Empirical Paper

ijbd

International Journal of Behavioral Development
2026, Vol. 50(5) 740–753

DOI: 10.1177/01650254251383697
journals.sagepub.com/home/jbd
Sage

Components of socioeconomic status differentially predict development of cool versus hot executive function in young children

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Abstract

It is established that higher family socioeconomic status predicts children's the development of stronger executive function, which has implications for outcomes in adulthood. However, no prior studies have examined whether individual components of socioeconomic status independently predict children's change in executive function. Moreover, research has distinguished between "hot" (affectively salient) and "cool" (affectively neutral) executive function. The present study examines the unique contributions of components of socioeconomic status in predicting change in children's hot or cool executive function. Participants included a community sample of 231 children (109 girls) and their caregivers as part of a longitudinal study spanning ages 3–7.5 years. Children completed behavioral tasks, and parents reported their income, occupational prestige, and educational attainment. Cross-lagged panel models examined how components of socioeconomic status independently predicted change in children's hot versus cool executive function 9 months later. We found support for a two-factor model of hot versus cool executive function in children. Some evidence suggested that parental occupational prestige predicted children's change in hot executive function. Parental education, but not parental occupational prestige or family income, positively predicted children's change in cool executive function. Findings suggest that parental education may uniquely contribute to children's development of cool executive function.

Keywords

Hot executive function, cool executive function, executive function, education, socioeconomic status, income, occupation, development, self-regulation

Introduction

Executive functions—higher-order cognitive processes that exert control over thoughts, emotions, and behaviors—are essential for planning and executing everyday tasks and decisions (Best & Miller, 2010). In children, stronger executive function is associated with greater academic achievement and psychological health (Yang et al., 2022). Executive function has been thought of as occurring on a spectrum from "hot"—cognitive functioning during more motivationally or affectively laden tasks; for example, delaying gratification of a desired reward—to "cool"—or cognitive functioning during more abstract, decontextualized, and affectively neutral tasks, for example, sorting objects by color (Zelazo & Carlson, 2012). It is established that higher family socioeconomic status predicts development of stronger executive function in children (Berthelsen et al., 2017; Lawson et al., 2018). However, it is not known whether individual components of socioeconomic status—for example, family income, parental occupational prestige, and parental educational attainment—independently predict the development of children's hot or cool executive function. Identification of the unique ways in which socioeconomic factors promote children's executive function may lead to more effective interventions that support executive function development.

Conceptualizations of Executive Function

The effects of socioeconomic status may differ for individual components of executive function. Thus, it is important to consider the structure of executive function in childhood. Research in adults supports a three-factor structure, comprised of monitoring and updating mental representations (i.e., working memory), inhibiting prepotent responses (i.e., inhibition), and flexibly shifting between

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task demands (i.e., cognitive flexibility; Miyake et al., 2000). When examined during childhood, however, several different conceptualizations of executive function have been supported.

Some have argued that a single-factor model most accurately captures executive function in children (Laureys et al., 2022). Some research has supported a single-factor model among both preschool-aged children (Kälin & Roebers, 2021) and children between 7 and 12 years old (Laureys et al., 2022). A single-factor model of executive function is not universally supported, however. Some work shows that executive function becomes differentiated with development, with a two-factor model best reflecting its structure in early-to-middle childhood and a three-factor structure emerging in adolescence (Lee et al., 2013). Because early childhood (i.e., around ages 3–7) is a time of rapid development in executive function, after which individual differences continue to stabilize (Zelazo & Carlson, 2012), it is important to consider the possibility that executive function may not be unitary in childhood.

Executive function has been conceptualized as the ability to engage distinct processes to perform "cool" tasks that are emotionally neutral versus "hot" tasks that are emotionally salient or involve motivational stakes (Zelazo & Carlson, 2012). This distinction depends on the intrinsic affective and motivational valence of a task. Cool executive function tasks involve abstract, decontextualized problems, where outcomes such as rewards or punishments are not intrinsically salient (Fernández García et al., 2021). Put differently, cool executive function tasks require reasoning and focus in calm, emotionally uncharged settings. Skills necessary to complete "cool" tasks (i.e., cool executive function skills) are thought to encompass the traditional executive function skills of working memory, inhibitory control, and cognitive flexibility as used in affectively neutral contexts. For example, the dimensional card sort task requires participants to sort cards according to changing rules, applying working memory and cognitive flexibility to effectively neutral problem-solving (Zelazo, 2006).

Hot executive function is engaged in tasks in which affect and motivation are intrinsically salient and is thought to involve processes that are distinct from, yet interrelated with cool functions of working memory, inhibitory control, and cognitive flexibility (Fernández García et al., 2021). These processes include delay of gratification, decision-making during conditions of uncertainty, and affective and reward learning (Fernández García et al., 2021). For example, hot executive function is often measured in children by asking them to delay consuming a single reward (e.g., one cookie) in favor of larger later rewards (e.g., two cookies), reflecting their ability or preference to delay gratification (Casey et al., 2011; Michaelson & Munakata, 2016). Although hot and cool executive functions are conceptually distinct, they often work together to underlie performance in real-world tasks and share common processes such as inhibiting impulses (Zelazo & Carlson, 2012).

Consistent with this conceptualization, research has demonstrated that executive function tasks load onto separate "hot" and "cool" factors in children 2–5 years old (Montroy et al., 2019), as do inhibitory control tasks specifically in children as young as 3–4 years old (Kim et al., 2013). Hot and cool executive functions may have different antecedents, with sensitive parenting predicting stronger hot executive function (Conway, 2020) and higher parental education predicting stronger cool executive function (Conway et al., 2018). Moreover, hot and cool executive functions may have differential impacts on socially valued outcomes—for example, hot executive function is associated with socioemotional functioning, whereas cool executive function is associated with academic performance (Fernández García et al., 2021). In addition, they show differential impairments in clinical outcomes. For example, autism is characterized by greater deficits in hot executive function, whereas attention-deficit/hyperactivity disorder is characterized by greater deficits in cool executive function (Fernández García et al., 2021).

Thus, there are several empirically supported conceptualizations of executive function. The present study evaluates a two-factor (hot and cool) conceptualization of executive function to determine (a) whether such a structure fits well and (b) whether there is utility in distinguishing hot versus cool executive function insofar as they may be influenced by different environmental antecedents. Conceptual models of executive function that integrate both emotion and cognition are necessary to fully understand distinct developmental pathways to outcomes like academic and social functioning (Peterson & Welsh, 2014). To understand these pathways, it is necessary to elucidate factors that support the development of executive function in childhood.

Environmental Factors in Development of Executive Function

One environmental factor that has been consistently associated with executive function in childhood is socioeconomic status. Socioeconomic status refers to the social standing or class of an individual or group (Saegert et al., 2006) and is commonly measured at the family-level via household income, education, occupational prestige, or a combination of these and other factors (Farah, 2017). Meta-analytic work has demonstrated small concurrent relations between higher general family socioeconomic status (measured using a range of indices such as income and education) and children's stronger executive function (overall $r = .16$) (Lawson et al., 2018). Longitudinal studies have also shown that family socioeconomic status predicts later executive function development. For instance, higher general family socioeconomic status at ages 4–5 predicted stronger executive function at ages 14–15 (Berthelsen et al., 2017).

It is well established that general socioeconomic status is associated with child executive function. However, it is unclear what specific aspects of socioeconomic status influence children's development of executive function and thus account for the apparent associations between general socioeconomic status and executive function. Furthermore, very little work has examined whether socioeconomic status specifically affects hot or cool executive function (i.e., Vrantsidis et al., 2020). To disentangle pathways underlying the association between socioeconomic status and children's hot or cool executive function, it is useful to break socioeconomic status into component parts. The most common indices of family socioeconomic status are parental education, occupational prestige, and family income (or, more usefully, income-to-needs ratio, as this includes household income relative to the poverty level after accounting household size; Duncan & Magnuson, 2012).

There are several reasons why individual components of low family socioeconomic status might confer risk for weaker hot or cool executive function in children. Parental education is known to be associated with children's broad executive function (Conway et al., 2018; Hackman et al., 2015). Parents who are highly educated may provide more cognitive enrichment to their children, leading to benefits for the child's cognitive development. Indeed, highly educated parents are more likely than parents with lower educational attainment to provide high-learning home environments (Volodina et al., 2023). For example, higher parental education is associated with more frequent reading to offspring and regular homework schedules (Tamayo Martinez et al., 2022; Volodina et al., 2023). Moreover, such cognitive enrichment might particularly impact cool executive function. Cool executive function tasks tend to involve skills emphasized through education such as critical thinking, reading, and writing (Hughes et al., 2024). There is some empirical support for the distinct influence of parental education on cool rather than hot executive function—Lensing and Elsner (2018) found that higher maternal education was correlated with higher levels of cool, but not hot, executive function in children aged 6 to 9 years.

No research to our knowledge has examined independent associations between occupational prestige and children's executive function. Work has only examined composite measures of socioeconomic status that include occupational prestige among other components, and such studies have observed associations with children's executive function broadly (e.g., Berthelsen et al., 2017). Effects of occupational prestige on both hot and cool executive functions are plausible. Speculatively, children of parents with high occupational prestige might receive more opportunities for cognitive stimulation due to higher social status. For example, teachers may have higher expectations for the child's academic performance, which prior research has found to influence children's intelligence scores via expectancy effects such as the Pygmalion effect (Raudenbush, 1984). In addition, other parents might encourage their children to develop friendships with children of high-prestige parents. More frequent social interaction might afford more opportunities to practice hot executive function skills such as affective learning and waiting one's turn. Indeed, social play has been found to support inhibitory control (White et al., 2021). Furthermore, resembling findings on parental education and cool executive function, more prestigious occupations tend to involve cool cognitive skills such as critical thinking and reading comprehension (Hughes et al., 2024). As such, parents with more prestigious occupations might model cool executive function skills or might bring cool executive function-stimulating materials (e.g., books) to the home environment. So, although not yet examined empirically, occupational prestige may contribute to the development of both hot and cool executive functions.

Family income alone may also influence the development of children's executive function. A low family income might reflect material hardship, which could limit the family's ability to access resources that are important for healthy development. Families with low incomes may have limited access to nutritious food, which could lead to deficiencies in essential micronutrients and in turn affect children's cognitive and behavioral development (de Oliveira et al., 2020; Hines et al., 2021). Indeed, research has found that a lower family income-to-needs ratio predicts poorer subsequent development of working memory and planning efficiency (Hackman et al., 2015).

Prior work also suggests that family income may particularly impact hot executive function. Speculatively, children growing up with limited resources may learn not to count on future availability of rewards—like high-quality foods—due to inconsistent and unpredictable access in their environment. Prioritizing immediate rewards would result in a lower score on many hot executive function tasks, such as the self-imposed waiting task, in which children are told that they may eat a treat immediately or wait to receive a larger treat (Metcalfe & Mischel, 1999). In support of this view, one study found that viewing poverty-related cues leads adults to select smaller immediate rewards over larger delayed rewards (Liu et al., 2012). Among children, one study found that a lower family income-to-needs ratio predicted poorer delay of gratification (Gordon et al., 2024), although other work has not found associations between income and hot executive function (Vrantsidis et al., 2020). Most work examining socioeconomic status and executive function, however, has only included cool measures such as working memory and planning efficiency (e.g., Conway et al., 2018; Hackman et al., 2015).

The work described prior has examined either composite or single components of socioeconomic status in relation to children's executive function. To our knowledge, only one study has simultaneously examined multiple individual socioeconomic components in relation to children's executive function to distinguish their unique associations (Vrantsidis et al., 2020). Vrantsidis and colleagues found that higher parental education, but not income, was concurrently associated with stronger cool executive function in children aged 6 to 36 months. Neither component of socioeconomic status correlated with hot executive function. However, Vrantsidis et al. (2020) did not examine occupational prestige as a component of socioeconomic status. Moreover, analyses did not control for children's prior level of executive function, so they were unable to examine whether aspects of socioeconomic status predicted change in children's executive function, which provides a stronger test for evaluating causal inferences.

The Present Study

To our knowledge, this is the first study to examine whether multiple aspects of socioeconomic status predict change in children's development of hot versus cool executive function. To do so, we examined whether different components of socioeconomic status, including family income-to-needs ratio, parental educational attainment, and parental occupational prestige, predicted children's hot and cool executive functions, controlling for children's prior level of executive function. Based on prior findings, we hypothesized that parental education would be associated with children's cool executive function (Lensing & Elsner, 2018; Vrantsidis et al., 2020), whereas family income-to-needs ratio would be related to children's hot executive function (Gordon et al., 2024). We had no hypotheses about how parental occupational prestige would be associated with children's hot or cool executive function due to a lack of research in this area. Because no prior studies have examined the relation between socioeconomic status and children's hot versus cool executive function while controlling for prior levels, we had no a priori hypotheses about which aspects of socioeconomic status would predict changes in children's hot versus cool executive function.

Method

Participants and Procedures

Participants consisted of young children ($N = 231$, 109 girls, age range = 3–7.5 years) in the Iowa City, Iowa area and their primary

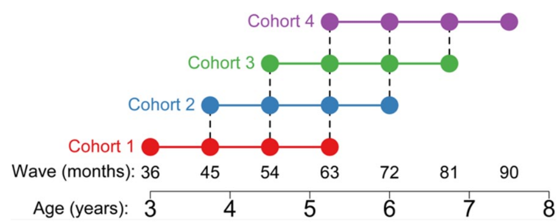

Figure 1. Research Design.

caregivers, who took part in an ongoing accelerated longitudinal study. The study was approved by the University of Iowa Institutional Review Board (Study #: 201701837). Children were recruited between 2018 and 2024 at one of the following ages (cohorts): 36 (n=62), 45 (n=54), 54 (n=53), or 63 (n=62) months (age at first time point: M=4.12 years, SD=0.87 years). Data were collected every 9 months over 4 timepoints (Figure 1). At each of these four timepoints, families completed two in-person laboratory visits approximately 1 week apart. During the first lab visit, the child completed performance-based tasks while their caregiver completed questionnaires. Caregivers were also given the opportunity to complete questionnaires at home. The second lab visit collected electroencephalography data, but these were not used in the present work. Further details about recruitment and inclusion criteria, as well as laboratory visit durations, are in Supplementary Appendix S1. Reasons for participant ineligibility and a flowchart of the final sample are in Supplementary Figure S1. Reasons for missingness and tests of systematic missingness are in Supplementary Appendix S2, and a table depicting variable measurement completeness is in Supplementary Table S1. Children with weaker hot executive function were more likely to be missing information about their socioeconomic status compared to children with stronger hot executive function.

The final sample of children was 62.8% Non-Hispanic White, 11.3% Hispanic or Latino, 6.9% Black or African American, 3.9% Asian, 10.4% multiracial, and 4.8% other race. The level of educational attainment across parents (including both primary caregivers and parenting partners) was: 5.2% doctoral degree, 4.8% professional degree, 25.2% master's degree, 33.6% bachelor's degree, 12.0% associate degree, 12.8% some college, 4.0% high school graduate, and 2.4% some high school (Grades 9–12, no degree). Additional details about primary caregivers (e.g., marital and parental status), as well as tests comparing screened families who consented versus did not consent, are in Supplementary Appendix S3.

Measures

The present work is part of a larger study. Data files, a data dictionary, analysis scripts, and a computational notebook for the present study are published online: https://osf.io/7mq24/?view_only=59767337eced42e087ecfa2085e89ef6. Full descriptions of measures, including each executive function task, are in Supplementary Appendix S4.

Components of Socioeconomic Status. We assessed socioeconomic status using questionnaire measures. The primary caregiver reported on the income of the family and their own educational attainment and provided a title and description of their occupation. If the primary caregiver indicated the presence of a parenting partner, the primary caregiver reported on the education and occupation of their parenting partner.

Family Income-to-Needs Ratio. Primary caregivers reported their family income. The financial needs of the family were determined using the U.S. Census Bureau's estimation of poverty thresholds according to the year and the number of adults and children under 18 in the household. We calculated the ratio of income to needs of each family by dividing the reported value of their income by the value of their needs.

Parental Educational Attainment. Primary caregivers reported their own educational attainment and that of their parenting partner (if applicable). Scores ranged from 1 (*No schooling or less than 1 year*) to 10 (*Doctorate degree*; see S4 for the full range). We operationalized educational attainment at the family level as the maximum education obtained from either parent.

Parental Occupational Prestige. Primary caregivers reported on their own occupation and that of their parenting partner by listing the title of their occupation and providing a brief description of their role and duties. We assigned a score to each caregiver's reported occupation according to the Nam-Powers-Boyd Occupational Scale (Boyd & Nam, 2015). Scores could range from 1 to 100, with higher scores reflecting greater occupational prestige. We operationalized occupational prestige at the family level as the maximum occupational prestige from either parent.

Child Executive Function. Children's hot and cool executive functions were assessed using laboratory tasks. Children's performance on each task was scored using the video recording of the lab visit. Each scored case was double-coded, and scores were averaged across raters. We converted the score for each measure into a proportion of maximum (POM) such that all scores had the same range (0–1), consistent with recommendations for longitudinal analyses (Little, 2024). We calculated the POM by subtracting the minimum possible score from the observed score and dividing the result by the maximum possible score. These scores therefore represent an individual's proportion of the maximum possible score on a given measure. Reliability estimates (inter-rater, internal consistency, cross-time stability) are in Supplementary Table S2.

Given concerns of using reflective approaches (e.g., latent variable) to operationalizing executive function that use only the common variance among tasks, researchers have argued for the use of formative approaches (e.g., average) to modeling executive function that leverage the total variance across tasks (Willoughby et al., 2016). Thus, for examining associations between socioeconomic status and executive function, we averaged scores on each measure to create two composite scores: one representing hot executive function, and the other representing cool executive function.

Hot Executive Function. Gift Delay. Gift Delay assesses children's motivational inhibition. The child was promised a gift but told that they needed to wait for it to be wrapped and for the experimenter to leave the room to retrieve a bow before they could open it. The child was told not to look into or open the present, while the experimenter was outside the room (3 min). Scores reflect the extent to which the child inhibited the prepotent response to look into or open the gift, such that higher scores reflect greater inhibition.

Less is More. Less is More is a motivationally salient symbolic representation task that assesses affective inhibition. The child was presented with two bowls: one was the child's bowl, and the other had a monkey puppet attached. On each trial, the child was given the option of two bags: one bag with five marshmallows and one bag with two marshmallows. The child was instructed to point to one bag, which would be put in the monkey's bowl. The other bag (i.e., the bag they did not point to) was put in the child's bowl. Scores were calculated based on whether the child indicated the small ("correct") or large ("incorrect") bag on each trial, such that higher scores reflect greater inhibition.

Self-imposed waiting task. The self-imposed waiting task assesses delay of gratification. Multiple treat options were presented from which the child chose a most- and least-preferred treat. The child was then presented with a plate with 10 pieces of their most preferred treat (e.g., chocolate chips), and another plate with two pieces of their least-preferred treat (e.g., oyster crackers). The child was informed that the experimenter would leave the room for a period, and that the child would be allowed to eat the big plate of preferred treats if they waited for the experimenter to return. The child could ring a bell at any time to bring the experimenter back into the room but could only eat the small plate of the less-preferred snack (and not their preferred snack) if they rang the bell. The duration of the waiting period (in seconds) was recorded for each child. Higher scores reflected greater delay of gratification.

Snack Delay. Snack Delay assesses children's motivational inhibition. The child was presented with a piece of candy placed under a clear plastic cup on a placemat displaying an image of handprints. The child was told to keep their hands on the placemat and to wait until the experimenter rings a bell before picking up the cup and eating the treat. Five test trials of differing delay times (5 s, 10 s, 20 s, 30 s, and 15 s) were administered in which the experimenter lifted the bell halfway through the trial but did not ring it until the full-time elapsed. Scores reflected the degree to which the child complied with the instruction to wait for the bell, such that higher scores reflect greater inhibition.

Cool Executive Function. All tasks were scored based on accuracy of response, such that higher scores reflect higher accuracy and, thus, stronger cool executive function.

Day/Night. Day/Night assesses inhibition. The child was presented with cards with either an image of a sun or an image of a moon and instructed to respond with "day" when they saw the card with a moon and with "night" when they saw the card with a sun.

Grass/Snow. Grass/Snow task assesses inhibition. In Grass/Snow, the child was asked to touch a green square when they heard the word "snow" and touch a white square when they heard the word "grass."

Hand Game. Hand Game assesses inhibition. In Hand Game, the experimenter either made a fist or pointed a finger, and the child was instructed to perform the opposite (i.e., point a finger when shown a fist) in response.

Knock/Tap. Knock/Tap assesses inhibition. The Knock/Tap task had two parts. First, the child was instructed to knock on the table when the experimenter tapped and to tap the table whenever the experimenter knocked. Then, the child was instructed to make a side fist when the experimenter knocked, to knock when the experimenter made a side fist, and to do nothing when the experimenter tapped the table.

Peg Tapping. Peg Tapping assesses inhibition. In Peg Tapping, the child observed the experimenter tap a pencil either once or twice on the table. The child was then instructed to tap a pencil the opposite number of times of what they observed. For example, if the experimenter taps the pencil once, the child is to tap the pencil twice and vice versa.

Picture Memory. Picture Memory assesses working memory. Children were shown an image for a specified amount of time (3 s, 5 s) and then instructed to select the picture(s) that they had been shown from options provided on a subsequent response page.

Simon Says. Simon Says assesses inhibition. In Simon Says, the child was instructed to perform simple motor actions (e.g., clap your hands, stomp your feet) only if the instructions began with the phrase "Simon Says."

Dimensional Change Card Sort. Dimensional Change Card Sort is part of the NIH Toolbox Cognitive Battery and assesses set shifting. The child was presented with pictures that varied by shape (i.e., ball or truck) and color (i.e., blue or yellow) and was asked to match a central image with one of two other images based on either color or shape. The dimension (color vs. shape) on which the child was instructed to sort varied across trials.

Covariates. We aimed to determine the extent to which various socioeconomic status components play a causal role in children's executive function. Thus, to test possible alternative explanations for associations, we included covariates that represented plausible confounds of the association between socioeconomic status and executive function. The child's age and sex were included as covariates. In addition, to control for a proxy of parents' own genetics that could contribute to both the family's socioeconomic status and the child's executive function, we controlled for parents' effortful control as assessed using parents' self-report on the Effortful Control subscale of the Adult Temperament Questionnaire (D. E. Evans & Rothbart, 2007). The Effortful Control subscale includes 35 items from the inhibitory control, activation control, and attentional control subscales. Parents rated how well items describe themselves on a Likert-type scale ranging from *extremely untrue* (1) to *extremely true* (7). We averaged scores across parents within a dyad.

Statistical Analysis

We used the lavaan package version 0.6-18 (Rosseel, 2012) in R version 4.4.1 (R Core Team, 2022) to estimate factor analysis and structural equation models. All models were fit with full information maximum likelihood (FIML) estimation, which uses all available data and is the gold standard approach for handling missingness when data are missing at random or completely at random (Enders & Bandalos, 2001). Models were fit with a robust maximum likelihood (MLR) estimator that provides robust standard errors to account for non-normally distributed data.

Data Structure. To leverage all timepoints of data for all participants for greater power, we stacked the data in long form for the analyses, so that each row was a unique combination of participant and timepoint. Participants could have observations at up to four timepoints. Thus, each participant could have up to four rows of observations. The long-form data structure allowed us to make use of all available information at all timepoints in examining associations without losing power by focusing on associations only within age group or timepoint. To account for participants having multiple observations due to the multiple timepoints in the longitudinal study, models used cluster-robust standard errors, which compute variances within clusters (i.e., individual participants) and then average these variances across clusters. Cluster-robust standard errors also scale variance by the number of clusters (i.e., participants) rather than the number of observations. This approach results in larger standard errors and more conservative tests.

Factor Analyses. We assessed the structure of children's executive functions with confirmatory factor analyses. We compared the fit of four models: (a) a one-factor model representing general executive functioning, (b) a model with two correlated factors representing hot and cool executive functions, (c) a model with two factors (representing hot and cool executive functions) each loading onto a higher-order general factor, and (d) a three-factor model corresponding to working memory, inhibition, and set shifting (although we note that we have only one indicator each of working memory and set shifting). To account for age-related differences, we regressed each indicator onto the child's age.

Model fit criteria included the model χ^2, the comparative fit index (CFI; good: $\geqslant .95$; acceptable: $\geqslant .90$), Tucker–Lewis Index (TLI; good: $\geqslant .95$; acceptable: $\geqslant .90$), root mean square error of approximation (RMSEA; good: $\leqslant .05$; acceptable: $\leqslant .08$), and the standardized root mean square residual (SRMR; good: $\leqslant .08$; acceptable: $\leqslant .10$), according to established cutoffs (Schermelleh-Engel et al., 2003; Schreiber et al., 2006). Nested models were compared with the best-fitting model using scaled chi-square difference tests.

Longitudinal Path Analyses. There may be some multicollinearity due to the moderate relations among the socioeconomic status components of educational attainment, occupational prestige, and income-to-needs ratio (rs = .31–.49, ps < .01). Such multicollinearity may render our results more conservative by leading to greater uncertainty in parameter estimates, making a given predictive relation more difficult to detect with statistical significance (Lindner et al., 2020). Nevertheless, the moderate associations indicate that the components of socioeconomic status are somewhat distinct. We chose to analyze each component in the same model because our research question revolves around the independent contributions of each component. However, we also report bivariate associations with Pearson's correlations.

To evaluate the roles that indices of socioeconomic status play in the development of executive function, we conducted a series of longitudinal path analyses. For both hot and cool executive functions, separately, we fit models in three steps (i.e., for a total of six models): (a) a model examining the *concurrent* association between the indices of socioeconomic status and child (cool or hot) executive function; (b) a model examining the *predictive* association between the indices of socioeconomic status and child (cool or hot) executive function 9 months later; and (c) a model examining the predictive association between the indices of socioeconomic status and later child (cool or hot) executive function, while controlling for children's prior levels of executive function (i.e., a cross-lagged model; see Figure 2 for our analysis model).

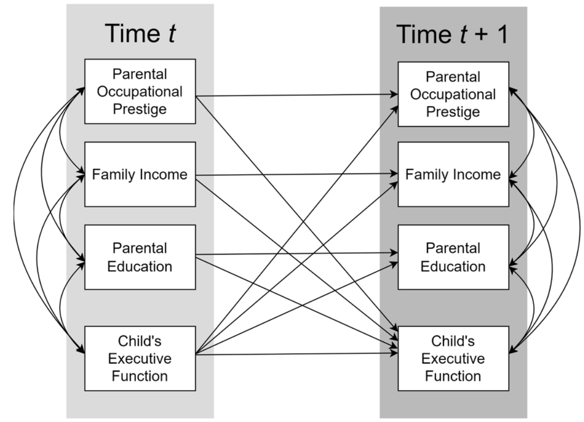

Figure 2. Cross-Lagged Panel Model Diagram.

The cross-lagged models (i.e., those at step three) examined whether aspects of socioeconomic status predict children's later executive function while controlling for their prior levels of executive function. Thus, these models tested whether children from families with high socioeconomic status relative to other families in the sample exhibit subsequent rank-order increases in executive function (S. C. Evans & Shaughnessy, 2024). In other words, the step three models examined whether aspects of socioeconomic status uniquely predict a child's *change* in executive function (relative to their peers).

For path models at all three steps, when estimating correlations between individual components of socioeconomic status and children's hot or cool executive function, we controlled for each of the other two components of socioeconomic status. We also controlled for child age and sex and for parents' self-reported effortful control in all path models. To leverage all timepoints and achieve maximal power, the predictive correlations (i.e., models at Steps 2 and 3) were staggered—in other words, each predictive model included correlations between age 36-month family socioeconomic status and age 45-month child executive function, as well as between age 45-month socioeconomic status and age 54-month executive function, and so on until the maximum age of 90 months. In other words, the predictive longitudinal path models examined the association between the indices of socioeconomic status at time t and executive function at time $t + 1$, with a 9-month lag.

Because the family income-to-needs ratio had a strong positive skew in our sample, we also replicated our analyses using a log-transformation of the income-to-needs ratio. In addition, because composite scores do not account for differential weightings of individual indicators in a latent factor, we also conducted a sensitivity analysis using factor scores for hot and cool executive functions extracted from our confirmatory factor analysis.

Results

Confirmatory Factor Analyses

All models except the three-factor model fit well according to CFI, TLI, RMSEA, and SRMR (Table 1). Each model showed some misfit according to χ^2, but this test is sensitive to larger sample

Table 1. Assessment of Adjusted Model Fit Using Full Information Maximum Likelihood.

Model	Chi-square value	Chi-square p-value	CFI	TLI	RMSEA estimate	RMSEA lower CI	RMSEA higher CI	SRMR
Two-Factor (Hot and Cool Executive Functions)	78.16	.014	.986	0.979	0.029	0.014	0.041	0.037
One-Factor (General Executive Function)	87.69	.003	.981	0.973	0.033	0.020	0.044	0.040
Hierarchical (General and Hot and Cool Executive Functions)	88.83	.002	.980	0.972	0.033	0.021	0.045	0.046
Three-Factor (Inhibitory Control, Working Memory, and Set Shifting)	1174.05	<.001	.369	0.105	0.188	0.179	0.197	0.258

Models controlled for child age. The best-fitting model (i.e., the two-factor model) results were nearly identical after controlling for child sex, so we do not report these results.

sizes even when fit differences are trivial (Alavi et al., 2020). Tests of model fit indicated that the two-factor model with correlated hot and cool executive function factors ($r=.77$) fit significantly better than the one-factor model ($\Delta\chi^2[1]=8.82$, $p=.003$), the two-factor model with a higher-order factor ($\Delta\chi^2[1]=5.93$, $p=.015$), and the three-factor model ($\Delta\chi^2[2]=759.94$, $p<.001$). As such, the two-correlated-factors model was retained; factor loadings are in Supplementary Table S3.

Associations Between Family Socioeconomic Status and Child Executive Function

Concurrent bivariate associations and descriptive statistics for each variable are in Table 2; predictive bivariate associations are in Table 3. Histograms depicting the distributions of family income-to-needs ratio, parental educational attainment, and parental occupational prestige are in Figures 3 to 5, and histograms depicting the distribution of composite scores of hot and cool child executive function are in Figures 6 and 7. Family income-to-needs ratio, parental educational attainment, and parental occupational prestige were all positively concurrently correlated with both hot and cool executive functions. Only parental educational attainment was positively correlated with cool executive function 9 months later at the $p<.05$ level; however, parental occupational prestige showed a trend-level positive association. No socioeconomic components were predictively associated with hot executive function at the $p<.05$ level; however, family income-to-needs ratio showed a trend-level positive association. Parents' effortful control was positively concurrently but not predictively associated with their child's cool executive function. Older children and girls were more likely to have stronger hot and cool executive functions.

Controlling for the other components of socioeconomic status, child age and sex, and parents' effortful control, parental educational attainment was concurrently positively associated with their child's cool executive function ($\beta=0.16$, $p<.001$; see Supplementary Table S4 and Supplementary Figure S2), as was family occupational prestige ($\beta=0.11$, $p=.049$). Only parental educational attainment continued to significantly predict cool executive function 9 months later ($\beta=0.18$, $p=.003$; see Supplementary Table S5 and Supplementary Figure S3). Parental educational attainment also continued to predict 9-month-later cool executive function when controlling for prior levels in a cross-lagged panel model ($\beta=0.10$, $p<.001$; see Figure 8 and Table 4). No components of socioeconomic status were significantly and independently associated with children's hot executive function. However, parental occupational prestige was marginally positively predictive of hot executive function, including concurrently ($\beta=.13$, $p=.057$), 9 months later ($\beta=.14$, $p=.094$), and 9 months later controlling for prior levels ($\beta=.14$, $p=.082$). Our results for both cool and hot executive functions were highly similar when using the log-transformed income-to-needs ratio, and the pattern of significant findings was unchanged (Supplementary Table S6). The pattern of significant findings also remained consistent when using factor rather than composite scores to represent hot and cool executive functions (results in Supplementary Table S7); histograms depicting latent factor score distributions for hot and cool executive functions are in Supplementary Figures 4 and 5.

Discussion

Prior research has established that family socioeconomic status is associated—concurrently (Lawson et al., 2018) and predictively (Hackman et al., 2015; Vrantsidis et al., 2020)—with executive function. However, fewer studies have examined the unique contributions of specific components of socioeconomic status. Various components of socioeconomic status—including family income, parental educational attainment, and parental occupational prestige—may differentially influence the development of children's executive function. Thus, it is important to consider the unique contributions of components of socioeconomic status to children's development of executive function (Duncan & Magnuson, 2012). In addition, few studies have examined whether components of socioeconomic status differentially predict cool versus hot executive function, and whether components of socioeconomic status predict children's later change in executive function. In the present study, we examined whether components of socioeconomic status uniquely predict a child's *change* in executive function (relative to their peers) across 9-month lags from 3 to 7 years of age.

We found differential associations between components of socioeconomic status and cool versus hot executive function. Although all socioeconomic status components showed concurrent bivariate associations with both cool and hot executive function, the pattern of associations differed when examining predictive associations and when examining the unique contributions of each socioeconomic component. In predictive bivariate associations, parental educational attainment significantly and

Table 2. Concurrent Bivariate Correlations and Descriptive Statistics for Each Variable.

	1	2	3	4	5	6	7	8
1. Child Hot Executive Function	-							
2. Child Cool Executive Function	.51***	-						
3. Family Income-to-Needs Ratio	.13*	.11*	-					
4. Parental Educational Attainment	.26***	.31***	.33***	-				
5. Parental Occupational Prestige	.25***	.21***	.33***	.52***	-			
6. Parents' Effortful Control	.03	.14***	-.05	.17***	.03	-		
7. Child's Age	.47***	.62***	.09†	.18***	.15***	.02	-	
8. Child's Sex	.12*	.15***	.05	.07†	-.09†	.13***	.06	-
Observations	404	497	534	558	404	507	576	924
Missingness (%)	56.42	46.39	42.39	39.81	56.42	45.31	37.86	0.32
Mean	0.78	0.52	3.73	7.49	79.07	4.53	4.93	0.47
Standard Deviation	0.22	0.27	3.05	1.43	19.89	0.71	1.19	0.50
Minimum	0	0	0	3	13	2.73	2.92	0
Maximum	1	0.98	33.66	10	100	6.53	7.80	1
Skewness	-1.37	-0.33	5.04	-0.27	-1.41	-0.13	0.20	0.11
Kurtosis	1.84	-1.12	39.82	0.17	1.11	-0.29	-0.60	-1.99

Note. $N = 231$ child/parent dyads with up to four timepoints each, for a total of 924 possible timepoint observations. Some children had not yet aged into the eligibility window for their later timepoints. Sex was coded as 0 = *Male*, 1 = *Female*.
†$p < .10$; *$p < .05$; ***$p < .001$.

Table 3. Predictive Bivariate Correlations.

	Variables at 9-month lags	
	Child hot executive function	Child cool executive function
Child Hot Executive Function	.43***	.40***
Child Cool Executive Function	.31***	.65***
Family Income-to-Needs Ratio	.13†	.07
Parental Educational Attainment	.08	.30***
Parental Occupational Prestige	.10	.13†
Parents' Effortful Control	.05	.05

Note. $N = 231$ child/parent dyads with up to 924 possible timepoints. Some children had not yet aged into the eligibility window for their later timepoints. Correlations are based on all available pairwise timepoint observations, not participant-level aggregations.
†$p < .10$; ***$p < .001$.

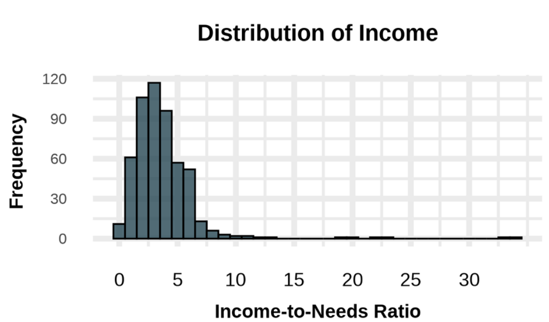

Figure 3. Histogram Depicting the Distribution of Family Income-to-Needs Ratio. $n = 534$ observations across up to four timepoints with 231 child/parent dyads. Some children had not yet aged into the eligibility window for their later timepoints. Family income-to-needs ratio is operationalized as the family income divided by their needs. The y-axis depicts the number of observations (i.e., data collection timepoints) with each income-to-needs ratio.

occupational status marginally predicted their child's cool executive function 9 months later, whereas families' income-to-needs ratio marginally predicted their child's later hot executive function.

Examining whether aspects of socioeconomic status showed *unique* concurrent associations with executive function, both parental educational attainment and parental occupational prestige were associated with their child's cool executive function. However, when predicting *later* executive function, only parental educational attainment remained a significant predictor. The association between parental educational attainment and their child's later cool executive function held when controlling for the child's prior levels of executive function 9 months earlier. That is, higher parental educational attainment predicted subsequent rank-order increases in cool executive function. No socioeconomic status component was significantly associated with hot executive function, although higher parental occupational prestige showed a trend-level association with stronger hot executive function at each stage of analysis—concurrently, prospectively,

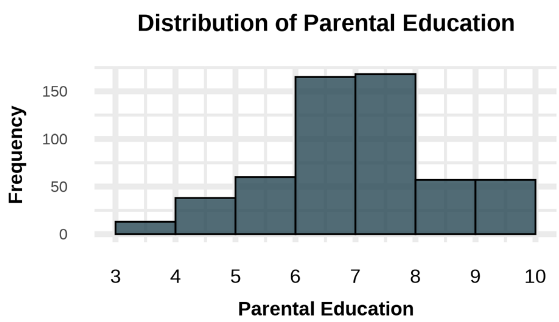

Figure 4. Histogram Depicting the Distribution of Parental Educational Attainment. $n = 558$ observations across up to four timepoints with 231 child/parent dyads. Some children had not yet aged into the eligibility window for their later timepoints. Parental education is operationalized as the maximum education obtained from either parent. The y-axis depicts the number of observations (i.e., data collection timepoints) with each education level. 3 = High school; 4 = High school graduate; 5 = Some college; 6 = Associate's degree; 7 = Bachelor's degree; 8 = Master's degree; 9 = Professional school degree; 10 = Doctorate degree.

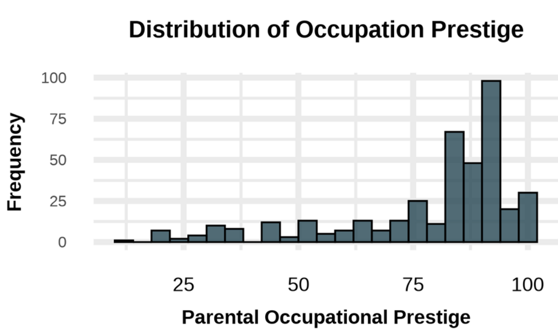

Figure 5. Histogram Depicting the Distribution of Parental Occupational Prestige. $n = 404$ observations across up to four timepoints with 231 child/parent dyads. Some children had not yet aged into the eligibility window for their later timepoints. Parental occupational prestige is operationalized as the maximum occupational prestige from either parent. The y-axis depicts the number of observations (i.e., data collection timepoints) with each Nam–Powers–Boyd occupational prestige rating.

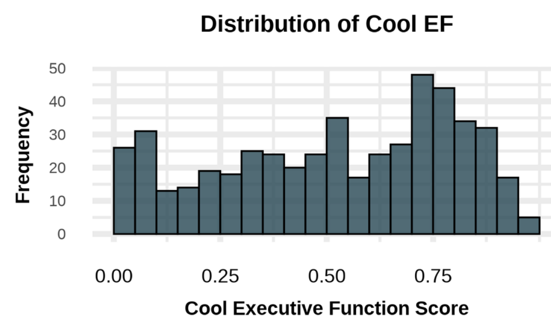

Figure 6. Histogram Depicting the Distribution of Children's Composite Cool Executive Function Scores. $n = 497$ observations across up to four timepoints with 231 children. Some children had not yet aged into the eligibility window for their later timepoints. The y-axis depicts the number of observations (i.e., data collection timepoints) with each proportion of maximum composite cool executive function score.

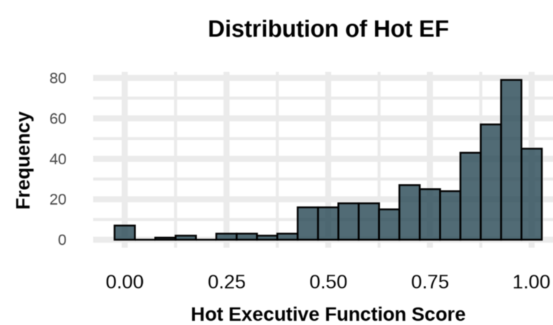

Figure 7. Histogram Depicting the Distribution of Children's Composite Hot Executive Function Scores. $n = 404$ observations across up to four timepoints with 231 children. Some children had not yet aged into the eligibility window for their later timepoints. The y-axis depicts the number of observations (i.e., data collection timepoints) with each proportion of maximum composite hot executive function score.

and prospectively when controlling for the child's prior levels of hot executive function.

These findings are consistent with prior research which found that higher parental education, but not parental income, was associated with children's cool executive function (Lensing & Elsner, 2018; Vrantsidis et al., 2020). Prior studies have also found no associations between aspects of socioeconomic status and children's hot executive function (Lensing & Elsner, 2018; Vrantsidis et al., 2020). Previous studies did not examine parental occupational prestige in relation to hot versus cool executive function. Thus, our findings extend previous research and suggest that parental occupational prestige does not uniquely contribute to the development of children's cool executive functioning above and beyond the contributions of other components of socioeconomic status, but that it may play a unique role in the development of children's hot executive function.

The differential associations between socioeconomic components and hot versus cool executive function support the divergence of cool versus hot executive function. Cool executive function represents higher-order cognitive processes in neutral, abstract, or decontextualized situations. These skills may exemplify the kinds of processes necessary for success in lower-stimulation, academic-like contexts. The knowledge or training gained through formal education may help parents support their child's development of cool executive function in various ways. Parents with more formal education may model inhibition and cognitive flexibility in their daily lives. Prior work has found that parents with higher executive function are more likely to engage in cool executive function-supporting activities at home, such as encouraging their children to stop and think (Korucu et al., 2020). In addition, parents with higher formal education may provide more resources or educational opportunities for practicing academic-like skills that require remembering information, inhibiting

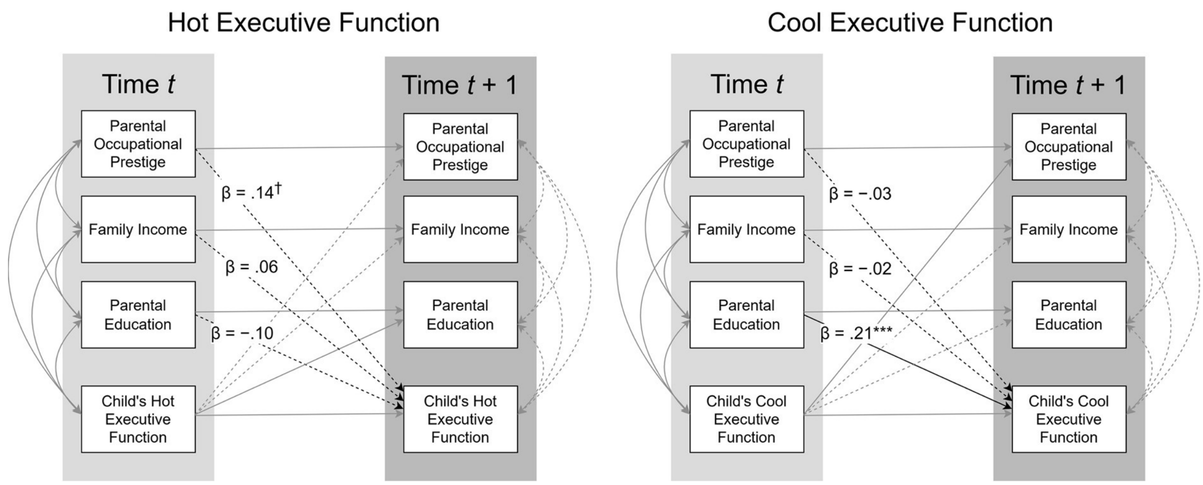

Figure 8. Cross-Lagged Panel Path Diagrams. $N = 231$ children.
†$p < .10$; ***$p < .001$.

Table 4. Cross-Lagged Panel Relations With Socioeconomic Status, Parental Effortful Control, and Child Age and Sex Predicting Child Hot and Cool Executive Functions.

	Child cool executive function						Child hot executive function					
	B	*SE*	95% CI		β	*p*	*B*	*SE*	95% CI		β	*p*
			LL	*UL*					*LL*	*UL*		
Family Income-to-Needs	−0.002	0.005	−0.012	−0.008	−0.02	.700	0.004	0.003	−0.002	0.010	0.06	.240
Parental Educational Attainment	**0.038**	**0.008**	**0.022**	**0.054**	**0.21**	**<.001**	−0.013	0.014	−0.040	0.014	−0.10	.348
Parental Occupational Prestige	0.000	0.001	−0.002	0.002	−0.03	.702	0.001	0.001	−0.001	0.030	0.14	.082
Parents' Effortful Control	−0.015	0.016	−0.046	0.016	−0.04	.331	0.012	0.013	−0.013	0.037	0.05	.344
Child's Age	0.028	0.017	−0.005	0.061	0.13	.099	0.012	0.012	−0.012	0.036	0.08	.328
Child's Sex	0.008	0.021	−0.033	0.049	0.02	.706	0.029	0.022	−0.014	0.072	0.08	.198

Note. $N = 231$ child/parent dyads with up to 924 possible timepoints. Some children had not yet aged into the eligibility window for their later timepoints. Estimates are based on all available pairwise timepoint observations. Bold text indicates a statistically significant result at $p < .05$. Models were performed separately with either hot or cool executive function as the outcome variable. Each model controlled for baseline levels of either hot or cool executive function, as well as for child age and sex, parents' effortful control, and every additional component of socioeconomic status when examining the effects of a single component.

compelling distractors, and flexibly shifting between tasks. For example, one prior study found that parents with higher education are more likely to read to their children (Volodina et al., 2023). Being read to regularly by a parent may support children's ability to maintain attention and process language in a calm context, supporting the development of their cool inhibitory control and working memory (Volodina et al., 2023).

Meanwhile, parental occupational prestige trended toward predicting children's hot executive function, although this was not statistically significant. This aligns with some prior evidence suggestive of links between occupational prestige and hot executive functions such as delay of gratification. For example, one prior study found that adults with higher delay of gratification were more likely to perceive themselves as having higher social rank (Ishii et al., 2017). Parents with higher-prestige occupations might therefore be more likely to model hot executive function skills to their children. In addition, another prior study found that high-status individuals (operationalized as a composite of both occupational prestige and education) were more likely to be perceived as trustworthy (Keijzer & Corten, 2022). It is possible that such social biases extend to the children of high-prestige parents, resulting in more frequent opportunities for social interactions and practice of hot executive function skills.

Interestingly, a family's income-to-needs ratio did not predict executive function above and beyond other aspects of socioeconomic status. This finding suggests that greater material resources are insufficient for children's development of executive function and that formal education offers parents unique skill sets for scaffolding their children's cognitive development. However, we cannot rule out the possibility that formal education may be a proxy for other mechanisms, such as one's proclivity toward learning academic skills that better represent the causal process.

The divergence in hot versus cool executive function was also supported by factor analyses. Models with two correlated factors ($r = .77$) representing cool and hot executive functions fit better than a one-factor model and fit better than the traditional model of executive function (from research with adults) with factors representing working memory, inhibition, and set shifting. However, we did not have multiple tasks that assess working memory or set shifting, so we are not well-positioned to evaluate the possibility of a three-factor structure. Nevertheless, our findings are consistent with the notion that cool and hot executive functions are correlated yet distinct factors. Moreover, there is apparent utility in distinguishing between cool and hot executive functions based on (a) their improved model fit relative to a one-factor model and (b) their differential associations with developmental antecedents—that is, aspects of socioeconomic status.

In terms of effect size, the bivariate associations between parental educational attainment and children's cool executive function were of medium magnitude (concurrent: $r = .31$; predictive: $r = .30$). When controlling for other aspects of socioeconomic status and covariates, the magnitudes were somewhat attenuated (concurrent: $\beta = .16$; predictive: $\beta = .26$). When controlling for prior levels of executive function, the magnitude was attenuated further ($\beta = .21$). Effect sizes from longitudinal studies tend to be considerably smaller than effect sizes from cross-sectional studies, particularly when controlling for longitudinal stability (Adachi & Willoughby, 2015). Thus, although the magnitude of the cross-lagged association was small, it is sizable in the context of the strong rank-order stability of cool executive function ($\beta = .65$) and the notable associations between parental educational attainment and other aspects of socioeconomic status (income-to-needs ratio: $r = .33$; occupational prestige: $r = .52$).

Strengths

The study had several strengths. First, we considered multiple aspects of socioeconomic status simultaneously to examine their unique contributions. Second, we assessed hot and cool executive functions using multiple performance-based tasks. Third, we controlled for the parents' effortful control, to better isolate the environmental contributions of the family's socioeconomic status. Fourth, the study was longitudinal, which allowed examining children's growth of executive function. Fifth, we examined whether aspects of socioeconomic status predicted later executive function while controlling for prior levels of executive function. The models thus tested whether aspects of socioeconomic status predict a child's *change* in executive function (relative to their peers), providing a stronger test of causality than tests of concurrent and lagged associations that do not control for prior levels.

Limitations

The study also had limitations. The design was correlational, so we cannot make definitive causal inferences. Many of the children performed close to the ceiling on our hot executive function tasks, limiting our statistical power (see Figure 7). Notably, though, we replicated our results using latent hot executive function factor scores, which were more normally distributed (see Supplementary Figure S4). Furthermore, all our participants were living in the Iowa City area, and 62.8% of the children were Non-Hispanic White. Thus, our results may not generalize beyond the Iowa City area and its constituent demographics. Future work should replicate our work with children from other racial-ethnic groups and geographic and cultural backgrounds.

Further, our sample was disproportionately composed of parents with middle- to high-prestige occupations and with college or post-graduate education relative to the U.S. population. Future work may possess greater statistical power with a more representative sample. For example, in our sample, no component of socioeconomic status uniquely significantly predicted the development of children's hot executive function. Parents with less formal education are more likely to experience unemployment or job instability (Hill & Ybarra, 2014; U.S. Bureau of Labor Statistics, 2024). Children of such parents might resultingly experience more instability in their home environment, which could increase their tendency to engage impulsively when emotions and rewards are salient, undermining their hot executive function (McCoy & Raver, 2014). Greater sampling of parents with more formal education or occupational prestige may strengthen researchers' ability to detect, or argue for the absence of, such unique effects.

Furthermore, children with weaker hot executive function were more likely to have missing data for socioeconomic status. This weakens any conclusions we may draw about a lack of evidence for independent associations between components of socioeconomic status and hot executive function. For example, these children may have been from lower socioeconomic status families, so their missing data may have reduced our ability to detect associations. An important future direction will be to examine the contributions of other aspects of the environment, such as the socioeconomic conditions of the neighborhood (e.g., Taylor et al., 2020).

Conclusion

In conclusion, parental educational attainment predicted the development of their child's cool executive function. No aspect of socioeconomic status predicted development of children's hot executive function. Parental education level may play a unique role—above and beyond other components of socioeconomic status—in the development of children's executive function in abstract, decontextualized situations. Findings underscore the critical role of expanding access and affordability of education. It will be important for future work to identify parenting practices or other mechanisms through which parental education may influence their children's development of cool executive function and to identify factors that support families with less formal education. It will also be valuable for future research to identify environmental factors that influence the development of executive function in more motivationally salient contexts. Understanding how precisely socioeconomic status influences children's executive function may ultimately inform more inclusive and equitable policy to promote healthy cognitive development for all children.

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Ethical Considerations

The present study was approved by the University of Iowa Institutional Review Board (Study #: 201701837).

Consent to Participate

Primary caregivers provided written consent to participate.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The project was funded by Grants HD098235 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD), T32GM149386 from the National Institute of General Medical Sciences (NIGMS), and UL1TR002537 from the National Center for Advancing Translational Sciences (NCATS).

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

The present study is part of a larger study, the School Readiness Study. Hypotheses and measures for the School Readiness Study were pre-registered: https://osf.io/jzxb8. Data files, a data dictionary, analysis scripts, and a computational notebook for the present study are published online: https://osf.io/7mq24/ (Demko et al., 2024). The preprint of this manuscript was posted at the following location: https://osf.io/preprints/osf/2kxjm.

Supplemental Material

Supplemental material for this article is available online.

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Supplementary Appendix S1. Recruitment methods and inclusion/exclusion criteria.

Participants were recruited from the local community in the Iowa City, Iowa area via university email listservs, databases acquired from the University of Iowa Department of Psychological and Brain Sciences and Institute for Clinical and Translational Science, local daycares and preschools, community flyers, social media, snowball sampling, and by word of mouth. Families were eligible for recruitment if they had a child younger than 5 years and 4 months of age and older than 2 years and 11 months. Exclusion criteria were: (1) child does not speak and understand English at a level to comprehend task instructions and communicate their basic needs, (2) their primary caregiver does not speak English, (3) the child does not have a permanent guardian (i.e., is in foster care or is a Ward of the Court), and (4) the child does not have normal or corrected-to-normal vision and hearing. Due to the COVID-19 pandemic, in-person data collection (i.e., all behavioral task data collection) was suspended and several prospective participants aged out of their eligibility window (i.e., 36, 45, 54, or 63 months of age) which made them ineligible to enroll.

Supplementary Appendix S2. Description of missing data.

The extent of completeness for model variables is provided in Supplementary Table S1. Among possible participant-by-wave instances, 22% had missing scores because the child was not yet eligible for a given wave. Among eligible participant-by-wave instances, approximately 68.55% had scores on cool executive function measures and 55.72% had scores on hot executive function measures (see Supplementary Table S1). Among missing lab visits at a given wave for which the child was eligible, reasons for missingness included: not interested (17.22%), too busy (15.56%), moved/relocated (6.67%), unable to contact (23.06%), COVID-19 (31.11%), and other (6.39%). Over one third of missing instances were due to the coronavirus (COVID-19) pandemic or to not yet being eligible. We suspended lab visits for 14 months during the COVID-19 pandemic (March 2020 – April 2021). Thus, we have limited scores on performance-based assessments at participants' fourth timepoints because many occurred during the COVID-19 pandemic shutdown.

Tests of systematic missingness revealed no significant differences in missingness as a function of the child's ethnicity or the family's socioeconomic status. However, boys were more likely to be missing data about family socioeconomic status ($\chi^2[1] = 8.65$, $p = .003$) and executive function ($\chi^2[1] = 7.98$, $p = .005$) compared to girls. Girls had complete data on their family's socioeconomic status for 82% of their eligible laboratory visits, compared to 72% of boys; girls had complete data on their executive function for 74% of laboratory visits compared to 64% of laboratory visits for boys. In addition, older children (compared to younger children) were more likely to be missing scores on both family socioeconomic status data ($t[18.422] = -2.88$, $p = .010$) and executive function data ($t[91.89] = -5.47$, $p < .001$), likely due to some attrition. Further, children who were missing any family socioeconomic status data during any laboratory visit for which they were eligible were more likely to have lower hot executive function, averaged across their observed laboratory visits (t[123.07] = 2.89, p = .005). Children with any missing family socioeconomic status data did not differ in cool executive function (t[204.01] = 1.03, p = .307). Children who were missing executive function data did not differ by their family's education, income-to-needs ratio, or occupational prestige (all p's > .20).

Supplementary Appendix S3. Sample demographics and comparisons between screened families who did versus did not consent to participate in the study.

For the consented primary caregivers (n = 232, M = 36.31 years of age, SD = 5.00 years), and parenting partners (n = 220, M = 37.95 years of age, SD = 7.06 years), of which 96.2% were biological parents, 0.4% were stepparents, 2.6% were adoptive parents, and 0.9% were other caregivers. Additionally, among primary caregivers, 78.2% were married, 12.6% were single/never married, 4.6% were divorced, 1.3% were re-married, and 3.4% were separated.

There were no significant differences in a child's age (t[149.01] = 0.37, p = .715) or sex (χ^2[1] = 0.12, p = .731) between participating families versus families that were screened but did not consent. There were significant differences in the race and ethnicity of participating families versus families that were screened did not consent (χ^2[3] = 21.364, $p < .001$), after filtering to only include racial/ethnic groups with 20 or more screened families to account for sparse cross-tabulation cells (e.g., a sparse number of screened families who identified as Native Hawaaiian or Pacific Islander). Specifically, 84% of (screened) families with Non-Hispanic White children consented to participate, compared to 73% of families with Multiracial children, 56% of families with Hispanic or Latino children, and 48% of families with Black or African American children. In sum, the participating and non-participating families appeared to differ in race and ethnicity but did not appear to differ in terms of the age or sex of their child.

Supplementary Appendix S4. Description of Measures.

Children completed the following executive function tasks during in-person laboratory visits while parents completed surveys about their socioeconomic status. These laboratory visits lasted 155.65 minutes on average (M = 155.65, SD = 20.54).

Parental educational attainment.

Primary caregivers reported their own educational attainment and that of their parenting partner (if applicable). Scores ranged from: 1 = No schooling completed, or less than 1 year; 2 = Nursery, kindergarten, and elementary (grades 1-8); 3 = High school (grades 9-12, no degree); 4 = High school graduate (or equivalent); 5 = Some college; 6 = Associate's degree (including occupational or academic degrees); 7 = Bachelor's degree; 8 = Master's degree; 9 = Professional school degree; 10 = Doctorate degree. We operationalized educational attainment at the family level as the maximum education obtained between the primary caregiver and parenting partner (if applicable).

Hot Executive Function Tasks.

Gift Delay. Gift Delay (Kochanska et al., 2000) assesses children's motivational inhibition. The child was promised a gift, but was told that it needed to be wrapped before they could receive it. The child's chair was turned away from the table and the child was instructed to not "peek" while wrapping occurred noisily for one minute (the "wrapping" waiting period). When the wrapping period was finished, the child was allowed to see the gift bag, but the experimenter announced that they would have to leave the room to retrieve a bow, and that the child should not look into or touch the gift bag until the experimenter returned (the "gift-in-bag" waiting period). After three minutes, the experimenter re-entered the room and prompted the child to open the gift.

The task was coded according to how the child interacted with the gift during the one-minute “wrapping” waiting period (wrap score; 1 = looks inside gift bag, touches paper or toy inside git bag, or opens gift; 2 = touches gift bag; 3 = looks at gift bag but does not stay in their seat the entire time; 4 = looks at gift bag, and stays in their seat the entire time; 5 = never looks at and never touches gift or gift bag) and the three-minute “gift-in-bag” waiting period (gift score; 1 = opens gift; 2 = touches paper or toy inside gift bag; 3 = looks inside gift bag; 4 = touches gift bag; 5 = never looks inside gift bag and never touches gift or gift bag but does not stay in their seat the entire time; 6 = never looks inside gift bag and never touches gift or gift bag, and stays in their seat the entire time), as adapted from Kochanska et al. (2000). The child’s wrap score was averaged with their gift score. Higher scores reflected greater inhibition.

Less is More. Less is More is a motivationally salient symbolic representation task that assesses affective inhibition (Carlson et al., 2005). The child was presented with two bowls, one with a monkey puppet attached and the other was the child’s bowl. The child was told that “the monkey is naughty because he wants all the treats for himself.” On each trial, the child was given the option of two bags: one bag with five marshmallows and one bag with two marshmallows. The child was instructed to point to one bag, which would be put in the monkey’s bowl, and the other bag (i.e., the bag they did not point to) was put in the child’s bowl. Responses were scored 0 = child points to large treats bag; 1 = child initially points to the large treats bag, then changes to the small treats bag; 2 = child points to the small treats bag, consistent with Kochanska et al., (1997). Scores were averaged across 16 test trials (0–2). Higher scores reflected greater inhibition.

Self-imposed waiting task. The self-imposed waiting task (Metcalfe & Mischel, 1999) assesses delay of gratification. During the task, the child was presented with a bell and was told that ringing the bell would bring the experimenter back into the room at any time. Multiple treat options were presented to the child: chocolate chips, bear-shaped graham crackers, and oyster crackers. The child chose a most preferred and a least preferred treat and then two plates of treats were presented: a plate with 10 pieces of their most preferred treat, and a plate with two pieces of their least preferred treat, as adapted from Duckworth et al. (2013), Mischel et al. (1972), and Razza & Raymond (2013).

Both plates of treats were present throughout the entire task. The child was informed that the experimenter would leave the room for a period, and that the child would be allowed to eat the big plate of preferred treats if they waited for the experimenter to return. The child was told that they could ring the bell at any time to bring the experimenter back into the room, but that, if they ring the bell, they could not eat the big plate of the preferred snack—they could only eat the small plate of the less-preferred snack instead. The duration of the waiting period (in seconds) was recorded for each child—i.e., the duration of time before either the child consumed a snack (either the preferred or less-preferred snack), or when the experimenter returned after 7 minutes. Higher scores reflected greater delay of gratification.

Snack Delay. Snack Delay (Kochanska et al., 1996) assesses children's motivational self-regulation. The child was presented with an M&M placed under a clear plastic cup on a placemat displaying an image of handprints. The child was told to keep their hands on the placemat and to wait until the experimenter rings a bell before picking up the cup and eating the treat. Five test trials of differing delay times (5s, 10s, 20s, 30s, and 15s) were administered in which the experimenter lifted the bell halfway through the trial but did not ring it until the full time elapsed. Thus, each trial contained two segments (i.e., bell on table and bell lifted), and each segment was scored from 0 to 3, with higher scores indicating greater delay performance: 0 = eats snack before bell is lifted (bell on table) or rung (bell lifted), 1 = touches snack before bell is lifted, 2 = touches glass and/or bell before bell is lifted; 3 = waits until bell is rung. Children who did not eat the treat at any point throughout the task were excluded from analyses. An additional point was awarded if the child's hands remained on the placemat throughout the segment, resulting in a final segment score of 0 to 4, as adapted from Kochanska et al. (2000). Scores were averaged across all ten segments.

Cool Executive Function Tasks.

Day/Night. This task measured inhibition. In Day/Night (Gerstadt et al., 1994), the child was presented with cards with either an image of a sun or an image of a moon and instructed to respond with "day" when they saw the card with a moon and with "night" when they saw the card with a sun. Sixteen test trials were scored on the following scale: incorrect (0), initially incorrect, but changed to correct (1), or correct (2). Scores were averaged across trials (0–2). Higher scores reflected greater inhibition.

Grass/Snow. This task measured inhibition. In Grass/Snow (Carlson & Moses, 2001), the child was asked to touch a green square when they heard the word "snow" and touch a white square when they heard the word "grass." Twelve test trials were scored as correct (1) or incorrect (0), and final scores were averaged across trials (0–1). Higher scores reflected greater inhibition.

Hand Game. This task measured inhibition. In Hand Game (Luria et al., 1964), the experimenter either made a fist or pointed a finger, and the child was instructed to perform the opposite (i.e., point a finger when shown a fist) in response. Fifteen test trials were scored on the following scale: incorrect (0), initially incorrect, but changed to correct (1), or correct (2), consistent with Kochanska et al. (1997). Scores were averaged across all trials (0–2). Higher scores reflected greater inhibition.

Knock/Tap. This task measured inhibition. The Knock/Tap task (Klenberg et al., 2001) had two parts. First, the child was instructed to knock on the table when the experimenter tapped, and to tap the table whenever the experimenter knocked. Then, the child was instructed to make a side fist when the experimenter knocked, to knock when the experimenter made a side fist, and to do nothing when the experimenter tapped the table. Fifteen test trials were scored on the following scale: incorrect (0), initially incorrect, but changed to correct (1), or correct (2), consistent with Kochanska et al. (1997). Scores were averaged across trials (0–2). Higher scores reflected greater inhibition.

Peg Tapping. This task measured inhibition. In Peg Tapping (Luria et al., 1964), the child observed the experimenter tap a pencil either once or twice on the table. The child was then instructed to tap a pencil the opposite number of times of what they observed. For example, if the experimenter taps the pencil once, the child is to tap the pencil twice and vice versa. Sixteen trials were scored as correct (1) or incorrect (0). Scores were averaged across trials (0–1). Higher scores reflected greater inhibition.

Picture Memory. This task assesses visual working memory and is part of the Wechsler Preschool and Primary Scale of Intelligence–Fourth Edition (Wechsler, 2012). The child was shown an image for a specified amount of time (3s, 5s) and then instructed to select the picture(s) that they had been shown from options provided on a subsequent response page. Trials were scored as correct (1) or incorrect (0) and administration continued until three consecutive incorrect scores were observed. Scores were summed across trials, with a higher score indicating greater working memory.

Simon Says. This task measured inhibition. In Simon Says (Strommen, 1973), the child was instructed to perform simple motor actions (e.g., clap your hands, stomp your feet) only if the instructions began with the phrase "Simon Says." Each no-go trial was scored from 1 to 4 (1 = full commanded movement, 2 = partial movement, 3 = wrong movement, and 4 = no movement), consistent with Carlson & Moses (2001); scoring was reversed for go trials. A composite score was computed by multiplying mean scores from 10 go trials and 10 no-go trials (20 trials total), consistent with Eisenberg et al. (2013). Higher scores reflected greater inhibition.

Dimensional Change Card Sort. This task is part of the NIH Toolbox Cognitive Battery and assesses set-shifting (Weintraub et al., 2013). The child was presented with pictures that varied by shape (i.e., ball or truck) and color (i.e., blue or yellow) and asked to match a central image with one of two other images based on either color or shape. The dimension on which the child was instructed to sort varied across 40 trials. We used the computed scores from the NIH Toolbox, which were calculated in terms of accuracy and reaction time: each correct response was awarded 0.125 points for a total possible accuracy score of 5 points. Any child with an accuracy score of less than 4 (80%) is not given a reaction time score. Children achieving 80% accuracy or higher could receive up to 5 additional points for their performance on reaction time. Reaction time (RT) scores were put onto a 5-point scale using the following log transformation: $\text{Reaction Time Score} = 5 - \left[5 \times \left(\frac{\log RT - \log(500)}{\log(3000) - \log(500)}\right)\right]$, where RT is the median reaction time, 500ms represents the minimum valid median reaction time, and 3000ms represents the maximum allowed reaction time (National Institutes of Health, 2021).

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Supplementary Table S1. Table depicting percent of participant laboratory visits with scores on each measure (out of eligible laboratory visits, i.e., excluding visits into which participants have not yet aged).

Measure	Percent of ID-Wave instances with Scores
Cool Executive Function Composite	68.55
Hot Executive Function Composite	55.72
Day/Night	47.72
Dimensional Change Card Sort	53.07
Educational Attainment	76.97
Gift Delay	43.17
Grass/Snow	47.45
Hand Game	40.97
Income-to-Needs Ratio	73.66
Knock Tap	42.90
Less is More	43.59
Occupational Prestige	55.72
Peg Tapping	40.97
Picture Memory (WPPSI-IV)	36.55
Self-Imposed Waiting Task	44.97
Simon Says	39.45
Snack Delay	49.66

Note. Some of the missingness is the executive function measures is due to instances not having been coded yet as part of an ongoing longitudinal study. "WPPSI-IV" = Wechsler Preschool and Primary Scale of Intelligence–Fourth Edition.

Supplementary Table S2. Table depicting reliability of measures.

Measure	Inter-rater Reliability	Internal Consistency Reliability	Cross-time 9-month Stability
ATQ: Effortful Control	n/a	α = .61	*r* = .87
Day/Night	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .94	*r* = .51
Dimensional Change Card Sort	n/a	Mean reliability of 1,000,000 split halves: (Repeat: .94; Switch: .71)	*r* = .41
Gift Delay	ICC[2,*k*] = .99	n/a	*r* = .33
Grass/Snow	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .96	*r* = .38
Hand Game	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .93	*r* = .36
Knock/Tap	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .95	*r* = .45
Less is More	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .89	*r* = .35
Peg Tapping	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .93	*r* = .50
Self-Imposed Waiting Task	ICC[2,*k*] = .99	n/a	*r* = .41
Simon Says	ICC[2,*k*] = .99	Mean reliability of all possible split halves: (Go: .93; No-go: .82)	*r* = .65
Snack Delay	ICC[2,*k*] = .99	Mean reliability of all possible split halves: .94	*r* = .38

Note. Inter-rater reliability was evaluated after raters resolved key discrepancies. For Dimensional Change Card Sort, a random sample of 1,000,000 split halves was used for calculating the mean split-half reliability rather than all possible split halves due to the large number of trials and the lengthy time it would take to compute the mean reliability of all possible split halves. These reliabilities are from the School Readiness Study, which includes laboratory visits that took place after the data presented here were analyzed. ATQ = Adult Temperament Questionnaire

Supplementary Table S3. Indicator factor loadings for model with correlated hot and cool executive function factors.

Model Parameter	Unstandardized		Standardized
	Estimate	SE	Estimate
Cool Executive Function Factor Loadings			
Peg Tapping	.176	.014	.50
Simon Says	.066	.013	.23
Picture Memory	.038	.008	.22
Knock/Tap	.201	.013	.60
Hand Game	.186	.017	.57
Grass/Snow	.204	.016	.56
Day/Night	.158	.016	.46
Dimensional Change Card Sort Task	.067	.012	.27
Hot Executive Function Factor Loadings			
Self-Imposed Waiting Task	.219	.028	.50
Gift Delay	.082	.013	.46
Snack Delay	.060	.013	.41
Less is More	.077	.016	.30
Factor Covariance	.771	.091	.77
Item Intercepts			
Peg Tapping	−0.322	0.058	−0.91
Simon Says	−0.402	0.033	−1.38
Picture Memory	−0.112	0.036	−0.63
Knock/Tap	−0.147	0.062	−0.44
Hand Game	−0.007	0.079	−0.02
Grass/Snow	−0.206	0.067	−0.57
Day/Night	−0.142	0.067	−0.41
Dimensional Change Card Sort Task	−0.335	0.037	−1.35
Self-Imposed Waiting Task	−0.160	0.090	−0.36
Gift Delay	0.600	0.053	3.33
Snack Delay	0.753	0.038	5.19
Less is More	0.271	0.062	1.07
Item Residual Variances			
Peg Tapping	.036	.006	.29
Simon Says	.033	.003	.39
Picture Memory	.015	.001	.47
Knock/Tap	.027	.004	.24
Hand Game	.039	.006	.37
Grass/Snow	.041	.006	.31
Day/Night	.055	.006	.46
Dimensional Change Card Sort Task	.034	.002	.56
Self-Imposed Waiting Task	.104	.013	.54

Gift Delay	.024	.002	.74
Snack Delay	.016	.004	.75
Less is More	.042	.005	.66
R^2 for Item Variances			
Peg Tapping			.71
Simon Says			.61
Picture Memory			.53
Knock/Tap			.76
Hand Game			.63
Grass/Snow			.69
Day/Night			.54
Dimensional Change Card Sort Task			.44
Self-Imposed Waiting Task			.46
Gift Delay			.26
Snack Delay			.25
Less is More			.34

Supplementary Table S4. Concurrent associations of socioeconomic status, parental effortful control, and child age and sex with child hot and cool executive function.

	Child Cool Executive Function				Child Hot Executive Function			
	B	*SE*	β	*p*	*B*	*SE*	β	*p*
Family Income-to-Needs Ratio	−0.002	0.003	−0.02	.648	0.002	0.003	0.03	.538
Parental Educational Attainment	**0.031**	**0.009**	**0.16**	**<.001**	0.015	0.011	0.10	.187
Parental Occupational Prestige	**0.001**	**0.001**	**0.11**	**.049**	0.001	0.001	0.13	.057
Parents' Effortful Control	**0.038**	**0.016**	**0.10**	**.017**	0.004	0.020	0.01	.829
Child's Age	**0.139**	**0.008**	**0.59**	**< .001**	**0.080**	**0.009**	**0.44**	**< .001**
Child's Sex	0.043	0.023	0.08	.061	0.040	0.023	0.09	.080

Note. Bold text indicates a statistically significant result at $p < .05$. Each model controlled for child age and sex, parents' effortful control, and every additional component of socioeconomic status when examining the effects of a single component.

Supplementary Table S5. Predictive associations of socioeconomic status, parental effortful control, and child age and sex with child hot and cool executive function.

	Child Cool Executive Function				Child Hot Executive Function			
	B	*SE*	β	*p*	*B*	*SE*	β	*p*
Family Income-to-Needs	−0.002	0.005	−0.03	.654	0.004	0.004	0.07	.282
Parental Educational Attainment	**0.045**	**0.010**	**0.26**	**< .001**	−0.005	0.015	−0.04	.720
Parental Occupational Prestige	0.000	0.001	0.03	.641	0.001	0.001	0.14	.094
Parents' Effortful Control	0.000	0.020	0.00	.983	0.009	0.016	0.04	.559
Child's Age	**0.112**	**0.013**	**0.53**	**< .001**	**0.040**	**0.010**	**0.27**	**< .001**
Child's Sex	**0.028**	**0.029**	**0.06**	**.028**	0.041	0.028	0.12	.137

Note. Bold text indicates a statistically significant result at $p < .05$. Each model controlled for child age and sex, parents' effortful control, and every additional component of socioeconomic status when examining the effects of a single component.

Supplementary Table S6. Cross-lagged panel relations with components of socioeconomic status predicting child hot and cool executive function, using a log-transformed income-to-needs ratio.

	Child Cool Executive Function				Child Hot Executive Function			
	B	*SE*	β	*p*	*B*	*SE*	β	*p*
Family Income-to-Needs Ratio[a]	−0.023	0.027	−0.04	.400	0.033	0.031	0.09	.291
Parental Educational Attainment	**0.040**	**0.009**	**0.22**	**< .001**	−0.013	0.014	−0.11	.347
Parental Occupational Prestige	0.000	0.001	−0.02	.752	0.001	0.001	0.11	.203
Parents' Effortful Control	−0.015	0.016	−0.04	.336	0.010	0.013	0.04	.457
Child's Age	0.027	0.017	0.13	.115	0.013	0.012	0.09	.262
Child's Sex	0.008	0.021	0.02	.699	0.028	0.022	0.08	.205

[a] This variable was log-transformed.

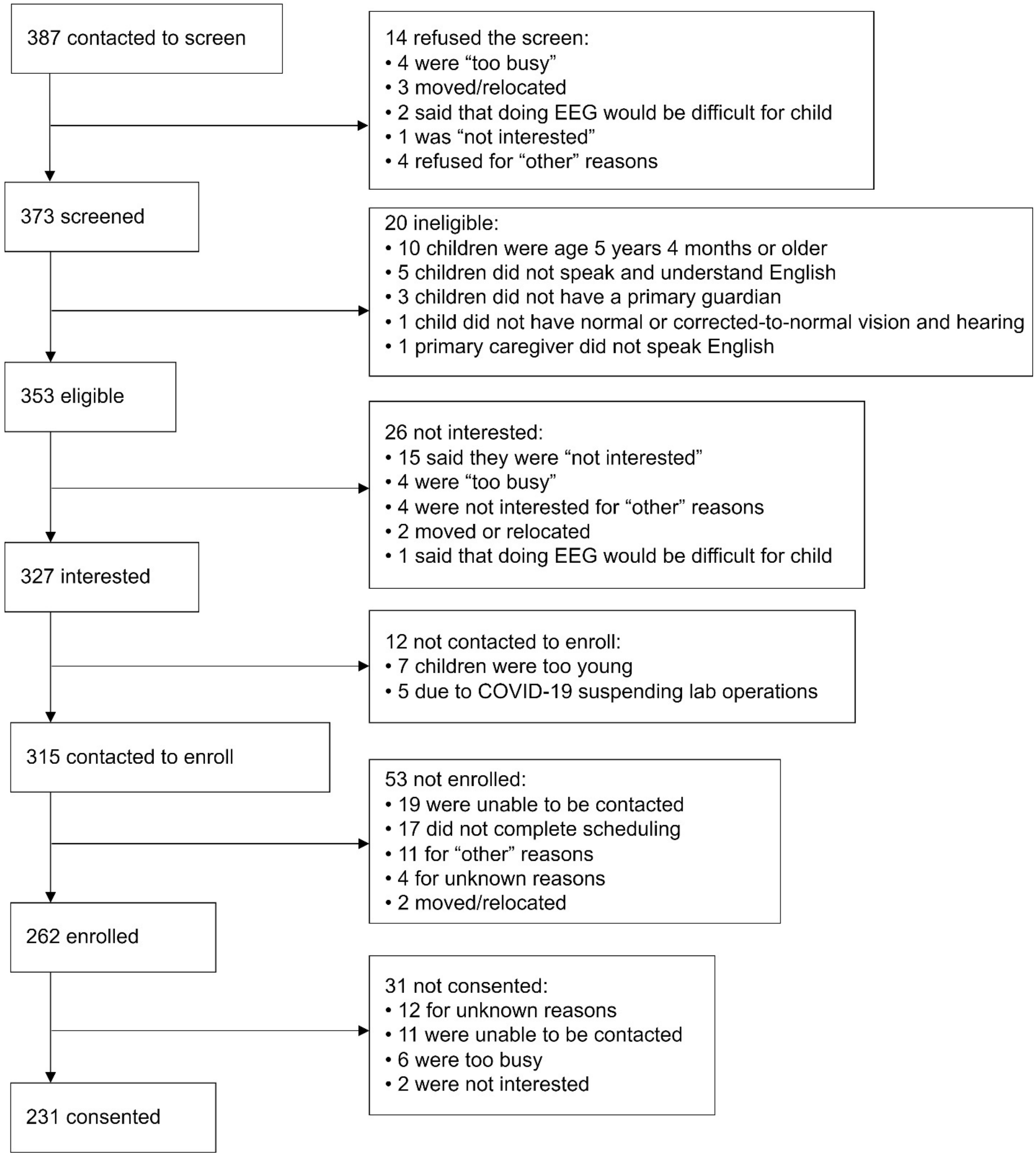
Note. Bold text indicates a statistically significant result at $p < .05$. Each model controlled for baseline levels of either hot or cool executive function, as well as for child age and sex, parents' effortful control, and every additional component of socioeconomic status when examining the effects of a single component.

Supplementary Table S7. Cross-lagged panel relations with components of socioeconomic status predicting child hot and cool executive function, using factor scores extracted from our two-factor confirmatory analysis.

	Child Cool Executive Function				Child Hot Executive Function			
	B	*SE*	β	*p*	*B*	*SE*	β	*p*
Family Income-to-Needs Ratio	0.010	0.008	−0.05	.201	0.010	0.008	0.05	.179
Parental Educational Attainment	**0.091**	**0.026**	**0.19**	**< .001**	0.040	0.025	0.10	.114
Parental Occupational Prestige	−0.002	0.002	−0.05	.267	0.000	0.001	0.01	.908
Parents' Effortful Control	−0.074	0.047	−0.08	.109	−0.039	0.035	−0.05	.276
Child's Age	**−0.190**	**0.035**	**−0.34**	**< .001**	**−0.167**	**0.029**	**−0.33**	**< .001**
Child's Sex	0.086	0.062	0.06	.162	0.081	0.053	0.07	.125

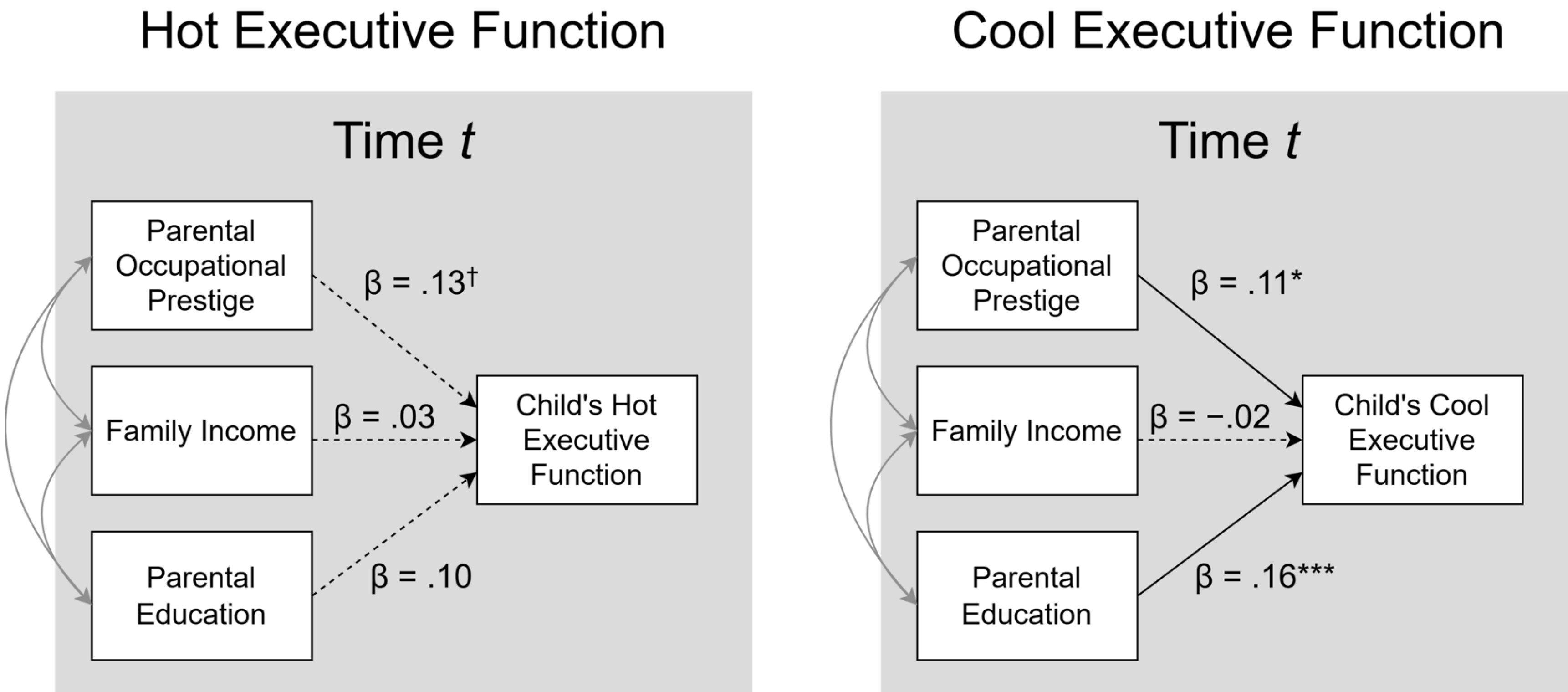
Note. Bold text indicates a statistically significant result at $p < .05$. Each model controlled for baseline levels of either hot or cool executive function, as well as for child age and sex, parents' effortful control, and every additional component of socioeconomic status when examining the effects of a single component.

Supplementary Figure S2. Participant Flow Chart and Reasons for Ineligibility.



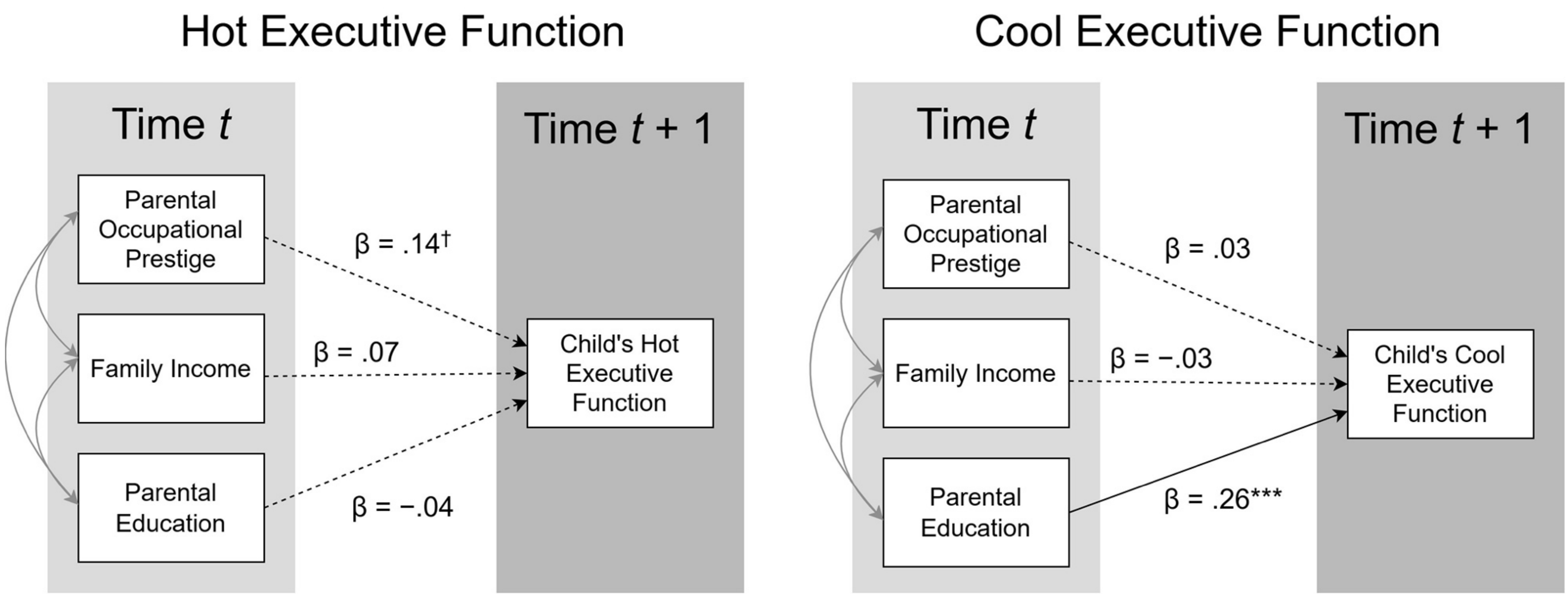
Note. EEG = "electroencephalography"

Supplementary Figure S2. Concurrent structural equation model relations between socioeconomic status and executive function.



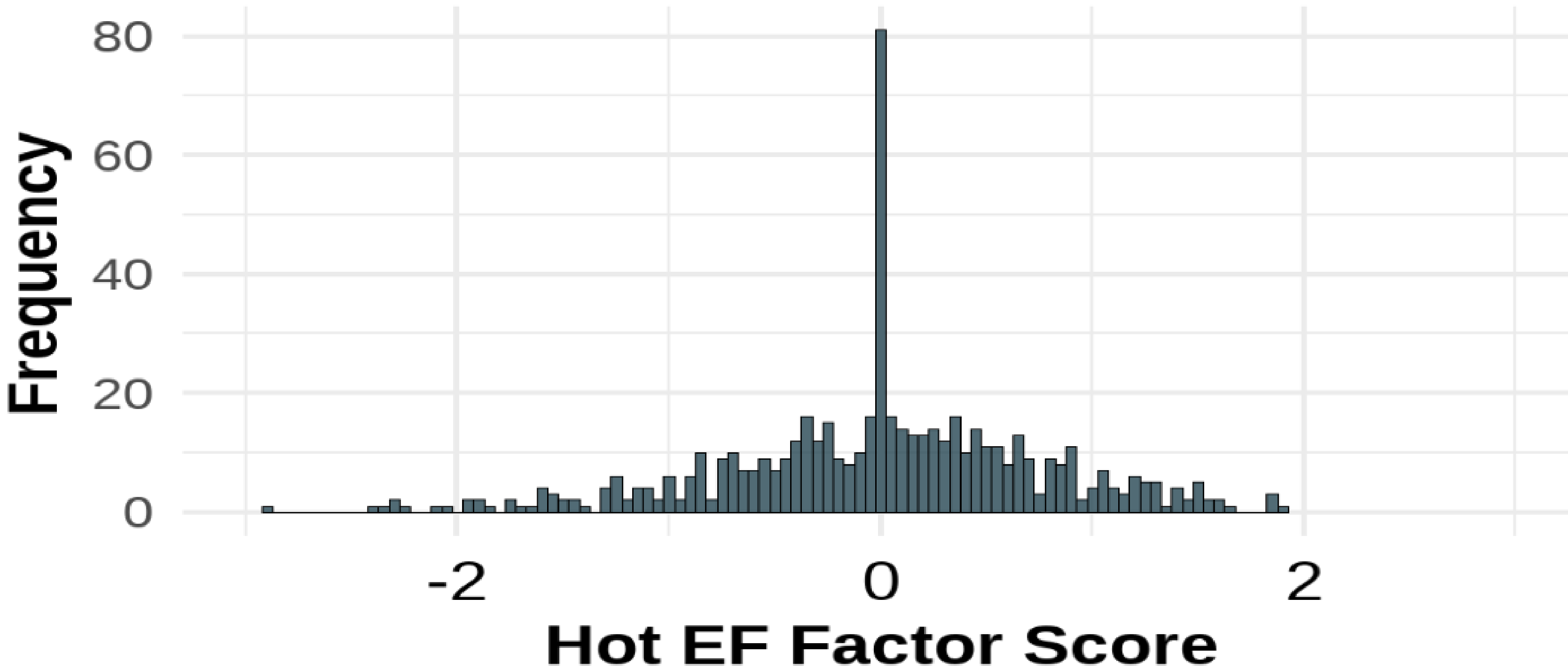
† $p < .10$; * $p < .05$; *** $p < .001$

Supplementary Figure S3. Predictive structural equation model relations between socioeconomic status and executive function.



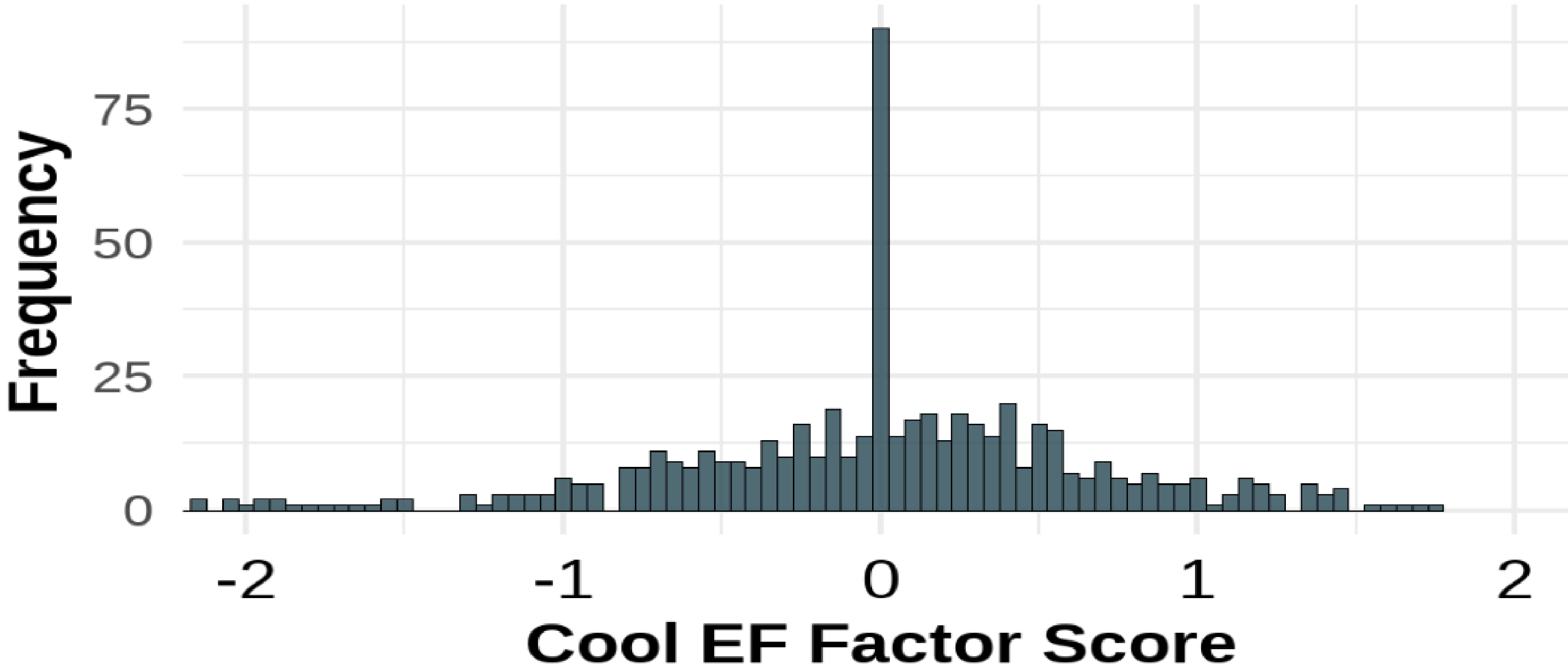
† $p < .10$; *** $p < .001$

Supplementary Figure S4. Histogram depicting the distribution of children's latent hot executive function factor scores.



Note. The y-axis depicts the number of observations (i.e., data collection timepoints) with a child's latent hot executive function factor score.

Supplementary Figure S5. Supplementary Figure S4. Histogram depicting the distribution of children's latent cool executive function factor scores.



Note. The y-axis depicts the number of observations (i.e., data collection timepoints) with a child's latent cool executive function factor score.