol reactivity.

Table 2.1. Sample Characteristics and Correlations Between the Major Variables

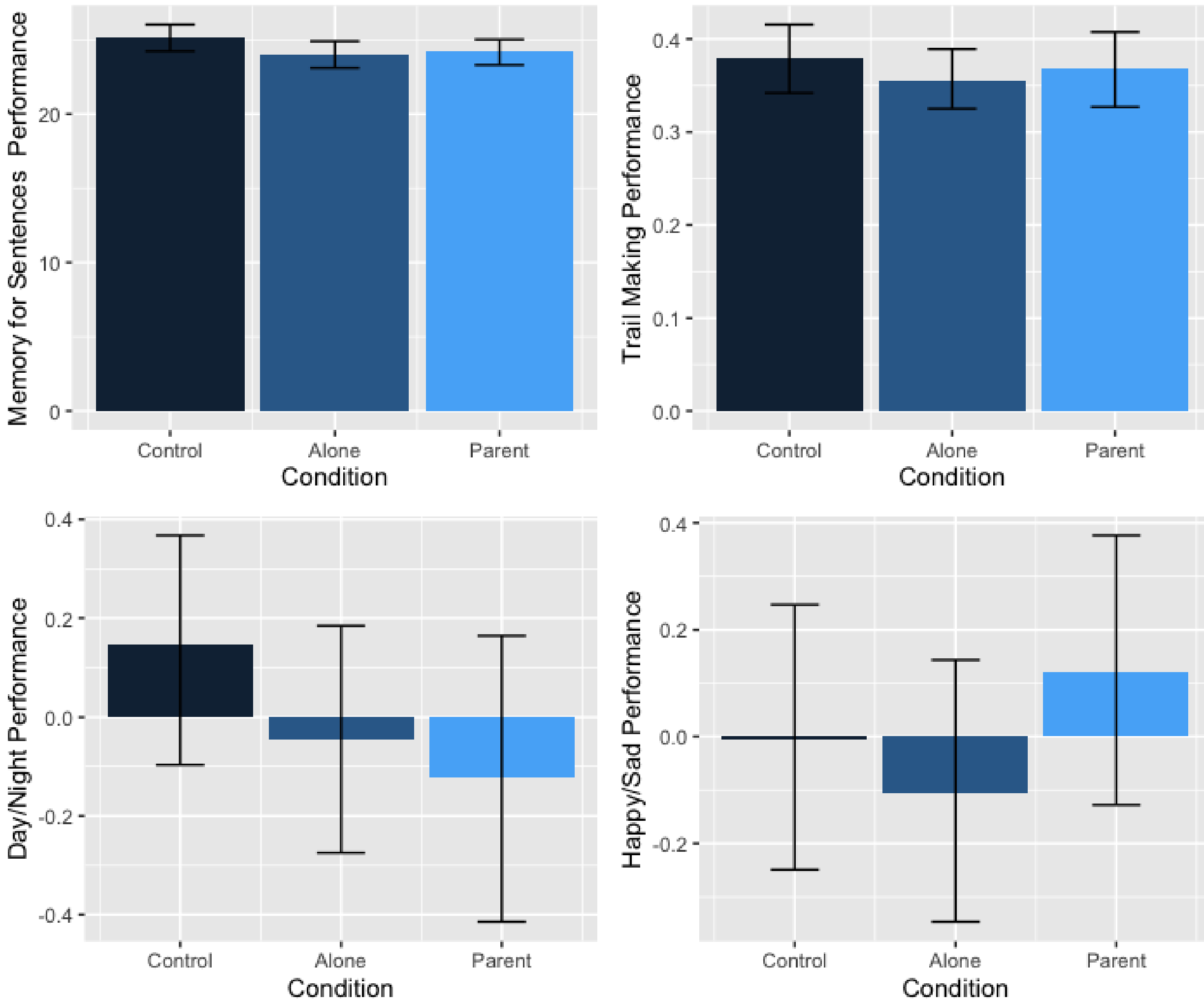
Variable	*n*	Mean (SD)	Range	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1. Memory for Sentences	174	24.48 (3.61)	16 – 36	-													
2. Trail Making Test Ratio	174	.37 (.14)	-.09 – .88	-.121	-												
3. Day/Night Task	174	.00 (1.00)	-1.72 – .90	.092	-.112	-											
4. Happy/Sad Task	174	.00 (1.00)	-1.15 – 1.49	.059	-.154	.200	-										
5. RSA Baseline	173	6.33 (1.23)	3.24 – 9.58	.003	-.035	.028	-.033	-									
6. RSA Change	166	.96 (.87)	-1.01 – 3.44	-.051	.075	.101	-.135	.377**	-								
7. PEP Baseline	159	79.74 (10.06)	42.67 – 106.80	-.077	-.093	-.045	.096	.050	-.047	-							
8. PEP Change	148	.93 (7.51)	-28.03 – 25.20	-.09	.082	-.004	.229*	-.065	-.116	.496**	-						
9. Cortisol Baseline	179	-1.09 (.24)	-1.62 – -.39	.111	-.082	.022	.087	-.046	-.071	.126	-.114	-					
10. Cortisol Reactivity	179	.10 (.29)	-.46 – 1.06	.085	-.007	.035	-.076	-.082	-.060	.050	.185	-.330**	-				
11. CBCL Total	120	19.57 (16.84)	0 – 120	.093	.041	-.005	-.001	.096	-.031	.075	.137	.079	-.055	-			
12. Parental Education	177	.10 (.29)	0 – 5	.155	-.091	.015	-.145	.040	-.004	.102	.032	.140	-.015	.129	-		
13. Child Age	180	9.91 (.56)	9.03 – 11.10	.149	-.222*	-.036	-.014	.189	.111	-.027	-.097	.087	-.149	-.005	-.051	-	
14. Child Sex *Male:* 91 (50.6%) *Female:* 89 (49.4%)				.201	-.026	-.104	-.040	.244*	-.006	-.015	-.204*	.170	-.274**	.182	-.030	.080	-

Note: **p* < .05, ***p* < .01. All correlations reported are partial correlations partialing out participant condition assignment. Correlations between sex with other variables are Spearman correlations.

Analyses of variance revealed that there was a significant main effect of condition on both cortisol reactivity, $F(2, 176) = 19.135$, $p < .001$, and RSA change, $F(2, 163) = 22.10$, $p < .001$, but not PEP change ($p = .427$). Post hoc comparisons using Bonferroni correction indicated a significantly higher cortisol reactivity in the alone condition ($M = .17$, $SE = .03$) compared to the control condition ($M = -.06$, $SE = .03$, $p < .001$), and higher reactivity in the parent condition ($M = .21$, $SE = .03$) compared to the control condition ($p < .001$). Similarly, post hoc comparisons using Bonferroni correction indicated a significantly greater RSA suppression in the alone condition ($M = 1.25$, $SE = .11$) compared to the control condition ($M = .43$, $SE = .10$, $p < .001$), and greater RSA suppression in the parent condition ($M = 1.27$, $SE = .11$) compared to the control condition ($p < .001$). However, there was not a significant difference between cortisol reactivity or RSA change between the parent and alone condition. There were no condition effects on PEP change ($p = .427$). This indicates that although the alone and parent condition did not differ in cortisol reactivity or RSA change, the TSST-M was indeed successful in eliciting a stress response from participants who experienced it.

To test our first and second hypotheses, we tested whether there were significant main effects of experimental condition. There was not a statistically significant difference in performance on the four EF measures based on condition, $F(8, 326) = 1.02$, $p = .418$, $Wilks\ \lambda = .95$ (see Figure 2.1). When adding in age and participant sex as covariates, there was not an effect of condition, $F(8, 322) = 1.01$, $p = .430$, $Wilks\ \lambda = .95$, gender, $F(4, 161) = .88$, $p = .481$, $Wilks\ \lambda = .98$, or age, $F(4, 161) = .80$, $p = .465$, $Wilks\ \lambda = .98$.

Figure 2.1. Performance on the Four Executive Function Tasks by Condition



*Note: These graphs show log-transformed values on the Trail Making Test ratio and Z-scored exponential transformed values on the Day/Night and Happy/Sad tasks.

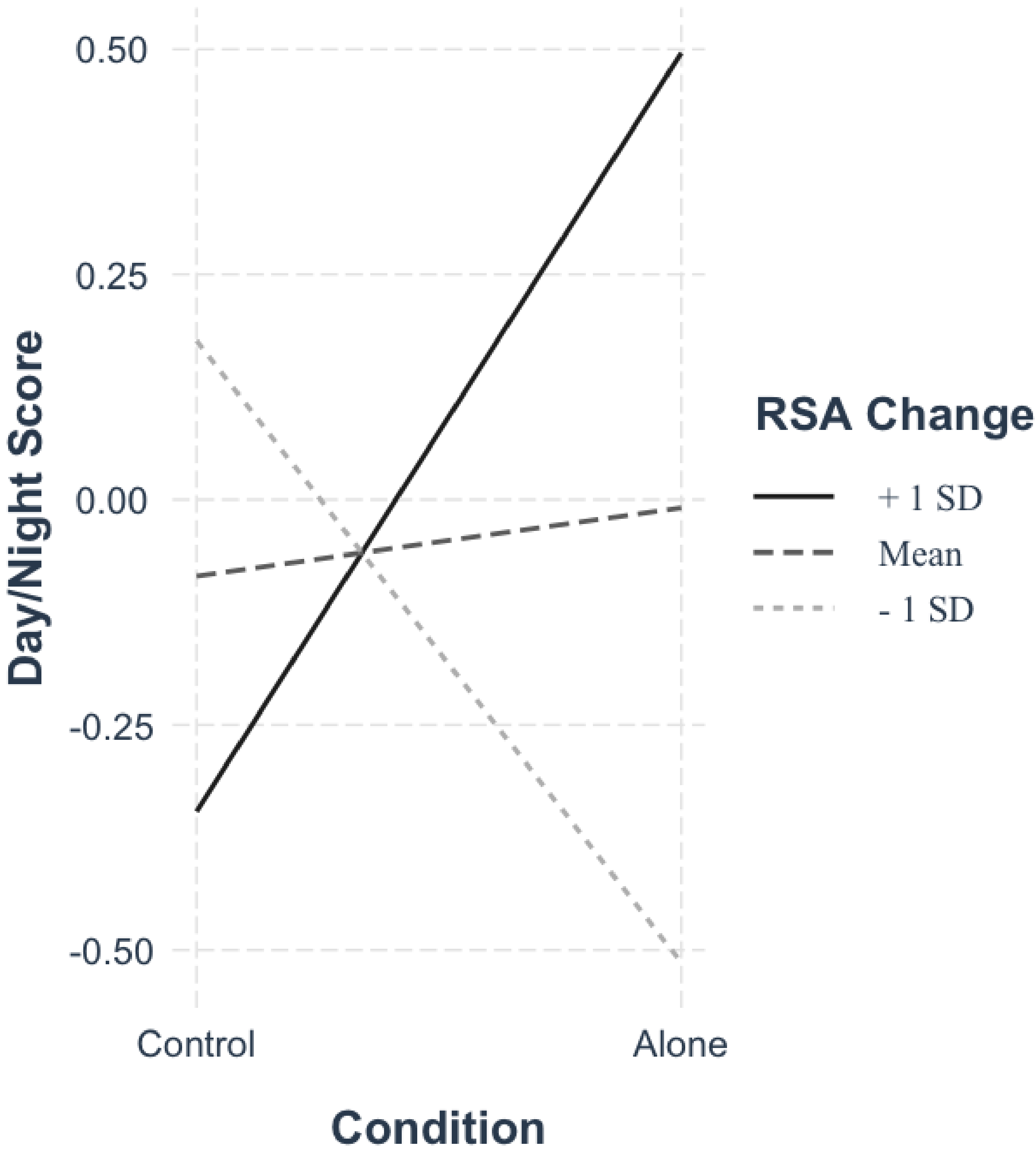
To test our three exploratory aims, we tested whether there were significant interactions between the condition that participants experienced (alone, parental support, or control condition) and four individual difference factors: RSA change, PEP change, child CBCL scores (i.e., behavioral and emotional problems), and cortisol reactivity, on children's performance on the four EF tasks.

Respiratory sinus arrhythmia (RSA) change. There was not a significant main effect of RSA change nor an interaction between condition and RSA change on performance on the working memory or cognitive flexibility tasks (*ps* > .05). However, there was a significant association of RSA change with performance on the inhibitory control task on average, $B = -.434$, $p = .020$, such that participants who exhibited more RSA suppression performed worse on the task later. There was also a significant interaction between condition and RSA change. RSA change significantly interacted with both assignment to the parent condition, $B = .351$, $p = .015$, as well as assignment to the alone condition, $B = .365$, $p = .003$ (see Table 2.2), relative to the control condition. However, when the Bonferroni correction was applied using a cutoff of $p < .0125$, only the interaction between assignment to the alone condition and RSA change remained statistically significant. Simple slopes analyses showed that the unstandardized simple slope for participants one *SD* below the mean of RSA change was -.69, $p = .03$, the unstandardized slope for participants with a mean level of RSA change was .08, $p = .74$, and the unstandardized simple slope for participants one *SD* above the mean of RSA change was .84, $p = .03$ (see Figure 2.2), indicating that, opposite to the pattern observed in the control group, children in the alone group who showed higher levels of RSA suppression exhibited better performance on the inhibitory control task in comparison to those who showed average RSA change or RSA augmentation.

Table 2.2. Moderating Effects of RSA Change on Inhibitory Control Performance

Effect	Estimate	*SE*	Standardized Beta	95% CI LL	95% CI UL	*p*
Intercept	-1.523	1.393		-4.275	1.229	.276
Alone	.059	.232	.027	-.399	.517	.800
Parent	-.102	.232	-.048	-.560	.355	.659
RSA Baseline	-.037	.073	-.043	-.181	.108	.617
RSA Change	-.500	.213	-.434	-.920	-.080	.020*
Alone * RSA Change	.877	.288	.365	.309	1.445	.003*
Parent * RSA Change	.629	.255	.351	.125	1.133	.015*
Age	.172	.135	.100	-.094	.438	.203
Sex	-.184	.158	-.092	-.497	.129	.247

Figure 2.2. Moderation of the Stress-EF Relation by RSA Change. Note: higher Day/Night score indicates better task performance.



*Note: This graph shows Z-scored Exponential transformed values.

There was a significant association of RSA change with performance on the emotional inhibitory control task, $B = -.446$, $p = .018$, such that participants who exhibited more RSA suppression performed worse on the task on average. However, when the Bonferroni correction was applied using a cutoff of $p < .0125$, this effect was no longer statistically significant.

Pre-ejection period (PEP) change. There was not a significant main effect of PEP change nor an interaction between condition and PEP change on performance on the working memory, cognitive flexibility, inhibitory control, or emotional inhibitory control tasks (*ps* > .05).

Cortisol reactivity. There was not a significant main effect of cortisol reactivity nor an interaction between condition and cortisol reactivity on working memory, cognitive flexibility, inhibitory control, or emotional inhibitory control task performance (*ps* > .05).

Child emotional and behavioral problems (CBCL). There was not a significant main effect of CBCL nor an interaction between condition and CBCL on working memory, cognitive flexibility, or inhibitory control task performance (*ps* > .05). There was a significant interaction between assignment to the parent condition and CBCL, $B = .211$, $p = .045$. However, when the Bonferroni correction was applied using a cutoff of $p < .0125$, this finding was not statistically significant.

Discussion

The three aims of this experimental study were to test the effect of an acute stressor on EF performance, to examine whether social buffering from parents would "rescue" any effects of the stressor on EF performance, and to assess the role of four potential moderators of these relations: RSA reactivity, SNS reactivity, cortisol reactivity, and child behavioral and emotional problems. EF is essential to important life outcomes such as peer relations (Holmes et al., 2016; Nakamichi, 2017) and academic performance (Cortés Pascual et al., 2019; Wang & Zhou, 2020).

The importance of EF for these significant outcomes makes it imperative that the factors that influence EF, such as stress, are understood. However, the current literature on the relation between acute stressors and EF in childhood is sparse, with only four studies to date examining this relation (de Veld et al., 2014; Mücke et al., 2020; Quesada et al., 2012; Tsai et al., 2021). The current study is the first to test the relation between acute stress and all of the main facets of EF in children, to our knowledge. In addition, this is the first study to test the potential for social buffering as a protective factor in the relation between acute stress and EF.

The Effect of Acute Stress on EF Performance

Surprisingly, for our first aim, we did not find condition effects of acute stress exposure on EF performance. Children who experienced the TSST-M did not differ in their performance on any of the EF tasks in comparison to children in the control condition. This was despite the finding that the TSST-M elicited a significant stress response in children who experienced it. This result is consistent with two prior studies of the effect of acute stress on working memory (Quesada et al., 2012) and inhibitory control (Mücke et al., 2020) in children and adolescents, but in contrast to another study of the effect on working memory (de Veld et al., 2014). It is also in contrast to findings from Shields et al. (2016a)'s meta-analysis on the effects of acute stress on EF in adults and two meta-analyses on the effects of chronic stress on EF in children (Lawson et al., 2018; Op den Kelder et al., 2018). Additionally, there were not significant main effects of age or participant sex. This is consistent with prior literature that found no sex differences in working memory tasks in children (de Veld et al., 2014; Quesada et al., 2012), but in contrast to age effects found in children's working memory performance under stress (de Veld et al., 2014; Tsai et al., 2021).

The results of this study and prior studies of acute stress in children indicate that although there is a robust pattern of impaired EF after acute stress in adults and for chronic stressors in children, this pattern was not observed in this sample of children after an acute stressor. There are a few potential reasons for this. First, it is possible that the lack of acute stress effects in childhood despite robust patterns in adulthood is due to unique features of this developmental period. Adolescence is a time of active neurodevelopmental change (reviewed in Guyer et al., 2018; Larsen & Luna, 2018; Perlman et al., 2007), particularly in brain areas that are important for EF, such as the PFC. This may indicate that there is a shift in the way that stress impacts EF in the transition from childhood to adolescence, such that prolonged exposure is needed to have an effect, rather than an acute exposure. Second, it is possible that there were aspects of the procedure, such as the timing of EF assessments, that may have impacted the ability to find a significant effect of acute stress on EF performance. Shields and colleagues (2016a) found in their meta-analysis that for working memory, if the delay between the stressor and the task was longer, the working memory impairment was stronger. In the current study, the EF tasks took place immediately after the TSST-M, which mirrors the procedure in the study by Quesada and colleagues (2012), which also found no acute stress effects on working memory. It is possible that this lack of delay weakened our ability to see the effects of the TSST-M on EF performance, if the effects of acute stress on aspects of EF occur after a certain time period post-stressor. Lastly, emerging research with adults found differential effects of stress on EF performance in adults based on differential catechol-O-methyltransferase (COMT) genotypes in the PFC (Zareyan et al., 2021). Therefore, it is possible that there are genetic factors that influence individuals' response to stressors, such that some experience decreases and others increases in

EF performance under stress. These individual differences would be masked by group averages. The role of genetics should be examined in future research with children.

The Role of Parent Support

Additionally, for our second aim, there was no effect of parental social buffering, as there was not a difference in performance between children in the parent condition, alone condition, or the control condition on any of the tasks. While this is the first study to examine this relation, this is in contrast to studies that have found relations between both parental support and positive parenting and child EF (e.g., Moilanen et al., 2010; Rocksam et al., 2014; Vandenbroucke et al., 2017). Interestingly, children in the parent condition exhibited a stress response that did not significantly differ from children in the alone condition, both of which were higher than children in the control condition. In previous work from this same study, there was a significant interaction between the effect of condition and highest parental education level, such that children whose parents had less than a 4-year college degree exhibited a buffered profile and children whose parents had a 4-year college degree or higher exhibited higher cortisol reactivity (Parenteau et al., 2021). The authors speculated that this finding may be due to different kinds of support given by parents based on their education status. In order to double-check the pattern of results here, a correlation between parent education and the four EF measures within the parent condition was conducted, but there were no significant relations. The lack of an effect of acute stress on EF likely diminished our ability to find an effect of parental social buffering.

Just as it may be possible that exposure to a more prolonged stressor is necessary to see an impact of stress on EF in children, it may be possible that more prolonged exposure is necessary to see the impact of parental social buffering. It is also possible that there are specific parental behaviors that could be particularly helpful to children who are experiencing a stressor.

A meta-analysis by Valcan and colleagues (2020) found that both positive parenting behaviors, like warmth and responsiveness, and cognitive parenting behaviors, like scaffolding and autonomy support, were positively correlated with EF performance. Future research should examine the role of specific parenting behaviors in buffering children from the effects of stress on EF.

Moderators of the Relation Between Acute Stress and EF

For our third aim, we assessed the role of three potential moderators of these relations: RSA reactivity, cortisol reactivity, and child behavioral and emotional problems. Interestingly, while RSA reactivity was a significant moderator of the relation between condition and inhibitory control performance, it was not a significant moderator for the other EF tasks. Children in the alone condition who had higher levels of RSA suppression performed better on the task than children who had average levels of RSA change or low levels of RSA change, opposite to the pattern observed in the control condition. A similar pattern was present for children in the parent condition, but this finding did not survive correction for multiple comparisons, indicating that this was a weak effect. Additionally, there was an association of RSA change with performance on both inhibitory control and emotional inhibitory control tasks, such that more RSA suppression was related to worse task performance. However, these did not survive correction for multiple comparisons, again indicating that these were weak effects. RSA change as a moderator in the relation between acute stress and inhibitory control performance is consistent with the sole prior study of this relation, which was conducted with adults (Roos et al., 2017a). This finding indicates that children who recruit the PNS to cope with threat, while experiencing a threat, show a level of arousal that allows them to flexibly respond to the stressor, leading to better performance on the subsequent inhibitory control task. It is interesting that this interaction pattern was also present for the “hot” emotional inhibitory control task, although not statistically significant. These findings may indicate that the PNS is more strongly involved in cool inhibitory control, rather than hot, and may not play as large of a role in working memory and cognitive flexibility. Future research needs to replicate these findings, as this is the first study to examine these effects in children and the first to examine the role of the PNS in hot inhibitory control, working memory, and cognitive flexibility performance.

PEP reactivity was not a significant moderator of the relation between condition and working memory, cognitive flexibility, inhibitory control, or emotional inhibitory control performance. The two studies that have examined the role of SNS reactivity in the stress-EF relation have focused on working memory and found conflicting results. De Veld and colleagues (2014) found no association between SNS reactivity to the TSST and working memory performance. Tsai and colleagues (2021) examined different processes involved in working memory performance on the n-back task, purely working memory, as indexed by accuracy, and inhibitory control, as indexed by false alarms. They found that higher SNS reactivity predicted better accuracy (working memory), while arousal driven by either the SNS or HPA axis, but not both, was related to fewer false alarms (inhibitory control) on the n-back task (Tsai et al., 2021). Given the differing effects found in previous work, the role of the SNS in the stress-EF relation should be examined further in future work.

Interestingly, there were no significant associations of cortisol reactivity nor interactions between cortisol reactivity and TSST-M condition on performance on any of the EF tasks. The finding that cortisol reactivity was not a significant moderator of the relation between acute stress and EF task performance adds to the mixed literature on this relation and is consistent with other studies in adults that found no effect of cortisol (e.g., Human et al., 2018; Shields et al., 2016b). It is possible that cortisol is one of many biological mechanisms that work together to exert effects on EF (e.g., Tsai et al., 2021), and future research should examine these biological mechanisms in concert to assess this potential explanation. Alternatively, the effects of glucocorticoids could take longer to manifest, and assessing the EF tasks immediately after the stressors may fail to reveal an effect of cortisol reactivity.

While there were not significant main effects of child emotional and behavioral problems nor interactions between these problems and TSST-M condition on working memory, cognitive flexibility, or inhibitory control task performance, there was a significant interaction between assignment to the parent condition and child emotional and behavioral problems on emotional inhibitory control. This finding did not survive correction for multiple comparisons, indicating that this was a weak effect. The finding that child emotional and behavioral problems were not a significant moderator or were a weak moderator of the stress-EF association is in contrast to prior literature, which has found that children who have both internalizing (e.g., Mullin et al., 2018; Wang & Zhou, 2020), and externalizing (e.g., Mullin et al., 2018; Schoemaker et al., 2013) problems exhibit worse EF in comparison to children who do not. Our sample was a low-risk sample, which may have limited our ability to assess this relation. Thus, we did not find significant associations of EF tasks with CBCL scores, or a moderating role for CBCL scores in the stress condition-EF links. The vast majority of parents in the current study reported that their children had low levels of behavioral and emotional problems and there was a low level of variability in the sample. Future research should examine this potential moderator in a higher-risk sample.

Limitations, Strengths, and Conclusions

This study was not without limitations. First, there were characteristics of our EF measures that may have limited our ability to detect condition differences in EF performance. There was evidence of ceiling effects on both the Day/Night and Happy/Sad tasks. The mean performance on both tasks was near perfect on both tasks, which may indicate that these tasks were not sufficiently difficult for participants, limiting our ability to detect differences based on stressor exposure for these tasks. The cognitive flexibility and working memory tasks, however, did not show ceiling effects, and had broader variability in performance. Future research should replicate these results with other tasks that index inhibitory control, emotional inhibitory control, and working memory. Second, participants in this study were largely White and of relatively high socioeconomic status. While this sample is representative of the local community population, it is possible that the findings in this study may not generalize to other geographical regions and communities. Future research should endeavor to replicate these findings with a nationally representative sample. Lastly, this sample was relatively low-risk. This may have limited our ability to detect the effects of stress on EF, as well as assess the role of the three moderators. Despite these limitations, this study has several strengths. First, this is the first study to date to examine the effects of acute stress and parental social buffering on multiple core facets of EF in children. The examination of both "hot" and "cool" inhibitory control also contributes novel information.

In conclusion, this experimental study did not find evidence that acute stress exposure or parental social buffering impacts EF performance in 9-11-year-old children. Interestingly, we found evidence that RSA reactivity moderated the impact of stressor condition on inhibitory control performance, indicating that children who recruit the PNS during challenge are showing a flexible, potentially adaptive physiological response, such that they are better able to respond to the stressor, leading to better inhibitory control performance. Importantly, we observed these results in healthy, low-risk children under conditions of relatively mild, social-evaluative challenge. Considering the importance of EF to both short- and long-term outcomes for individuals, a fuller understanding of how and when stress can impact EF is of great value.

CHAPTER 3

STUDY 3: A PILOT STUDY EXAMINING FINANCIAL STRESS DURING COVID-19 AND EXECUTIVE FUNCTION AND MENTAL HEALTH IN PARENTS AND CHILDREN

The COVID-19 pandemic has been an ongoing, unprecedented, worldwide crisis, characterized by a staggering death toll, long lockdowns, and financial shocks. In the United States, unemployment has exceeded rates seen during the Great Depression (U.S. Bureau of Labor Statistics, 2020), and many families who remained employed are working fewer hours than before the pandemic. This kind of economic shock is unprecedented, and previous research indicates that the financial and other impacts of the pandemic may be far-reaching and serious. Previous research on similar stressors like natural disasters, although scarce, indicates that experiencing these disasters is linked to worse cognitive performance (Gomez & Yoshikawa, 2017; Pfefferbaum et al., 2016). Related work on the relation between socioeconomic status (SES) and cognitive functions such as executive function (EF) indicates that SES is consistently linked to EF performance, such that children and adults who live in lower SES households exhibit worse executive function performance (Deer et al., 2020; Hackman et al., 2015; Last et al., 2018; Lawson et al., 2018; Micalizzi et al., 2019; St John et al., 2019). This is important, as EF is critical for many outcomes such as mental and physical health, academic performance, marital harmony, and involvement in the justice system (Diamond, 2013).

The importance of cognitive processes like EF to these outcomes makes it vital to understand how COVID-19-related stressors, such as financial shocks, may impact EF. The Family Stress Model (Conger et al., 2010) posits that fluctuations in economic conditions such as income loss, unstable work, and job loss, among others, are highly stressful, as the parents have to worry about finding new employment, paying bills, and other necessities to ensure that their family stays afloat. This increase in stress can increase marital and child-parent conflict, inhibit parents' emotional warmth, lower their parenting skills, self-regulation, and resources, and possibly increase erratic or disengaged behavior by the parents (Conger et al., 2010). This mix of heightened family conflict and lowered parental skills and resources can lead to poorer health, achievement, and adjustment for the children in the family (reviewed in Masarik & Conger, 2017).

COVID-19 and Executive Function

To our knowledge, no studies have directly assessed the relation between economic stress during COVID-19 and executive function in a family context. However, there is a small literature that assesses this relation between COVID-19-related economic stress and self-reported executive function in adults (Fiorenzato et al., 2021; Kira et al., 2021a; b). Kira and colleagues (2021a) found that among Turkish adults, COVID-19-related stressors, such as economic shocks, fear of infection, and isolation, predicted self-reported deficits in working memory performance, but not inhibitory control. Another study from Kira and colleagues (2021a) found that among adults from 11 Middle Eastern countries, economic stress due to COVID-19 was related to worse self-reported working memory but not inhibitory control. Similarly, Fiorenzato and colleagues (2021) found that Italian adults who reported being underemployed during lockdown also reported worse global executive function. Although the relation between COVID-19-related economic stress and executive function has not been examined in children, one study of Spanish children and adolescents (6-18 years old) found that their participants, who were experiencing a lockdown, had worse parent-reported EF than samples not under lockdown (Lavigne-Cerván et al., 2021). This extant literature points to the potential for COVID-19-related economic shocks, such as parental job loss, to have an impact on child and parent executive function.

COVID-19 and Mental Health

Along with changes in executive functioning, the COVID-19 pandemic and related economic changes may impact the mental health of parents and children. Some of the same processes that operate in the family to impact self-regulatory processes like EF may also impact the mental health of family members. Indeed, changes in mental health have been noted throughout the pandemic. Research from countries such as China, Italy, Spain, Turkey, and the United States have documented significant increases in anxiety and depression symptoms and diagnoses during the COVID-19 pandemic (Cao et al., 2020; Fiorenzato et al., 2021; Holman et al., 2020; Kira et al., 2021a; 2021b; Lavigne-Cerván et al., 2021; Patrick et al., 2020; Wang et al., 2020). Although this increase in mental health disorders is likely due to multiple causes, economic stress has been identified as one potential factor. Kira and colleagues (2021a; b) found that among other COVID-19-related stressors, economic stress predicted anxiety and depression symptoms in adults. Another study of children living in China found socioeconomic inequities in child mental health during COVID-19 (Li et al., 2021). They found that children (3-11 years old) who lived in provinces with lower gross domestic product per capita and children whose parents had lower levels of education exhibited worse mental health than children from higher SES locations and families (Li et al., 2021). This is in line with research prior to the COVID-19 pandemic, which found that lower socioeconomic status in both childhood (Peverill et al., 2021) and adulthood (Hoebel et al., 2017) was linked to poorer mental health.

The Present Study

The present study aimed to examine the association between COVID-19-related financial stress and both child and parent executive function performance, as well as to test the relation between financial stress and the mental health of both parents and children. This study is the first to use task-based executive function measures in examining these relations specific to the COVID-19 pandemic. This is important, as task-based and self-report measures may tap into different aspects of behavior (reviewed in Friedman & Banich, 2019). Additionally, as families' experiences during the pandemic are heterogeneous, the present study assessed two measures of economic shock: parental job loss, and family financial stress.

We aimed to examine the following four hypotheses: (1) parental job loss due to the COVID-19 pandemic would be related to poorer executive function performance in both parents and children; (2) family financial stress due to the COVID-19 pandemic would be related to poorer executive function performance in both parents and children, (3) parental job loss due to the COVID-19 pandemic would be related to poorer mental health in both parents and children; and (4) family financial stress due to the COVID-19 pandemic would be related to poorer child and parent mental health.

Methods

Participants

Participants included 83 children, aged 9-17 years old and their parents residing in the state of California. Participants were recruited from both a previous, ongoing study assessing the impacts of COVID-19 on parenting (*n* = 31) and Facebook advertisements (*n* = 52). Sample demographic information can be found in Table 3.1. Participating youth were 9-17 years old (*M* = 13.01 years, *SD* = 2.27 years; 51.2% male and 48.8% female at birth; current gender identification: 52.4% male, 37.8% female, 6.1% non-binary, 2.4% transgender, and 1.2% other identification). Participating parents were 33-57 years old (*M* = 43.26 years, *SD* = 5.07 years; 2.4% male and 97.6% female). Participants were screened to participate via email with a parent. Inclusion criteria included both the parent and child having normal or corrected to normal vision, both the parent and child being fluent in English, and both the parent and child living in California.

Demographic information was obtained via parent and child reports. For race/ethnicity, 56.6% of children were White, 3.6% were Asian, 3.6% were Hispanic/Latino, 1.2% were Native Hawaiian or other Pacific Islander, 1.2% were Black/African American, and 33.7% were more than one race/ethnicity. For parent race/ethnicity, 72.3% were White, 12.0% were Asian, 1.2% were Hispanic/Latino, and 14.5% were more than one race/ethnicity. Mean total annual household income was $129,479.61 (*SD* = $55,068.55), ranging from $2,500 to more than $200,000. The highest parental education level was the highest education level among the participant's parents that culminated in the obtainment of a degree and was coded as a 6-level ordinal variable such that: 0 = *less than high school* (0%), 1 = *high school diploma or GED* (3.7%), 2 = *two-year or vocational degree* (8.5%), 3 = *four-year degree* (29.3%), 4 = *master's degree* = 4 (36.5%), and 5 = *doctoral-level degree* (22.0%). Of the 83 families who participated in the study, 62.2% experienced no parental job loss or wage loss, while 37.8% experienced at least one parent losing their job or wages due to the COVID-19 pandemic.

Procedure

Participants completed all tasks and questionnaires online via the online platforms Gorilla (www.gorilla.sc; Anwyl-Irvine et al., 2019) and Qualtrics (Qualtrics, Provo, UT) between April 25th, 2021, and June 1st, 2021. Parents and children were instructed to first each complete the three executive function tasks (described below) on the Gorilla platform. The Gorilla platform is an online graphical experiment builder where there are a number of prebuilt tasks that can be used to assess a number of different psychological constructs. Recent research has found that across a number of different computer operating systems and browsers, Gorilla provides good accuracy and precision for the duration of display and manual response time (Anwyl-Irvine et al., 2020). On Gorilla, participants were first asked to complete a bot check task to assure us that bots were not completing the study. They then started the tasks. Each participant first completed the inhibitory control tasks, then the cognitive flexibility tasks, and lastly the working memory task. Following the executive function tasks, participants then each completed a set of questionnaires on the Qualtrics platform (described below). This study was approved by the Institutional Review Board of the University of California-Davis.

Measures

Inhibitory control. Inhibitory control for both parents and children was measured using the Eriksen Flanker task (Eriksen & Eriksen, 1974) implemented online via the Gorilla platform. In this task, participants are shown a target stimulus surrounded by non-target stimuli and are asked to indicate the direction that the target stimulus is pointing. Incongruent trials require participants to inhibit responding to the non-target stimuli and instead only respond to the target stimulus. In this version of the task, the stimuli are five fish in a row (Christ et al., 2011). This task has been used with both children 3-15 years of age (Zelazo et al., 2013) and with adults (Zelazo et al., 2014). Participants are shown either *congruent* trials, where the non-target fish point in the same direction as the target fish, or *incongruent* trials, where the non-target fish point in a different direction than the target fish, and are asked to indicate the direction of the target fish. To indicate their identification of the direction of the target fish, participants were asked to press a corresponding key on their keyboard. Participants were shown the instructions with an example of the stimulus they might see with instructions for which button to push based on the direction the target fish was facing. For each trial, participants first saw a fixation cross for either 400, 800, or 1200 ms (random by trial), followed by the line of fish. When the participant saw the fish, they indicated the direction of the fish and received feedback on whether this was correct, which was visible for 500 ms before moving on to the next trial. If participants had not given a response 1600 ms after the fish were presented, the words "Too slow" appeared on the screen, but they were still allowed to give a response. After receiving instructions, participants were given an opportunity to practice the task for 20 trials. They were then reminded of the instructions once more before the task began. The task consisted of 60 trials of equal number of congruent and incongruent trials, presented in a randomized order. Average accuracy and reaction time (ms) on the congruent and incongruent trials were calculated. In line with prior work (Federico et al., 2016), the difference in accuracy between incongruent and congruent trials was calculated (incongruent accuracy – congruent accuracy). Similarly, the difference in reaction time between incongruent and congruent trials was calculated (incongruent RT – congruent RT).

For accuracy, higher scores indicate better inhibitory control performance, while for reaction time scores higher scores indicate worse inhibitory control.

Cognitive flexibility. Cognitive flexibility was measured using the Cued Task Switching task (reviewed in Monsell, 2003) in both parents and children. Similar paradigms have been used with children 8-16 years of age and with adults (e.g., Zheng & Church, 2021). In this task, participants are asked to follow different rules (color rule or shape rule) that switch frequently. In this version of the task, participants are asked to either identify the color (green or blue) or the shape (square or rectangle) of the object that they are being shown and they are told which rule they should use to identify the object. To indicate their identification of the object, participants were asked to press a corresponding key on their keyboard. Participants were shown the instructions and then were shown an example of the stimulus they might see (e.g., a blue rectangle) with instructions for which button to push based on the rule that they had been told to follow for that trial. For each trial, participants first saw a fixation cross and the rule to follow for the coming trial for 250 ms, and then the stimulus. When they saw the stimulus, they indicated the identification of the object based on the rule for the trial and received feedback on whether this was correct, which was visible for 200 ms before moving on to the next trial. After receiving instructions, participants were given an opportunity to practice the task for 16 trials. They were then reminded of the instructions once more before the task began. The task consisted of 40 trials, among which there were a random number of trials where the rule did not switch from the previous trial and a number of trials where the rule switched from the previous trial. Average accuracy and reaction time (ms) on the trials where there was not a switch and where there was a switch were calculated. To calculate the cognitive cost of switching between rules on task accuracy, in line with prior work (e.g., Wylie & Allport, 2000), the difference in accuracy between switch and no-switch trials was calculated. Similarly, to calculate the cognitive cost of switching between rules on reaction time, the difference in reaction time between switch and no-switch trials was calculated. For switch-cost accuracy higher scores indicate better cognitive flexibility performance while for reaction time scores, higher scores indicate worse cognitive flexibility.

Working memory. Working memory for both parents and children was measured using a version of the Backwards Digit Span task from the Wechsler Intelligence Scale for Children (WISC-V; Wechsler, 2014). The Backwards Digit Span task has been used with children 9-15 years of age (e.g., Rosenthal et al., 2006) and adults (e.g., Dobbs & Rule, 1989). The Backwards Digit Span task involved participants being shown a string of numbers for 400 ms each, then asked to type them in reverse order, with the strings of numbers increasing in length by one as the task goes on. After receiving instructions, participants were first given an opportunity to practice the task twice, first with a string of two numbers, and then with a string of three numbers. Participants were reminded of instructions once more before the task began. The task continued until two consecutive strings were entered incorrectly by the participant. Children were shown a total of six strings with the longest string consisting of seven numbers while parents were shown a total of eight strings with the longest string consisting of nine numbers. Participants' score on this task was recorded as the number of strings they correctly entered. Higher scores on this task indicate better working memory performance.

Parental job loss due to COVID-19. Parental job loss due to COVID-19 was assessed through parent-report. Parents were asked whether they, and if applicable, their partner, had lost their job or any wages because of the COVID-19 pandemic and indicated either that they had lost their job due to COVID-19, they had lost wages due to COVID-19, or that their employment was unaffected. For the current analyses, this variable was collapsed so that 0 indicates that neither parent lost wages or their job due to the pandemic and 1 indicates that at least one parent either lost wages or their job due to the pandemic.

Family financial stress due to COVID-19. Family financial stress due to COVID-19 was assessed through parent-report. This scale was calculated using one item from the California Families Project Economic Hardship Scale (Conger & Elder, 1994), one from the Financial Anxiety Scale (Archuleta et al., 2014), and two items from the COVID Impact on Health and Wellbeing Scale (Eng, 2020). The four items used to create the family financial stress are as follows: (1) "in the past two months, my financial situation has been worse than it was before the pandemic", (2) "in the past two months, I have felt anxious about my financial situation", (3) "while sheltering in place/at home, how hard has it been for you to pay for the very basics like food, housing, medical care, and heating", and (4) "how would you describe the money situation in your household right now". On all four of these measures, higher values indicate more financial stress and worries about finances. The first two measures were on a five-point scale while the second two were on a four-point scale, so these four measures were Z-scored and added together to create one scale of family financial stress. The scale had high reliability (Chronbach's $\boldsymbol{\alpha}$ = .89).

Child anxiety and depression symptoms (RCADS-short). Child anxiety and depression symptoms were measured via child-report, using the Revised Child Anxiety and Depression Scale – Short Version (RCADS-short; Ebustani et al., 2012). The RCADS-short includes items that may reflect anxiety or depression symptoms in children *("I worry that something awful will happen to someone in my family", "I feel sad or empty"*), which children rate from 0 to 3 (0 = never, 1 = sometimes, 2 = often, 3 = always). Items are then counted and summarized into three final scores: Anxiety subscale, Depression subscale, and Total score. On this scale, higher scores indicated worse mental health. For the current analyses the total score was utilized. The full scale used to compute the total score had high reliability (Chronbach's α = .88).

Parent mental health symptoms (MHI-5). Parent mental health symptoms were measured via parent-report, using the Mental Health Inventory (MHI-5; Berwick et al., 1991). The MHI-5 is a brief questionnaire that includes items that may reflect mental health problems over the past two months (*"Been a very nervous person", "Felt downhearted and blue"*), which participants rate from 1 to 6 (1 = none of the time, 2 = a little of the time, 3 = some of the time, 4 = a good bit of the time, 5 = most of the time, 6 = all of the time). Two items ask about positive feelings (*"Been a happy person"*) so they are reverse scored. Items are then summed to create one total mental health score with higher scores indicating worse mental health. The scale had high reliability (Chronbach's α = .80).

Data Analysis

Statistical analyses were conducted using SPSS version 27. Due to the small amount of missingness (less than 5% on primary variables), listwise deletion was used. Because of outliers present in both the child and parent cued task reaction times and accuracy as well as in the child and parent Flanker task reaction times and accuracy, each value was winsorized at the equivalent of 3 standardized deviations in normally distributed data, such that 1.7% of the data at extreme values were replaced with the values at the trimmed quantile.

To test our first hypothesis that there are differences in EF performance in both parents and children based on the presence of COVID-19-related parental job loss, two multivariate analyses of covariances (MANCOVA) with parental job loss as the fixed effect, controlling for participant age and sex were conducted. To test our second hypothesis that there are differences in EF performance in both parents and children by the presence of family financial stress due to the COVID-19 pandemic, a series of regressions were conducted. For child EF performance, a series of regressions with family financial stress as the predictor, each of the five EF outcomes as an outcome, controlling for child age and sex were conducted. The same set of regressions were conducted to assess this relation in parents with parent EF. A Bonferroni correction of $p < .01$ was used to account for multiple comparisons. To test our third hypothesis that there are differences in both child and parent mental health based on parental job loss, two analyses of covariances (ANCOVA) with parental job loss as the fixed effect, controlling for participant age and sex were conducted. Lastly, to test our fourth hypothesis that there are differences in child and parent mental health based on family financial stress due to the COVID-19 pandemic, two regressions were conducted with family financial stress as the predictor and either child or parent mental health as the outcome, controlling for child age and sex. A Bonferroni correction of $p < .01$ was used to correct for multiple comparisons.

Results

Descriptive statistics for main study variables and bivariate correlations in the full sample appear in Table 3.1 and bivariate correlations appear in Table 3.2. There were significant correlations between child age and both working memory performance ($r = .266$, $p = .019$), and child mental health ($r = .228$, $p = .047$), such that older children exhibited better working memory performance and worse mental health than younger children. Parental age was significantly correlated with reaction-time measures of child cognitive flexibility ($r = .248$, $p = .025$) and child inhibitory control ($r = -.222$, $p = .045$), and child mental health ($r = .269$, $p = .016$), such that children with older parents showed worse cognitive flexibility, better inhibitory control, and reported worse mental health than children with younger parents. There were significant correlations between parental job loss and both child age ($r = -.236$, $p = .037$), and family financial difficulty ($r = .342$, $p = .002$), such that families who experienced parental job loss were more likely to have younger children and higher levels of financial stress. Family financial stress was significantly correlated with child inhibitory control accuracy ($r = -.232$, $p = .036$), parent working memory ($r = .261$, $p = .018$), and parent mental health ($r = .288$, $p = .009$), such that children in families who experienced higher levels of financial stress were more likely to exhibit worse inhibitory control accuracy while parents in these families were more likely to exhibit better working memory performance and worse mental health. When examining the associations among parent and child executive function, child inhibitory control reaction time was significantly correlated with parent inhibitory control accuracy ($r = .260$, $p = .018$), and child and parent working memory performance were significantly correlated with each other ($r = .307$, $p = .005$). Lastly, child biological sex was significantly correlated with child mental health ($r = .272$, $p = .014$), such that female participants exhibited poorer mental health. There were a number of significant correlations between the raw EF measures prior to calculating the difference between congruent and incongruent trials as well as the cognitive cost of task switching. These appear for the child measures in Supplementary Table 3.3 and for the parents in Supplementary Table 3.4.

Analysis of variance revealed that there was a significant difference in family financial stress based on parental job loss, $F(1, 80) = 15.205$, $p < .001$, such that families who had experienced parental job loss had higher financial stress ($M = 1.77$, $SD = .58$) than those who had not ($M = -1.08$, $SD = .45$).

Table 3.1. Sample characteristics. In the table, Fam Fin = Family financial, CF = Cognitive flexibility, IC = Inhibitory control, WM = working memory, Acc = Accuracy, RT = Reaction time, MH = Mental health

Variable	*N*	Minimum	Maximum	*M*	*SD*
Child Age	78	9.84	17.71	13.01	2.27
Parent Age	82	33	57	43.26	5.07
Fam Fin Stress	82	-2.62	12.59	.00	3.48
Child CF Acc	83	-.34	.24	-.04	.11
Child CF RT	83	-514.51	1461.07	127.33	307.06
Child IC Acc	83	-.12	.07	-.01	.04
Child IC RT	83	-538.96	372.15	14.20	145.23
Child WM	83	0	6	2.57	1.52
Parent CF Acc	83	-.23	.22	.02	.09
Parent CF RT	83	-1002.13	611.72	-.95.66	288.40
Parent IC Acc	83	-.09	.07	-.01	.03
Parent IC RT	83	-137.20	156.15	18.44	57.36
Parent WM	83	0	8	3.08	1.80
Child MH	80	0	29	5.05	6.17
Parent MH	82	6	23	11.93	3.72
Child Sex (% female)	82			48.8	
Parent Sex (% female)	82			97.6	
Parental Job Loss (% lost job or wages)	82			37.8	

Table 3.2. Correlations between the major variables. In the table, Fam Fin = Family financial, CF = Cognitive flexibility, IC = Inhibitory control, WM = working memory, Acc = Accuracy, RT = Reaction time, MH = Mental health

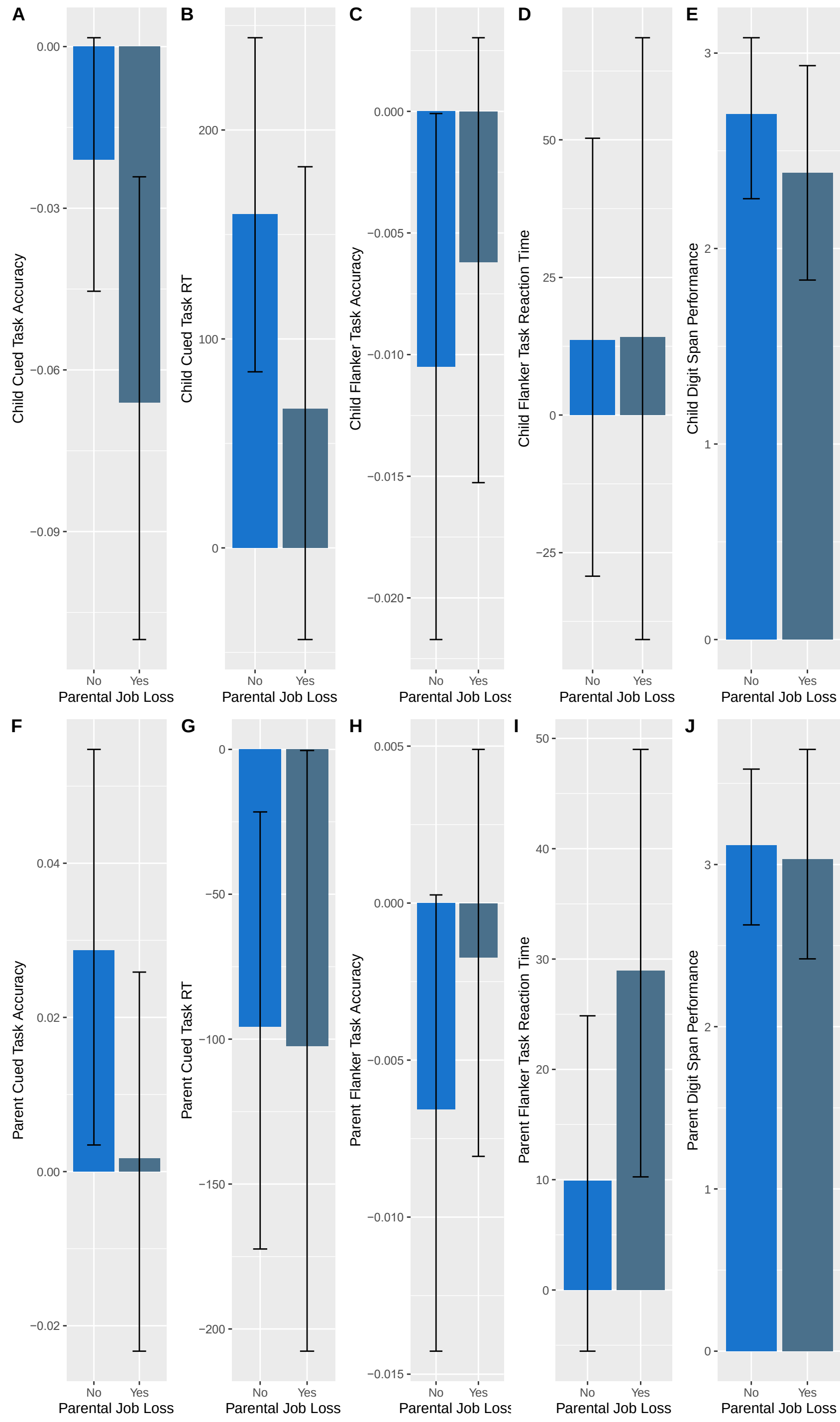
Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1. Child Age	-																	
2. Parent Age	.322**	-																
3. Fam Fin Stress	-.148	-.048	-															
4. Child CF Acc	.082	.013	-.025	-														
5. Child CF RT	-.012	.248*	-.023	-.012	-													
6. Child IC Acc	.086	.160	-.232*	-.108	.060	-												
7. Child IC RT	-.076	-.222*	.053	.136	-.074	.074	-											
8. Child WM	.266*	.108	-.024	.002	.191	.213	.029	-										
9. Parent CF Acc	.172	.081	-.025	-.033	.077	-.130	-.168	-.079	-									
10. Parent CF RT	.154	-.005	-.015	-.066	-.088	-.035	-.071	-.025	.077	-								
11. Parent IC Acc	.072	-.026	.083	.136	-.144	.202	.260*	.000	-.098	.002	-							
12. Parent IC RT	-.057	-.058	-.094	-.037	-.075	-.104	.014	-.069	-.108	.022	-.144	-						
13. Parent WM	.031	.129	.261*	.147	.123	.100	.137	.307**	.000	.017	-.012	-.005	-					
14. Child MH	.228*	.269*	-.105	.119	.120	.097	-.021	-.078	.110	.131	.175	.114	-.051	-				
15. Parent MH	.025	.091	.288**	-.073	-.179	.171	.014	.011	.102	-.067	.138	.211	.085	.035	-			
16. Child Sex	.013	.069	.063	.017	.215	.080	.073	.153	.145	.042	-.004	.112	-.035	.272*	.049	-		
17. Parent Sex	.059	-.064	.185	-.135	.000	-.066	.057	-.055	-.052	.127	.144	.120	-.058	-.095	.087	-.006	-	
18. Parental Job Loss	-.236*	-.099	.342**	-.213	-.125	.057	-.006	-.123	-.187	-.010	.011	.137	-.54	.008	.199	.182	.123	-

** Correlation is significant at the .01 level (2-tailed)
* Correlation is significant at the .05 level (2-tailed)

Parental job loss and EF performance. To test our first hypothesis, we tested whether there were significant main effects of parental job loss on the five child EF measures and then the five parent EF measures. There was not a statistically significant difference on the five child EF measures based on parental job loss, $F(5, 70) = 1.61$, $p = .168$, *Wilks* $\lambda = .90$. There were also no effects of sex, $F(5, 70) = 1.83$, $p = .118$, *Wilks* $\lambda = .88$, or child age, $F(5, 70) = 1.61$, $p = .1.67$, *Wilks* $\lambda = .90$. There was a significant main effect of age on children's performance on the working memory task, $F(1, 74) = 5.35$, $p = .023$, such that older children performed better. There was also a significant main effect of sex on cognitive flexibility reaction time, $F(1, 74) = 6.54$, $p = .013$, such that female participants ($M = 205.38$, $SD = 47.58$) exhibited worse performance than male participants ($M = 57.86$, $SD = 46.43$). However, when a Bonferroni correction was applied using a cutoff of $p < .01$, these effects were no longer statistically significant.

Similarly, there was not a statistically significant difference on the five parent EF measures based on parental job loss, $F(5, 74) = .77$, $p = .571$, *Wilks* $\lambda = .95$; no difference based on sex, $F(5, 74) = .55$, $p = .739$, *Wilks* $\lambda = .97$, and no difference based on age, $F(5, 74) = .33$, $p = .893$, *Wilks* $\lambda = .98$.

Figure 3.1. Performance on the Ten Executive Function Measures by Parental Job Loss



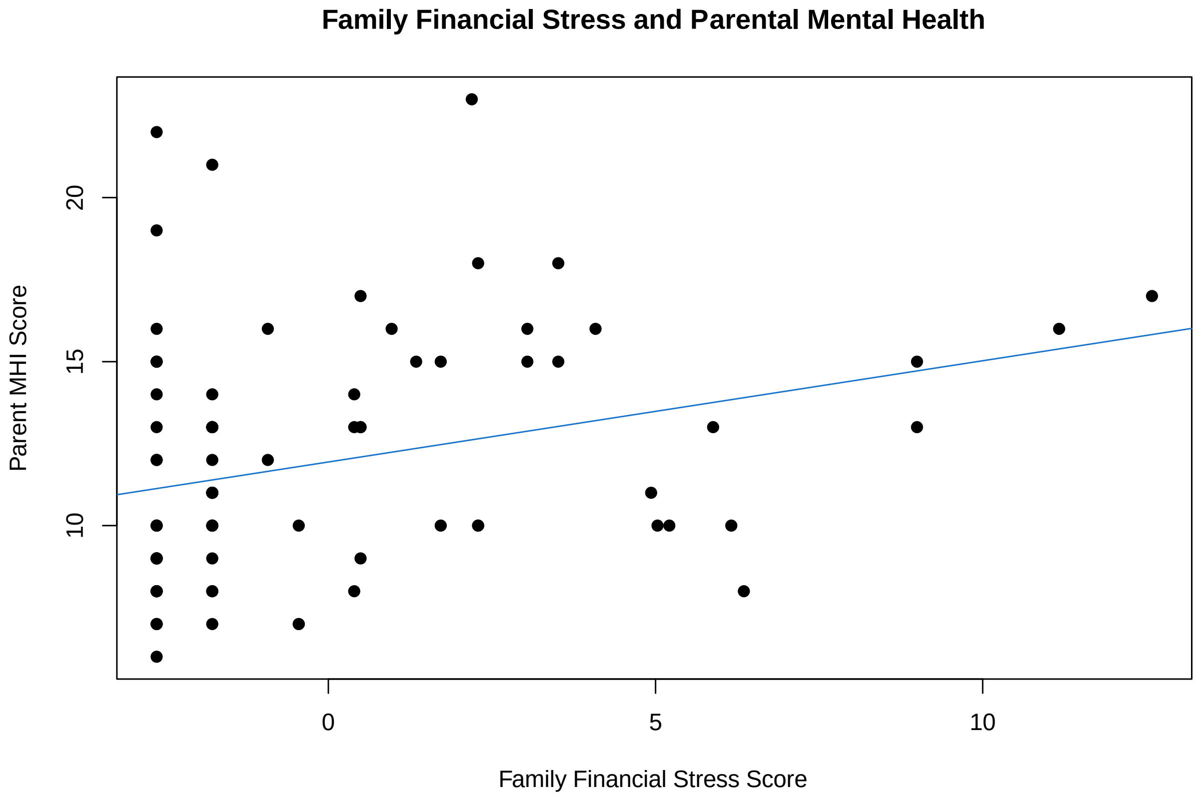
Family financial stress and EF performance. For our second hypothesis, we tested whether there were significant associations between family financial stress and both child and parent executive function performance. There was not a significant main effect of family financial stress on child performance on any of the executive function tasks (*ps* $> .05$). There was again a main effect of child age on working memory performance, $B = .279$, $p = .014$, and of sex on cognitive flexibility reaction time $B = .249$, $p = .031$. However, when a Bonferroni correction was applied using a cutoff of $p < .01$, these effects were no longer statistically significant.

There was not a significant main effect of family financial stress on parent performance on any of the executive function tasks (*ps* $> .05$) except for working memory. Parents who experienced more financial stress were more likely to exhibit better working memory ($B = .057$, $p = .013$), however, this effect did not survive a Bonferroni correction of $p < .01$. There were no significant effects of parent age or sex on EF performance (*ps* $> .05$).

Parental job loss and mental health. For the third hypothesis, we tested whether there were significant main effects of parental job loss on child and parent mental health. There were no main effects of parental job loss on either child, $F(1, 72) = .385$, $p = .537$, or parent mental health, $F(1, 78) = 1.654$, $p = .202$. There was a main effect of sex on child mental health $F(1,72) = 9.45$, $p = .003$, such that female participants ($M = 7.10$, $SD = .93$) reported more mental health symptoms than male participants ($M = 3.00$, $SD = .93$). There were no main effects of child age on child mental health nor main effects of parent age or sex on parent mental health (*ps* $> .05$).

Family financial stress and mental health. For our fourth hypothesis, we tested whether there were significant relations between family financial stress and both child and parent mental health. There was not an association between family financial stress and child mental health ($p = .229$) but there was one between family financial stress and parent mental health ($B = .287$, $p = .010$; see Figure 3.2), such that parents who reported more financial stress also reported worse mental health. Again, there was a significant association between child sex and child mental health (*B* = .343, *p* = .002). Again, there was not a significant association between either child or parent age and their mental health ($p > .05$).

Figure 3.2. The Relation Between Family Financial Stress and Parent Mental Health



Discussion

The aims of the present study were to examine the effects of COVID-19-related parental job loss and family financial stress on EF performance in children and parents and mental health in children and parents. The importance of both executive function and mental health to multiple life outcomes and well-being makes it imperative that the factors that influence them, such as financial stress, are understood. Understanding these relations are particularly important, as the current pandemic is not yet over and scientists are predicting future pandemics (Gill, 2020). Understanding these relations can inform governments about what sort of mitigation measures might be necessary and allow researchers to target interventions to those who might need them most. The current study is the first to test the relation between COVID-19-related economic stress and objective, task-based measures of EF in children as well as adults, which helps to broaden the available literature.

COVID-19 and Executive Function

Interestingly, for our first aim, we did not find associations between parental job loss and either child or parent EF performance. Children and parents from families who experienced job loss during the pandemic did not differ on any of the EF tasks in comparison to those who did not experience parental job loss. Similarly, for our second aim, we did not find any associations between family financial stress and child EF performance, and the one association we did find between family financial stress and parent working memory performance did not survive a Bonferroni correction for multiple comparisons. This is in contrast to the majority of the literature on socioeconomic status and EF (Hackman et al., 2015; Last et al., 2018; Lawson et al., 2018; Micalizzi et al., 2019; St John et al., 2019) and the literature on economic shocks during the pandemic and EF (Fiorenzato et al., 2021; Kira et al., 2021a; b).

There are a few potential reasons for this inconsistency with the prior literature. First, it is possible that the timing of this assessment precluded us from finding any effects of economic stress on EF. The three studies that found effects of COVID-19 economic stress on EF were all conducted earlier in the pandemic, one in April-May of 2020 (Fiorenzato et al., 2021), another in October-November of 2020 (Kira et al., 2021a), and the third in January-March, of 2021 (Kira et al., 2021b). It is possible that there are timing effects, such that the severity of economic stress families were experiencing differed across various pandemic time periods. Second, it is possible that the location of the present study precluded us from finding any effects of economic stress on EF. The participants in the present study were all residents of the state of California in the United States, while participants in previous studies of this relation took place in Europe and the Middle East. It is possible that different policies in place by governments in these different countries (e.g., economic stimulus checks mailed to the population in the United States) may have buffered participants' financial strain. Lastly, it is possible that the way that EF was measured impacted our ability to detect effects of economic stress. All three of the previous studies of this relation utilized self-report measures of executive function, while the present study utilized task-based measures. These two different measurement types may be tapping into different cognitive processes and therefore reflect different types of performance (reviewed in Friedman & Banish, 2019; Toplak et al., 2012). Families who agreed to participate in research during the pandemic may be more resilient to stress-related impairments in EF, which may limit researchers' ability to examine these processes.

COVID-19 and Mental Health

For our third and fourth aims, we assessed the association between COVID-19-related parental job loss and family financial stress, and both child and parent mental health. We did not find a significant association between parental job loss or family financial stress and mental health in children. This finding is in contrast to previous literature both before (Peverill et al., 2021) and during the COVID-19 pandemic (Li et al., 2021). One potential explanation for this finding is that it is possible that there are factors that influence children's awareness of their family's financial status that we did not measure in this study. Previous work has found that parenting practices and parental well-being buffered children from the effects of socioeconomic status on mental health (Bøe et al., 2014). Future research should examine this potential moderator in this relation.

Importantly, there was a significant and consistent relation between family financial stress and parent mental health, such that parents who reported more financial stress also reported worse mental health. It is possible that the fluid dynamics of family finances throughout the pandemic and the timing of this assessment explain this pattern of results. There are numerous reasons for parental job loss during this pandemic and it is possible that the question used to index job loss was not sensitive to these many reasons. Mental health in financially stable families where a parent has chosen to leave their job to care for children who are suddenly home due to the pandemic may be different than in families where there is less financial stability and a parent forcibly lost their job. Future research should examine the reason for parental job loss in addition to its occurrence. Additionally, it is possible that whether a family was receiving unemployment insurance impacted their mental health. Research conducted during the pandemic found that mental health was better in individuals who were unemployed but received unemployment insurance compared to those who did not receive the insurance (Berkowitz & Basu, 2021). Future research could benefit from inquiring about supports given to families that are specific to the pandemic.

Additionally, there was a consistent effect of child sex on child mental health, such that female participants reported worse mental health than male participants. This is consistent with a large body of prior literature, which finds that girls are at an increased risk of internalizing disorders than boys, particularly in adolescence (e.g., Alloy et al., 2016).

Limitations, Strengths, and Conclusions

This study was not without limitations. First, this study captured a snapshot of time through a pandemic that has lasted over a year, which may have limited our ability to detect effects of economic stress on EF performance and mental health. It is possible that families moved in and out of economic hardship throughout the pandemic, or had financial support from other sources that were not surveyed in this study. Second, although over a third of the participants in this study reported losing their job or wages due to COVID-19, this sample was of relatively high income and had high levels of parental education, which could be associated with access to greater savings that would attenuate the impact of lost wages. It is possible that this restricted range limited our ability to detect effects, and that we may be missing an effect at the lower end of the socioeconomic spectrum. Future research should replicate these results with a more socioeconomically representative sample. Lastly, this sample was relatively low-risk. This may have limited our ability to detect the effects of economic stressors on mental health. Despite these limitations, this study has several strengths. First, this is the first study to examine the effects of COVID-19-related economic stress on EF in children and is the first to examine this relation using task-based measures of EF. Additionally, this is the first study to examine these relations in both parents and children, adding a more complete picture of the effects of COVID-19 to the literature.

In conclusion, this small pilot study established the feasibility of examining EF using computerized measures online. Although preliminary analyses did not find evidence that COVID-19-related parental job loss or family financial stress was associated with child EF, parent EF, or child mental health, examining these effects with a larger sample will be important for ensuring adequate statistical power. Interestingly, while parental job loss was not related to parent mental health, family financial stress was, such that higher levels of financial stress were related to poorer parent mental health. This may indicate that more subjective measures of economic stress are important for understanding the link between economic stress and mental health.

Supplementary Table 3.3. Sample characteristics and correlations between the raw child EF variables. In the table, CF = Cognitive flexibility, IC = Inhibitory control, WM = Working memory, Acc = Accuracy, RT = Reaction time, Con = Congruent, Incon = Incongruent.

Variable	*n*	Mean (SD)	Range	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. CF No-switch Acc	83	.83 (.16)	.32 – 1.00	-								
2. CF Switch Acc	83	.79 (.17)	.42 – 1.00	.776**	-							
3. CF No-switch RT	83	1042.39 (687.77)	274.64 – 5036.26	-.097	-.115	-						
4. CF Switch RT	83	1125.66 (592.35)	295.62 – 3695.76	.088	.048	.715**	-					
4. IC Con Acc	83	.97 (.04)	.68 – 1.00	.328**	.367**	.126	.306**	-				
5. IC Incon Acc	83	.96 (.05)	.69 – 1.00	.288**	.255*	.037	.174	.646**	-			
7. IC Con RT	83	699.58 (299.88)	389.84 – 1966.41	-.307**	-.334**	.526**	.389**	-.013	-.209	-		
8. IC Incon RT	83	2453.75 (301.95)	381.63 – 2453.75	-.485**	-.434**	.529**	.358**	-.040	-.200	.817**	-	
9. WM	83	2.57 (1.52)	0 – 6	.238*	.238*	-.152	-.016	.014	.183	-.255*	-.250*	-

** Correlation is significant at the .01 level (2-tailed)

* Correlation is significant at the .05 level (2-tailed)

Supplementary Table 3.4. Sample characteristics and correlations between the raw parent EF variables. In the table, CF = Cognitive flexibility, IC = Inhibitory control, WM = Working memory, Acc = Accuracy, RT = Reaction time, Con = Congruent, Incon = Incongruent.

Variable	*n*	Mean (SD)	Range	1.	2.	3.	4.	5.	6.	7.	8.	9.
1. CF No-switch Acc	83	.87 (.17)	.40 – 1.00	-								
2. CF Switch Acc	83	.89 (.16)	.32 – 1.00	.863**	-							
3. CF No-switch RT	83	1153.45 (519.97)	237.37 – 2889.08	.076	.142	-						
4. CF Switch RT	83	1060.44 (418.89)	404.14 – 2698.51	-.162	-.059	.822**	-					
4. IC Con Acc	83	.99 (.01)	.93 – 1.00	.084	.045	.167	.182	-				
5. IC Incon Acc	83	.99 (.03)	.75 – 1.00	.008	-.059	.126	.121	.204	-			
7. IC Con RT	83	571.92 (120.46)	373.86 – 944.25	-.179	-.157	.243*	.344**	.075	-.254*	-		
8. IC Incon RT	83	591.35 (139.77)	395.50 – 1264.67	-.057	-.058	.132	.212	.038	-.415**	.875**	-	
9. WM	83	3.08 (1.80)	0 – 8	.034	.045	.093	.127	.193	.076	.111	.102	-

** Correlation is significant at the .01 level (2-tailed)

* Correlation is significant at the .05 level (2-tailed)

References

Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA School-Age Forms & Profiles*. Burlington, VT: University of Vermont, Research Center for Children, Youth, & Families.

Achenbach, T. M. (2019). International findings with the Achenbach system of empirically based assessment (ASEBA): Applications to clinical services, research, and training. *Child and Adolescent Psychiatry and Mental Health, 13,* 30. https://doi.org/10.1186/s13034-019-0291-2

Aikens, N. L., & Barbarin, O. (2008). Socioeconomic differences in reading trajectories: The contribution of family, neighborhood, and school contexts. *Journal of Educational Psychology, 100*, 235-251. https://doi.org/10.1037/0022-0663.100.2.235

Alen, N. V., Deer, L. K., Karimi, M., Feyzieva, E., Hastings, P. D., & Hostinar, C. E. (2021). Children's altruism following acute stress: The role of autonomic nervous system activity and social support. *Developmental Science,* e13099 https://doi.org/10.1111/desc.13099

Alloy, L. B., Hamilton, J. L., Hamlat, E. J., & Abramson, L. Y. (2016). Pubertal development, emotion regulatory styles, and the emergence of sex differences in internalizing disorders and symptoms in adolescence. *Clinical Psychological Science, 4*(5), 867-881. https://doi.org/10.1177/2167702616643008

Amicarelli, A. R., Kotelnikova, Y., Smith, H. J., Kryski, K. R., Hayden, E. P. (2018). Parenting differentially influences the development of boys' and girls inhibitory control. *British Journal of Developmental Psychology, 36*(3), 371-383. https://doi.org/10.1111/bjdp.12220

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*, 71-82. https://doi.org/10.1076/chin.8.2.71.8724

Anwyl-Irvine, A. L., Dalmaijer, E. S., Hodges, N., & Evershed, J. K. (2020). Realistic precision and accuracy of online experiment platforms, web browsers, and devices. *Behavior Research Methods.* https://doi.org/10.3758/s13428-020-01501-5

Anwyl-Irvine, A. L., Massionnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2019). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods, 52,* 388-407. https://doi.org/10.3758/s13428-019-01237-x

Archuleta, K. L., Dale, A., & Span, S. M. (2013). College students and financial distress: Exploring debt, financial satisfaction, and financial anxiety. *Journal of Financial Counseling and Planning, 24*(2), 50-62. https://doi.org/10.1037/t131109-000

Arffa, S. (2007). The relationship of intelligence to executive function and non-executive function measures in a sample of average, above average, and gifted youth. *Archives of Clinical Neuropsychology, 22,* 969-978. https://doi.org/10.1016/j.acn.2007.08.001

Arnsten, A. F. T. (2009). Stress signaling pathways that impair prefrontal cortex structure and function. *Nature Reviews Neuroscience, 10*(6), 410-422. https://doi.org/10.1038/nrn2648

Autor, D. H. (2014). Skills, education, and the rise of earnings inequality among the "other 99 percent". *Science, 344,* 843-851. https://doi.org10.1126/science.1251868

Bagley, E. J., & El-Sheikh, M. (2014). Relations between daytime pre-ejection period reactivity and sleep in late childhood. *Journal of Sleep Research, 23*(3), 335-338. https://doi.org/10.1111/jsr.12117

Berkowitz, S. A., & Basu, S. (2021). Unemployment insurance, health-related social needs, health care access, and mental health during the COVID-19 pandemic. *JAMA Internal Medicine, 181*(5), 699-702. https://doi.org/10.1001/jamainternmed.2020.7048

Bernier, A., Carlson, S. M., Deschênes, M., & Matte-Gagné, C. (2012). Social factors in the development of early executive functioning: A closer look at the caregiving environment. *Developmental Science, 15,* 12-24. https://doi.org/10.1111/j.1467-7687.2011.02093.x

Bernier, A., Beauchamp, M. H., Carlson, S. M., & Lalonde, G. (2015). A secure base from which to regulate: Attachment security in toddlerhood as a predictor of executive functioning at school entry. *Developmental Psychology, 51*(9), 1177-1189. https://doi.org/10.1037/dev0000032

Berntson, G. G., Bigger, J. T., Eckberg, D. L., Grossman, P., Kaufmann, P. G., Malik, M., Nagaraja, H. N., Porges, S. W., Saul, J. P., Stone, P. H., & van der Molen, M. W. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*(6), 623-648. https://doi.org/10.1111/j.1469-8986.1997.tb02140x

Berntson, G. G., Cacioppo, J. T., Quigley, K. S. (1994). Autonomic cardiac control. I. Estimation and validation from pharmacological blockades. *Psychophysiology, 31,* 572-858. https://doi.org/10.111/j.1469-8986.1994.tb02350.x

Berntson, G. G., Lozano, D. L., Chen, Y. J., Cacioppo, J. T. (2004). Where to Q in PEP. *Psychophysiology, 41*(2), 333-337. https://doi.org/10.1111.j.469-8986.2004.00156.x

Berwick, D. M., Murphy, J. M., Goldman, P. A., Ware, J. E., Barsky, A. J., & Weinstein, M. C. (1991). Performance on a five-item mental health screening test. *Medical Care, 29,* 169-176. https://www.jstor.org/stable/3766262

Blair, C. (2010). Stress and the development of self-regulation in context. *Child Development Perspectives, 4,* 181-188. https://doi.org/10.1111/j.1750-8606.2010.00145.x

Blair, C., Granger, D. A., Willoughby, M., Mills-Koonce, R., Cox, M., Greenberg, M. T., . . . Investigators, F. (2011). Salivary cortisol mediates effects of poverty and parenting on executive functions in early childhood. *Child Development, 82*, 1970-1984. https://doi.org/10.1111/j.1467-8624.2011.01643.x

Blair, C., & Raver, C. C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PLoS One, 9*. https://doi.org/10.1371/journal.pone.0112393

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology, 66*, 711-731. Blair, C., & Raver, C. C. (2016). Poverty, stress, and brain development: New directions for prevention and intervention. *Academic Pediatrics, 16*, S30-S36. https://doi.org/10.1146/annurev-psych-010814-015221

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647-663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Bøe, T., Siversten, B., Heiervang, E., Goodman, R., Lundervold, A. J., & Hysing, M. (2014). Socioeconomic status and child mental health: The role of parental emotional well-being and parenting practices. *Journal of Abnormal Child Psychology, 42*, 705-715. https://doi.org/10.1007/s10802-013-9808-9

Boyd, A., Golding, J., Macleod, J., Lawlor, D. A., Fraser, A., Henderson, J., Molloy, L., Ness, A., Ring, A., & Smith, G. D. (2013). Cohort profile: The 'Children of the 90s'-the index offspring of the Avon Longitudinal Study of Parents and Children. *International Journal of Epidemiology, 42*, 111-127. https://doi.org/10.1093/ije/dys064

Brody, G. H., Flor, D. L., & Gibson, N. M. (1999). Linking maternal efficacy beliefs, developmental goals, parenting practices, and child competence in rural single-parent African American families. *Child Development, 70*, 1197-1208. https://doi.org/10.1111-1467-8624.00087

Brydges, C. R., Reid, C. L., Fox, A. M., & Anderson, M. (2012). A unitary executive function predicts intelligence in children. *Intelligence, 40*, 458-469. https://doi.org/10.1016.j.intell.2012.05.006

Brydges, C. R., Fox, A. M., Reid, C. L., & Anderson, M. (2014). The differentiation of executive functions in middle and late childhood: A longitudinal latent-variable analysis. *Intelligence, 47*, 34-43. https://doi.org/10.1016/j.intell.2014.08.010

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives, 8*, 36-41. https://doi.org/10.1111/cdep.12059

Cacioppo, J. T., Berntson, G. G., Binkley, P. F., Quigley, K. S., Uchino, B. N., & Fieldstone, A. (1994). Autonomic cardiac control. II. Noninvasive indices and basal response as revealed by autonomic blockades. *Psychophysiology*, *31*, 586-598. https://doi.org/10.1111/j.1469-8986.1994.tb02351.x

Cao, W., Fang, Z., Hou, G., Han, M., Xu, X., Dong, J., & Zheng, J. (2020). The psychological impact of the COVID-19 epidemic on college students in China. *Psychiatry Research, 287*, 112934. https://doi.org/10.1016/jpsychres.2020.112934

Carey, W. B., & DeVitt, S. C. (1978). Revision of the Infant Temperament Questionnaire. *Pediatrics, 61*, 735-739.

Case, R., Kurland, M. D., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33,* 386-404. https://doi.org/10.1016/0022-0965(82)90054-6

Christ, S. E., Kester, L. E., Bodner, K. E., & Miles, J. H. (2011). Evidence for selective inhibitory impairment in individuals with autism spectrum disorder. *Europe PMC, 25*(6), 690-701. https://doi.org/10.1037/a0024256

Conger, R. D., Conger, K. J., & Martin, M. J. (2010). Socioeconomic Status, Family Processes,and Individual Development. *Journal of Marriage and Family*, *72*(3), 685–704. https://doi.org/10.1111/j.1741-3737.2010.00725.x

Conger, R. D., & Elder, G. H. (1994). *Families in troubled times: adapting to change in rural America.* New York: Aldine de Gruyter.

Cortés Pascual, A., Moyano Muños, N., Quílez, Robres, A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in Psychology, 10*, 1582. https://doi.org/10.3389/fpsyg.2019.01582

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: The indirect role of parental expectations and the home environment. *Journal of Family Psychology, 19*, 294 –304. https://doi.org/10.1037/0893-3200.19.2.294

de Veld, D. M. J., Riksen-Walraven, J. M., & de Weerth, C. (2014). Acute psychosocial stress and children's memory. *Stress, 17*(4), 305-313. https://doi.org/10.3109/10253890.2014.919446

Deer, L. K., Hastings, P. D., & Hostinar, C. E. (2020). The role of childhood executive function in explaining income disparities in long-term academic achievement. *Child Development, 91*(5), e1046-e1063. https://doi.org/10.1111/cdev.13383

Dekker, M. C., Ziermans, T. B., Spruijt, A. M., & Swaab, H. (2017). Cognitive, parent and teacher rating measures of executive functioning: Shared and unique influences on school achievement. *Frontiers in Psychology, 8.* https://doi.org/10.3389/fpsyg.2017.00048

Demetriou, A., & Spanoudis, G. (2015). On the structure and development of executive functions in middle and late childhood: Remodeling and commentary on Brydges, Fox, Reid, and Anderson. *Intelligence, 50*, 131-134. https://doi.org/10.1016/j.intell.2015.03.008

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education and Development*, *21*, 780-793. https://doi.org/10.1080/10409289.2010.514522

Diamond, A. (2013). Executive functions. *Annual Reviews in Psychology, 64,* 135-168. https://doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*, 959-964. https://doi.org/10.1126/science.1204529

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355-391. https://doi.org/10.1037/0033-2909.130.3.355

Duncan, G. J., Magnuson, K., & Votruba-Drzal, E. (2017). Moving beyond correlations in assessing the consequences of poverty. *Annual Review of Psychology*, *68*, 413-434. https://doi.org/10.1146/annurev-psych-010416-044224

Duncan, G. J., & Murnane, R. J. (2011). Introduction: The American Dream, then and now. *Whither Opportunity? Rising Inequality, Schools, and Children's Life Chances,* 3-23.

Duncan, G. J., Ziol-Guest, K. M., & Kalil, A. (2010). Early-childhood poverty and adult attainment, behavior, and health. *Child Development, 81*, 306-325. https://doi.org/10.1111/j.1467-8624.2009.01396.x

Ebustani, C., Reise, S. P., Chorpita, B. F., Ale, C., Regan, J., Young, J., Higa-McMillan, C., & Weisz, J. R. (2012). The revised child anxiety and depression scale – short version: Scale reduction via exploratory bifactor modeling of the broad anxiety factor. *Psychological Assessment, 24*(4), 833-845, https://doi.org/10.1037/a0027283

Eccles, J. S. (2005). Influences of parents' education on their children's educational attainments: The role of parent and child perceptions. *London Review of Education, 3*, 191–204.

Enders, C. K., & Bandalos, D. L. (2001). The relative performance of Full Information Maximum Likelihood estimation for missing data in structural equation models. *Structural Equation Modeling-a Multidisciplinary Journal, 8,* 430-457.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*, 143-149. https://doi.org/10.3758/BF03203267

Evans, G. W., & English, K. (2002). The environment of poverty: Multiple stressor exposure, psychophysiological stress, and socioemotional adjustment. *Child Development, 73*, 1238-1248. https://doi.org/10.1111/1467-8624.00469

Evans, G. W., Gonnella, C., Marcynyszyn, L. A., Gentile, L., & Salpekar, N. (2005). The role of chaos in poverty and children's socioemotional adjustment. *Psychological Science, 16*, 560-565. https://doi.org/10.1111/j.0956-7976.2005.01575.x

Evans, G. W., & Schamberg, M. A. (2009). Childhood poverty, chronic stress, and adult working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 6545-6549. https://doi.org/10.1073/pnas.0811910106

Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., Malmud, E. K., & Hurt, H. (2006). Childhood poverty: Specific associations with neurocognitive development. *Brain Research, 1110*, 166-174. https://doi.org/10.1016/j.brainres.2006.06.072

Farb, A. F., & Matjasko, J. L. (2012). Recent advances in research on school-based extracurricular activities and adolescent development. *Developmental Review, 32*, 1-48. https://doi.org/10.1016/j.dr.2011.10.001

Federico, F., Marotta, A., Martella, D., & Casagrande, M. (2016). Development in attention functions and social processing: Evidence from the Attention Network Test. *British Journal of Developmental Psychology, 35*(2), 169-185. https://doi.org/10.1111/bjdp.12154

Fiorenzato, E., Zabberoni, S., Costa, A., & Cona, G. (2021). Cognitive and mental health changes and their vulnerability factos related to COVID-19 lockdown in Italy. *PLoS One, 16*, e0246204. https://doi.org/10.1371/journal.pone.0246204

Fitzpatrick, C., McKinnon, R. D., Blair, C. B., & Willoughby, M. T. (2014). Do preschool executive function skills explain the school readiness gap between advantaged and disadvantaged children? *Learning and Instruction, 30*, 25-31. https://doi.org/10.1016/j.learninstruc.2013.11.003

Forouzanfar, M., Baker, F. C., de Zambotti, M., McCall, C., Giovangrandi, L., Kovacs, G. T. A. (2018). Toward a better noninvasive assessment of preejection period: A novel automatic algorithm for B-point detection and correction on thoracic impedance cardiogram. *Psychophysiology*, *55*(8), 1-12. https://doi.org/10.1111.psyp13072

Fraser, A., Macdonald-Wallis, C., Tilling, K., Boyd, A., Golding, J., Smith, G. D., Henderson, J., Macleod, J., Molloy, L., Ness, A., Ring, S., Nelson, S. M., & Lawlor, D. A. (2013).

Cohort profile: The Avon Longitudinal Study of Parents and Children: ALSPAC mothers cohort. *International Journal of Epidemiology, 42*, 97-110. https://doi.org/10.1093/ije/dys066

Fredricks, J. A., & Simpkins, S. D. (2012). Promoting positive youth development through organized after-school activities: Taking a closer look at participation of ethnic minority youth. *Child Development Perspectives, 6*, 280-287. https://doi.org/10.1111/j.1750-8606.2011.00206.x

Friedman, N. P., & Banich, M. T. (2019). Questionnaires and task-based measures assess different aspects of self-regulation: Both are needed. *PNAS, 116*(49), 24396-24397. https://doi.org/10.1073/pnas.1915315116

Gabrys, R. L., Howell, J. W., Cebulski, S. F., Anisman, H., & Matheson, K. (2019). Acute stressor effects on cognitive flexibility: Mediating role of stressor appraisals and cortisol. *Stress, 22*(2), 182-189. https://doi.org/10.1080/10253890.2018.1594152

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3 1/2-7 years old on a Stroop-like day–night task. Cognition, 53, 129–153. https://doi.org/10.1016/0010-0277(94)90068-x

Gill, V. (2020, June 6). *Coronavirus: This is not the last pandemic.* BBC. https://www.bbc.com/news/science-environment-52775386

Golding, J., Pembrey, M., Jones, R., & Team, A. S. (2001). ALSPAC-The Avon Longitudinal Study of Parents and Children - I. Study methodology. *Paediatric and Perinatal Epidemiology, 15*, 74-87. https://doi.org/10.1046/j.1365-3016.2001.0035.x

Gomez, C. J., & Yoshikawa, H. (2017). Earthquake effects: Estimating the relationship between exposure to the 2010 Chilean earthquake and preschool children's early cognitive and executive function skills. *Early Childhood Research Quarterly, 38*, 127-136. https://doi.org/10.1016/j.ecresq.2016.08.004

Goodman, R., Ford, T., Richards, H., Gatward, R., & Meltzer, H. (2000). The Development and Well-Being Assessment: Description and initial validation of an integrative assessment of child and adolescent psychopathology. *Journal of Child Psychology and Psychiatry, 41*, 645-655.

Gunnar, M. R., Hostinar, C. E., Sanchez, M. M., Tottenham, N., & Sullivan, R. M. (2015). Parental buffering of fear and stress neurobiology: Reviewing parallels across rodent, monkey, and human models. *Society for Neuroscience, 10*(5), 474-478. https://doi.org/10.1080/17470919.2015.1070198

Guyer, A. E., Pérez-Edgar, K., Crone, E. A. (2018). Opportunities for neurodevelopmental plasticity from infancy through early adulthood. *Child Development*, *89*(3), 687-697. https://doi.org/10.1111/cdev.13073

Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, *13*, 65-73. https://doi.org/10.1016/j.tics.2008.11.003

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic Status and Executive Function: Developmental Trajectories and Mediation. *Developmental Science, 18*(5), 686-702. https://doi.org/10.1111/desc.12246

Haushofer, J., & Fehr, E. (2014). On the psychology of poverty. *Science, 344,* 862-867. https://doi.org/10.1126/science.1232491

Hoebel, J., Maske, U. E., Zeeb, H., & Lampert, T. (2017). Social inequalities and depressive symptoms in adults: The role of objective and subjective socioeconomic status. *PLoS One*, *12*, e0169764. https://doi.org/10.1371/journal.pone.0169764

Holman, E. A., Thompson, R. R., Garfin, D. A., & Silver, R. C. (2020). The unfolding COVID-19 pandemic: A probability-based, nationally representative study of mental health in the United States. *Science Advances*, *6*(42), eabd5390. https://doi.org/10.1126/sciadv.abd5390

Holmes, C. J., Kim-Spoon, J., & Deater-Deckard, K. (2016). Linking executive function and peer problems from early childhood through middle adolescence. *Journal of Abnormal Child Psychology, 44,* 31-42. https://doi.org/10.1007/s10802-015-0044-5

Hostinar, C. E., Johnson, A. E., & Gunnar, M. R. (2015). Parent support is less effective in buffering cortisol stress reactivity for adolescents compared to children. *Developmental Science, 18,* 281-297. https://doi.org/10.1111/desc.12195

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling-A Multidisciplinary Journal, 6,* 1-55. https://doi.org/10.1080/10705519909540118

Human, R., Henry, M., Jacobs, W. J., & Thomas, K. G. F. (2018). Elevated cortisol leaves working memory unaffected in both men and women. *Frontiers in Human Neuroscience, 12,* 299. https://doi.org/10.3389/fnhum.2018.00299

Johnson, R. C., & Schoeni, R. F. (2011). The influence of early-life events on human capital, health status, and labor market outcomes over the life course. *B E Journal of Economic Analysis & Policy*, *11*(3), 2521. https://doi.org/10.2202/1935-1682.2521

Kira, I. A., Alpay, E. H., Anya, Y. E., Shuwiekh, H. A. M., Ashby, J. S., & Turkeli, A. (2021a). The effects of COVID-19 continuous traumatic stressors on mental health and cognitive functioning: A case example from Turkey. *Current Psychology*. https://doi.org/10.1007/s12144-021-01743-2

Kira, I. A., Shuwiekh, H. A. M., Ashby, J. S., Rice, K. G., & Alhuwailah, A. (2021b). Measuring COVID-19 stressors and their impact: The second-order factor model and its four first-order factors: Infection fears, economic, grief, and lockdown factors. *Journal of Loss and Trauma*. https://doi.org/10.1080/15325024.2021.1920270

Kirschbaum, C., Pirke, K. M., & Hellhammer, D. H. (1993). The 'Trier Social Stress Test'—a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology, 28*(1-2), 76-81. https://doi.org/10.1159/000119004

Laborde, S., Mosley, E., & Thayer, J. F. (2017). Heart rate variability and cardiac vagal tone in psychophysiological research – Recommendations for experiment planning, data analysis, and data reporting. *Frontiers in Psychology, 8*, 1-18. https://doi.org/10.3389/fpsyg.2017.00213

Lagattuta, K. H., Sayfan, L., & Monsour, M. (2011). A new measure for assessing executive function across a wide age range: Children and adults find happy-sad more difficult than day-night. *Developmental Science, 14*(3), 481-489. https://doi.org/10.1111/j.1467-7687.2010.00994.x

Larsen, B., Luna, B. (2018). Adolescence as a neurobiological critical period for the development of higher-order cognition. *Neuroscience and Biobehavioral Reviews, 94*, 179-195. https://doi.org/10.1016/j.neubiorev.2018.09.005

Last, B. S., Lawson, G. M., Breiner, K., Steinberg, L., & Farah, M. J. (2018). Childhood socioeconomic status and executive function in childhood and beyond. *PLoS ONE, 13*(8). https://doi.org/10.1371/journal.pone.0202964

Lavigne-Cerván, R., Costa-Lopéz, B., Juárez-Ruiz de Mier, R., Real-Hernández, M., Sánchez-Muñoz de León, M., & Navarro-Soria, I. (2021). Consequences of COVID-19 confinement on anxiety, sleep, and executive functions of children and adolescents in Spain. *Frontiers in Psychology, 12*, 565516. https://doi.org/10.3389/fpsyg.2021.565516

Lawson, G. M., & Farah, M. J. (2017). Executive function as a mediator between SES and academic achievement throughout childhood. *International Journal of Behavioral Development, 41*, 94-104. https://doi.org/10.1177/0165025415603489

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*, 59-80. https://doi.org/10.1348/026151003321164627

Lind, T., Lee, R. K., Caron, E. B., Roben, C. K. P., Dozier, M. (2017). Enhancing executive functioning among toddlers in foster care with an attachment-based intervention. *Development and Psychopathology, 29*, 575-586. https://doi.org/10.1017/S0954579417000190

Li, W., Wang, Z., Wang, G., Ip, P., Sun, X., Jiang, Y., Jiang, F. (2021). Socioeconomic inequality in child mental health during the COVID-19 pandemic: First evidence from China. *Journal of Affective Disorders*, *287*(15), 8-14. https://doi.org/10.1016/j.ad.2021.03.009

Lozano, D. L., Norman, G., Knox, D., Wood, B. L., Miller, B. D., Emery, C. F., & Berntson, G. G. (2007). Where to B in dZ/dt. *Psychophysiology, 44*, 113-119. https://doi.org/10.1111/j.1469-8986.2006.00468.x

Lupien, S. J., McEwen, B. S., Gunnar, M. R., & Heim, C. (2009). Effects of stress throughout the lifespan on the brain, behaviour and cognition. *Nature Reviews Neuroscience*, *10*, 434-445. https://doi.org/10.1038/nrn2639

Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1998). *Test of Everyday Attention for Children, the (TEA-Ch)*: Pearson.

Marcovitch, S., Leigh, J., Calkins, S. D., Leerks, E. M., O'Brien., & Blankson, A. N. (2010). Moderate vagal withdrawal in 3.5 year old children is associated with optimal performance on executive function tasks. Developmental *Psychobiology, 52*, 603-608. https://doi.org/10.1002/dev.20462

Masarik, A. S., & Conger, R. D. (2017). Stress and child development: A review of the Family Stress Model. *Current Opinion in Psychology, 13*, 85-90. https://doi.org/10.1016/j.copsyc.2016.05.008

McLoyd, V. C. (1998). Socioeconomic disadvantage and child development. *American Psychologist*, *53*, 185-204. https://doi.org/10.1037/0003-066x.53.2.185

Micalizzi, L., Brick, L. A., Flom, M., Ganiban, J. M., & Saudino, K. J. (2019). Effects of socioeconomic status and executive function on school readiness across levels of household chaos. *Early Childhood Research Quarterly*, *47*, 331–340. https://doi.org/10.1016/j.ecresq.2019.01.007

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science, 21*, 8-14. https://doi.org/10.1177/0963721411429458

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41*, 49-100. https://doi.org/10.1116/cogp.1999.0734

Merz, E. C., Landry, S. H., Montroy, J. J., Williams, J. M. (2017). Bidirectional associations between parental responsiveness and executive function during early childhood. *Social Development, 26*(3), 591-609. https://doi.org/10.1111/sode.12204

Mezzacappa, E. S., Kelsey, R. M., & Katkin, E. S. (1999). The effects of epinephrine administration on impedence cardiographic measures of cardiovascular function. *International Journal of Psychophysiology, 31*, 189-196.

Moilanen, K. L., Shaw, D. S., Dishion, T. J., Gardner, F., & Wilson, M. (2009). Predictors of longitudinal growth in inhibitory control in early childhood. *Social Development*, *19*(2), 326-347. https://doi.org/10.1111/j.1467-9507.2009.00536.x

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences*, *7*(3), 134-140. https://doi.org/10.1016/S1364-6613(03)00028-7

Morris, D. S. (2015). Actively closing the gap? Social class, organized activities, and academic achievement in high school. *Youth and Society*, *47*, 267-290.

Mücke, M., Ludyga, S., Colledge, F., Pühse, U., & Gerber, M. (2020). Association of exercise with inhibitory control and prefrontal brain activity under acute psychosocial stress. *Brain Sciences*, *10*(7), 439. https://doi.org/10.3390/brainsci10070439

Mullin, B. C., Perks, E. L., Haraden, D. A., Snyder, H. R., & Hankin, B. L. (2018). Subjective executive function weaknesses are linked to elevated internalizing symptoms among community adolescents. *Assessment*, *27*(3), 560-571. https://doi.org/10.1177/1073191118820133

Munakata, Y., Snyder, H. R., & Chatham, C. H. (2012). Developing cognitive control: Three key transitions. *Current Directions in Psychological Science, 21*, 71-77. https://doi.org/10.1177/0963721412436807

Nakamichi, K. (2017). Differences in young children's peer preference by inhibitory control and emotion regulation. *Psychological Reports*, *120*(5), 805-823. https://doi.org/10.1177/0033294117709260

NICHD Early Child Care Research Network. (2005). Duration and developmental timing of poverty and children's cognitive and social development from birth through third grade. *Child Development*, *76*, 795-810. https://doi.org/10.1111/j.1467-8624.2005.00878.x

Noble, K. G., & Farah, M. J. (2013). Neurocognitive consequences of socioeconomic disparities: the intersection of cognitive neuroscience and public health. *Developmental Science, 16*, 639-640. https://doi.org/10.1111/desc.12076

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science, 10*, 464-480. https://doi.org/10.1111/j.1467-7687.2007.00600.x

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*, 74-87. https://doi.org/10.1111/j.1467-7687.2005.00374.x

Op den Kelder, R., Van den Akker, A. L., Guerts, H. M., Lindauer, R. J. L., & Overbeek, G. (2018). Executive functions in trauma-exposed youth: A meta-analysis. *European Journal of Psychotraumatology, 9,* 1450595. https://doi.org/10.10180/20008198.2018.1450595

Osborne, J., Costello, A., & Kellow, J. (2008). Best practices in exploratory factor analysis. In Osborne, J. *Best practices in quantitative methods* (pp. 86-99). Thousand Oaks, CA: SAGE Publications Inc. https://doi.org/10.4135/9781412995627

Parenteau, A. M., Alen, N. V., Deer, L. K., Nissen, A. T., Luck, A. T., & Hostinar, C. E. (2020). Parenting matters: Parents can reduce or amplify children's anxiety and cortisol responses to acute stress. *Development and Psychopathology, 32,* 1799-1809. https://doi.org/10.1017/S095457942001285

Patrick, S. W., Henkhaus, L. E., Zickafoose, J. S., Lovell, K., Halvorson, A., Loch, S., Letterie, M., & Davis, M. M. (2020). Well-being of parents and children during the COVID-19 pandemic: A national survey. *Pediatrics, 146*(4), e2020016824. https://doi.org/10.1542/peds.2020-016824

Perlman, W. R., Webster, M. J., Herman, M. M., Kleinman, J. E., & Weickert, C. S. (2007). Age-related differences in glucocorticoid receptor mRNA levels in the human brain. *Neurobiology of Aging, 28*(3), 447-458. https://doi.org/10.1016/j.neurobiolaging.2006.01.010

Peverill, M., Dirks, M. A., Narvaja, T., Herts, K. L., Comer, J. S., & McLaughlin, K. A. (2021). Socioeconomic status and child psychopathology in the United States: A meta-analysis of population-based studies. *Clinical Psychology Review, 83*, 101933. https://doi.org/10.1016/j.cpr.2020.101933

Pfefferbaum, B., Noffsinger, M. A., Jacobs, A. K., & Varma, V. (2016). Children's cognitive functioning in disasters and terrorism. *Current Psychiatry Reports, 18*. https://doi.org/10.1007/s11920-016-0685-2

Porcelli, A. J., Cruz, D., Wenberg, K., Patterson, M. D., Biswal, B. B., Rypma, B. (2008). The effects of acute stress on human prefrontal working memory systems. *Physiology & Behavior, 95*, 282-289. https://doi.org/10.1016/jphysbeh.2008.04.027

Quigley, K. S., & Stifter, C. A. (2006). A comparative validation of sympathetic reactivity in children and adults. *Psychophysiology, 43*(4), 357-365. https://doi.org/10.1111/j.1469-8986.2006.00405.x

Quesada, A. A., Wiemers, U. S., Schoofs, D., & Wolf, O. T. (2012). Psychosocial stress exposure impairs memory retrieval in children. *Psychoneuroendocrinology, 37*, 125-136. https://doi.org/10.1016/j.psyneuen.2011.05.013

Raver, C. C. (2012). Low-income children's self-regulation in the classroom: Scientific inquiry for social change. *American Psychologist, 67*, 681-689. https://doi.org/10.1037/a0030085

Raver, C. C., Blair, C., & Willoughby, M. (2013). Poverty as a predictor of 4-year-olds' executive function: New perspectives on models of differential susceptibility. *Developmental Psychology, 49*, 292-304. https://doi.org/10.1037/a0028343

Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. *Whither Opportunity?Rising Inequality, Schools, and Children's Life Chances*, 91-115.

Reitan, R. M., & Wolfson, D. (1985). *The Halstead-Reitan Neuropsychological Test Battery:Theory and Interpretation*. Tuscon, AZ: Neuropsychology Press.

Roos, L. E., Knight, E. L., Beauchamp, K. G., Berkman, E. T., Faraday, K., Hyslop, K., & Fisher, P. A. (2017a). Acute stress impairs inhibitory control based on individual differences in parasympathetic nervous system activity. *Biological Psychology*, *125*, 58-63. https://doi.org/10.1016/j.biopsycho.2017.03.004

Roos, L. E., Knight, E. L., Beauchamp, K. G., Giuliano, R. J., Fisher, P. A., & Berkman, E. T. (2017b). Conceptual precision is key in acute stress research: A commentary on Shields, Sazma, & Yonelinas, 2016. *Neuroscience and Biobehavioral Reviews, 83*, 140-144. https://doi.org/10.1016/j.neubiorev.2017.10.005

Rosenthal, E. N., Riccio, C. A., Gsanger, K. M., & Pizzitola Jarratt, K. (2006). Digit Span components as predictors of attention problems and executive functioning in children. *Archives of Clinical Neuropsychology, 21*(2), 131-139. https://doi.org/10.1016/j.acn.2005.08.004

Roskam, I., Stievenart, M., Meunier, J. C., Noël, M. P. (2014). The development of children’s inhibition: Does parenting matter? *Journal of Experimental Child Psychology*, *122*, 166-182. https://doi.org/10.1016/j.jecp.2014.01.003

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*, 1-36. https://doi.org/10.18637.jss.v048.i02

Sackett, P. R., Kuncel, N. R., Beatty, A. S., Rigdon, J. L., Shen, W., & Kiger, T. B. (2012). The role of socioeconomic status in SAT-grade relationships and in college admissions Decisions. *Psychological Science*, *23*, 1000-1007. https://doi.org/10.1177/0956797612438732

Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society, 17,* 120-132. https://doi.org/10.1017/S1355617710001335

Sattler, J. M. (1988). *Assessment of children (3rd edition).* San Diego.

Schoon, I., Bynner, J., Joshi, H., Parsons, S., Wiggins, R. D., & Sacker, A. (2002). The influence of context, timing, and duration of risk experiences for the passage from childhood to midadulthood. *Child Development, 73,* 1486-1504. https://doi.org/10.1111/1467-8624.00485

Schächinger, H., Weinbacher, M., Kiss, A., Ritz, R., & Langewitz, W. (2001). Cardiovascular indices of peripheral and central sympathetic activation. *Psychosomatic Medicine, 63*, 788-796. https://doi.org/10.1097.00006842-200109000-00012

Schoemaker, K., Mulder, H., Deković, M., & Matthys, W. (2013). Executive functions in preschool children with externalizing behavior problems: A meta-analysis. *Journal of Abnormal Child Psychology, 41,* 457-471. https://doi.org/10.1007/s10802-012-9684-x

Schwabe, L., Höffken, O., Tegenthoff, M., Wolf, O. T. (2013). Stress-induced enhancement of response inhibition depends of mineralocorticoid receptor activation. *Psychoneuroendocrinology, 38,* 2319-2326. https://doi.org/10.1016/j.psyneuen.2013.05.001

Seltzer, L. J., Ziegler, T. E., & Pollak, S. D. (2010). Social vocalization can release oxytocin in humans. *Proceedings of the Royal Society B: Biological Sciences, 277*(1694), 2661-2666. https://doi.org/10.1098/rspb.2010.0567

Sherwood, A., Allen, M. T., Fahrenberg, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. P. (1990). Methodological guidelines for impedance cardiography. *Psychophysiology, 27,* 1-23.

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016a). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience and Biobehavioral Reviews, 68,* 651-668. https://doi.org/10.1016/j.neubiorev.2016.06.038

Shields, G. S., Trainor, B. C., Lam, J. C. W., & Yonelinas, A. P. (2016b). Acute stress impairs cognitive flexibility in men, not women. *Stress, 19*(5), 542-546. https://doi.org/10.1080/10253890.2016.1192603

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75,* 417-453. https://doi.org/10.3102/00346543075003417

Sosic-Vasic, Z., Kröner, J., Schneider, S., Vasic, N., Spitzer, M., & Streb, J. (2017). The association between parenting behavior and executive functioning in children and young adolescents. *Frontiers in Psychology, 30*(8), 472. https://doi.org/10.3389/fpsyg.2017.00472

Spruijt, A. M., Dekker, M. C., Ziermans, T. B., & Swaab, H. (2018). Attentional control and executive functioning in school-aged children: Linking self-regulation and parenting strategies. *Journal of Experimental Child Psychology, 166*, 340-359. https://doi.org/10.1016/jjecp.2017.09.004

St John, A. M., Kibbe, M., & Tarullo, A. R. (2019). A Systematic Assessment of Socioeconomic Status and Executive Functioning in Early Childhood. *Journal of Experimental Child Psychology,* 178, 352-368. https://doi.org/10.1016/j.jecp.2018.09.003

Thayer, J. F., Hansen, A. L., Saus-Rose, E., & Johnsen, B. H. (2009). Heart rate variability, prefrontal neural function, and cognitive function: The neurovisceral integration perspective on self-regulation, adaptation, and health. *Annals of Behavioral Medicine, 37*(2), 141-153. https://doi.org/10.1007/s12160-009-9101-z

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Technical manual, Stanford-Binet Intelligence scale: Fourth edition.* Chicago Riverside.

Toplak, M. E., West, R. F., & Stanovich, K. E. (2012). Practitioner review: Do performance-based measures of executive function assess the same construct? *The Journal of Child Psychology and Psychiatry, 54*(2), 131-143. https://doi.org/10.1111/jcpp.12001

Tsai, N., Mukhopadhyay, S., & Quas, J. A. (2021). Stress and working memory in children and adolescents: Insights from a multisystem approach. *Journal of Experimental Child Psychology, 209,* 105176. https://doi.org/10.1016/j.jecp.2021.105176

Ursache, A., & Noble, K. G. (2016). Neurocognitive development in socioeconomic context: Multiple mechanisms and implications for measuring socioeconomic status. *Psychophysiology, 53*, 71-82. https://doi.org/10.1111/psyp.12547

U.S. Bureau of Labor Statistics. (2020, May 8). *Employment Situation Summary*. https://www.bls.gov/news.release/empsit.nr0.htm

Valcan, D. S., Davis, H., Pino-Pasternak, D. (2018). Parental behaviors predicting early childhood executive functions: A meta-analysis. *Educational Psychological Review, 30*, 607-649. https://doi.org/10.1007/s10648017-9411-9

Vandenbroucke, L., Spilt, J., Verschueren, K., & Baeyens, D. (2017). Keeping the spirits up: The effects of teachers' and parents' emotional support on children's working memory performance. *Frontiers in Psychology, 8,* 512. https://doi.org/10.3389/fpsyg.2017.00512

Vogel, S., Fernández, G., Joëls, M., & Schwabe, L. (2016). Cognitive adaptation under stress: A case for the mineralcorticoid receptor. *Trends in Cognitive Sciences, 20*, 192-203. https://doi.org/10.1016/j.tics.2015.12.003

von Stumm, S., & Plomin, R. (2015). Socioeconomic status and the growth of intelligence from infancy through adolescence. *Intelligence, 48*, 30-36. https://doi.org/10.1016/j.intell.2014.10.002

Voyer, D., & Voyer, S. D. (2014). Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin, 140*, 1174-1204. https://doi.org/10.1037/a0036620

Wang, Y., & Zhou, X. (2019). Longitudinal relations between executive function and internalizing problems in grade school: The role of peer difficulty and academic performance. *Developmental Psychology, 55*(10), 2147-2158. https://doi.org/10.1037/dev0000790

Wechsler, D., Pearson Education, Inc., & Psychological Corporation. (2014). *WISC-V: Wechsler Intelligence Scale for Children.* San Antonio, Tex: NCS Pearson, Inc.

Winzer, A., Ring, C., Carroll, D., Willemsen, G., Drayson, M., & Kendall, M. (1999). Secretory immunoglobulin A and cardiovascular reactions to mental arithmetic, cold pressor, and exercise: Effects of beta-adrenergic blockade. *Psychophysiology, 36*, 591-601. https://doi.org/10.1111/1469-8986.3650591

Wunsch, K., Meier, M., Ueberholz, L., Strahler, J., & Kasten, N. (2019). Acute psychosocial stress and working memory performance: The potential of physical activity to modulate cognitive functions in children. *BMC Pediatrics, 19*, 271. https://doi.org/10.1186/s12887-019-1637-x

Wylie, G., & Allport, A. (2000). Task switching and measurement of "switch costs". *Psychological Research, 63*(3), 212-233. https://doi.org/10.1007/s004269900003

Yeung, W. J., Linver, M. R., & Brooks-Gunn, J. (2002). How money matters for young children's development: Parental investment and family processes. *Child Development, 73*, 1861-1879. https://doi.org/10.1111/1467-8624.t01-1-00511

Yim, I. S., Quas, J. A., Cahill, L., & Hayakawa, C. M. (2010). Children's and adults' salivary cortisol responses to an identical psychosocial laboratory stressor. *Psychoneuroendocrinology, 35*(2), 241-248. https://doi.org/10.1016/j.psyneuen.2009.06.014

Yim, I. S., Quas, J. A., Rush, E. B., Granger, D. A., & Skoluda, N. (2015). Experimental manipulation of the Trier Social Stress-Modified (TSST-M) to vary arousal across development. *Psychoneuroendocrinology, 57*, 61-71. https://doi.org/10.1016.j.psyneuen.2015.03.021

Yuan, K. H., & Bentler, P. M. (2000). Three likelihood-based methods for mean and covariance structure analysis with nonnormal missing data. In M. E. Sobel & M. P. Becker (Eds.), *Sociological Methodology* (pp. 165-200). Washington, DC: ASA.

Zareyan, S., Zhang, H., Wang, J., Song, W., Hampson, E., Abbot, D., & Diamond, A. (2021). First demonstration of double dissociation between COMT-Met158 and COMT-Val158 cognitive performance when stressed and when calmer. *Cerebral Cortex*, *31*(3), 1411-1426. https://doi.org/10.1093/cercor/bhaa276

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., Conway, K. P., Gershon, R., & Weintraub, S. (2014). NIH Toolbox Cognition Battery (CB): Validation of executive function measures in adults. *Journal of the International Neuropsychological Society*, *20*(6), 620-629. https://doi.org/10.1017/S1355617714000472

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. *Monographs of the Society for Research in Child Development*, *78*(4), 16-33. https://doi.org/10.1111/mono.12032

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). *Executive Function: Implications for Education (NCER 2017-2000)*. Washington, DC.

Zelazo, P. D., Carlson, S. M., & Kesek, A. (2008). Development of executive function in childhood. In C. A. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (2nd ed.). Cambridge, MA: MIT Press.

Zheng, A., & Church, J. A. (2021). A developmental eye tracking investigation of cued task switching performance. *Child Development,* 1-21. https://doi.org/10.1111/cdev.13478