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Children’s Non-Cognitive Skills and the Effects of Family SES on Academic Achievement
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Abstract

Combining the theory of resources substitution and recent evidence on the importance of children’s non-cognitive skills from social sciences, this study asks whether the effects of family SES on achievement are contingent on or moderated by children’s non-cognitive skills. I address this question from a longitudinal perspective by focusing on two developmental stages: early childhood and early adolescence. To overcome the methodological involved in answering these questions, I use Structural Nested Mean Models (SNMM), a recent development in statistical methods. Using data from Early Childhood Longitudinal Program (ECLS), I test the hypothesis that better non-cognitive skills will reduce family SES’s effects on achievement in a longitudinal setting. The results corroborate the hypothesis, indicating that non-cognitive skills will moderate family SES’s effects, and higher non-cognitive skills will weaken family SES’s effects on achievement. In addition, such moderation effects are significant during both focal developmental stages of early childhood and early adolescence.
INTRODUCTION

Family socioeconomic status (SES) has long been shown an important determinant in intergenerational mobility and an influential factor of one’s achievement across many domains, from the labor market, to health, to education, among others. Over the past several decades, it has been established that a child’s educational attainment and achievement are strongly associated with his/her family’s socioeconomic status (Entwisle, Alexander, and Olson 2012; Sewell and Hauser 1975). Specifically, the positive SES gradient in educational achievement, usually measured by standardized achievement test scores and GPAs, is observed as early as children enter kindergarten, and persists into their later educational career, such as in middle school (Entwisle, Alexander, and Olson 1997; Lee and Burkam 2002; Mayer 1997; Reardon 2011). This positive relationship between SES and children’s academic achievement has been a focus of sociological studies, and myriad studies have developed around understanding the mechanisms and pathways, such as education investment and parenting style, that lead to this pattern and are shaped by family’s financial resources, cultural and social capital – the basic elements of family SES (e.g., Bourdieu and Passeron 1990; Lamont and Lareau 1988; Mayer 1997; Sewell and Hauser 1975).

However, fewer studies have examined whether the effects of family SES on achievement are contingent on other factors, such as children’s characteristics. Theoretically, as suggested by resource substitution theory, it is possible that children’s non-cognitive skills may weaken the effects of family financial, cultural and social resources on children’s achievement. While low SES families may lack financial resources and social capital, and parents from these families are likely to be less educated, children from these families may still thrive and achieve success if they have good non-cognitive skills such as self-control, conscientiousness attention, motivation and persistence. In other words, non-cognitive skills can modify the relationship between family SES and children’s achievement in school. Better non-cognitive skills will weaken family SES’s effects on achievement, and non-cognitive skills will make up for the disadvantage of family origins in terms of achievement for low-SES children. In the meantime, it is possible that such modification by non-cognitive skills could differ across different developmental stages; some periods, such as early childhood, may show greater possibility for
such moderation as literature suggested that children’s well-being are more sensitive to the environment during this period (Duncan et al. 1998; Heckman 2006). Unfortunately, little work has empirically examined these questions systematically, with related research yielding mixed findings on whether non-cognitive skills can modify family SES’s effects on achievement (Duncan et al. 2007; Shanahan et al. 2014). Yet, these are important and interesting questions, as not only will they contribute to our understanding of social stratification processes, but will also provide us insightful intervention points by which policies could be used to reduce inequality in education.

Using data from Early Child Longitudinal Survey-Kindergarten (ECLS-K), this paper investigates how family SES effects on children’s achievement are moderated by children’s non-cognitive skills during two developmental stages: early childhood and early adolescence. To answer this empirical question, two methodological challenges arise: (1) family SES, children’s non-cognitive skills and other covariates vary over time; (2) non-cognitive skills, the proposed moderator of family SES effects on achievement, are themselves influenced by early family SES and can mediate previous SES’s effects on achievement. Because of these two challenges, conventional regression methods fail to yield unbiased estimates. I thus use Structural Nested Mean Models in my analysis to address these methodological challenges. The results suggest that non-cognitive skills weaken family SES effects on children’s achievement during both developmental stages of early childhood and early adolescence.

This paper contributes to current knowledge in several ways: first, it expands our understanding of the relationship between family SES, non-cognitive skills and educational achievement; second, it suggests that intervening on children’s non-cognitive skills could be beneficial because they appear to reduce the impacts of family origin on educational achievement; third, it shows how methodological developments can benefit sociological research on child development in a longitudinal setting.

FAMILY SES AND CHILDREN’S EDUCATION ACHIEVEMENT

Since 1960s, when the Coleman report suggested the importance of family to children’s education achievement, myriad sociological studies have shown that family socioeconomic status (SES), usually measured by family income and parental education and occupation, is a
prominent predictor of children’s educational achievement in adolescence and young adulthood (e.g. Alexander, Eckland, & Griffin, 1975; Coleman & Campbell, 1966; Sewell & Hauser, 1975). To understand the association between family SES and achievement, social scientists have examined the causes and underlying mechanisms. As family SES roughly represents family’s economic resources, cultural and social capital, it is argued that parents pass on their advantage in socioeconomic standing to their children mainly through pathways and factors involving these three type of resources.

Specifically, family economic resources, usually operationalized as family income, is claimed to be a most influential factor in children’s development and educational achievement. Becker originally argued that family economic resources influence children’s human capital through “…(parents’) expenditures on their (children’s) skills, health, learning, motivation, ‘credentials’, and many other characteristics” (Becker and Tomes 1994). Financial resources such as income thus matter to children’s achievement because they directly determine parents’ financial ability to invest in children’s education and development. Families with higher incomes are able to purchase more and better materials, such as books and CDs, to build a cognitive stimulating family environment (Baharudin and Luster 1998; Garrett, Ng’andu, and Ferron 1994; Votruba-Drzal 2003); to afford private schools, or access to high quality public schools by residing in a wealthy neighborhood when children are of school age (Coleman and Campbell 1966; Gamoran 2001; Hanushek 1997); and to obtain other educational services and extracurricular activities such as tutors and music classes to enrich children’s life (Becker and Tomes 1994; Kaushal, Magnuson, and Waldfogel 2011). All of these enhance children’s chances of education success. Economic resources can also influence children’s achievement indirectly through parents’ mental wellbeing and daily interaction with children. Specifically, “role model” and “parental-stress” theory suggests that financial stresses from low income and poverty harm parents’ emotional and mental well-being, which jeopardizes their child-rearing capacities and thus children’s development. For example, parents facing financial insecurity and stress may adopt a harsher parenting style which is detrimental to children’s development (Yeung, Linver, and Brooks-Gunn 2002).

Family SES does not only reflect the tangible assets of economic resources, but also the intangible assets of cultural and social capital. The effects of family intangible resources on children’s achievement can be as far-reaching as those of the monetary resources discussed
above, if not more so. For example, it has been argued by sociologists that transmission of social and cultural capital from parents to children is particularly important in reproducing class and creating inequalities in children’s educational attainment (Bourdieu and Passeron 1990). Studies have shown that parents’ expectation and parenting practices, which strongly depend on parents’ cultural capital such as education, mediates a good portion of family SES effects on school-age children’s achievement (Davis-Kean 2005). Recent work by Lareau (2011) further documents a systematic difference in parenting practices between middle class parents and working class parents that can be traced to more intangible aspects of SES, such as cultural and social capital. While middle class parents engage in “concerted cultivation” and more purposeful practices in daily interactions with their children; working class parents tend to let their children grow naturally and minimally intervene on their growth. Such differences, as argued by Lareau, are a manifestation of the class differences in cultural and social resources. Empirical studies from social demography support this as well; in contrast to parents in lower SES families, parents in higher SES families arrange children’s daily lives and activities in more structured ways so as to enhance their development (Cheadle 2008, 2009; Heckman 2006).

**NON-COGNITIVE SKILLS AND CHILDREN’S ACHIEVEMENT**

In addition to the rich evidence of family effects on children’s achievement, recent developments in the social sciences have begun to show that personal characteristics, in particular non-cognitive skills including behavioral traits such as motivation, perseverance and tenacity, are important to social achievement and success throughout life (e.g., Almlund et al. 2011; Duckworth and Seligman 2006; Heckman 2006). For instance, traits such as conscientiousness, perseverance, self-discipline and attention are consistently associated with educational attainment and achievement (Claessens, Duncan, and Engel 2009; Duncan et al. 2007; Entwisle et al. 2012). Self-control, besides predicting subsequent changes in grades, has been shown to make up for shortcomings in IQ (Duckworth and Seligman 2005, 2006; Duckworth, Tsukayama, and May 2010; Zhou, Main, and Wang 2010). Persistence, concentration, attention, and (low) activity in early childhood predict both course grades and standardized achievement test scores in short term and even after years (Alexander, Entwisle, and Dauber 1993; Duncan et al. 2007; Martin 1989). It has also been suggested that non-cognitive skills account for the observed achievement gaps between different groups. As Hsin
and Xie’s (2014) work pointed out, a good proportion of Asian students’ academic premium over other racial groups, such as Whites, can be attributed to their strong work ethic and greater academic efforts.

**NON-COGNITIVE SKILLS AND THE EFFECTS OF FAMILY SES ON ACADEMIC ACHIEVEMENT**

In general, non-cognitive skills can play two types of role in reproducing SES differences in academic achievement during children’s early life course: mediator and a moderator (Table 1).

**Non-Cognitive Skills as a Mediator**

First, non-cognitive skills are not determined at the time of birth. Rather, they develop over time as children grow up, and thus are influenced by the environment in the family. As suggested by past studies, non-cognitive skills such as behaviors, habits and traits are deeply influenced by parents and family where children spent most of their time as they grow up. (Bowles et al. 2001; Lareau 2011) For example, it has been shown that middle- and higher-class parents adopt “concerted cultivation” (Lareau 2011), a parenting approach that instills in children behavioral patterns and non-cognitive skills such as persistence and conscientiousness, resources that are beneficial to educational achievement (Bodovski and Farkas 2008; Calarco 2011).

Non-cognitive skills and behavioral attributes are also affected by adult’s occupation and income, which are important dimensions of family SES. For instance, the labor market rewards conscientiousness an extra wage premium (Bowles et al. 2001). While jobs in different social classes emphasize different characteristics, middle-class jobs, in particular, value non-cognitive skills such as self-direction, initiatives, thought and independent judgement (Kohn and Schooler 1982; Kohn 1989). As jobs can also influence behavioral attributes reciprocally, by reinforcing certain characteristics that are required for a given position, it is plausible that parents from higher SES families are generally advantaged in skills such as conscientiousness, self-direction, and independent thinking. As parents tend to pass their own characteristics to their children (Bowles et al. 2001), children from higher SES families are more likely to develop better non-cognitive skills.
<table>
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<tr>
<th>The Role of Non-Cognitive Skills</th>
<th>Conceptual Interpretation</th>
<th>Graphic Illustration</th>
<th>Graphic Illustration (Longitudinal Setting)</th>
<th>Focus of the Current Study</th>
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<td>Mediator</td>
<td>A mediator is a third variable that accounts for the relation between an independent variable and a dependent variable.</td>
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<td><img src="image2" alt="Mediator Diagram (Longitudinal Setting)" /></td>
<td>No</td>
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<tr>
<td>Moderator</td>
<td>A moderator is a third variable that “affects the direction and/or strength of the relation” between an independent variable and a dependent variable.</td>
<td><img src="image3" alt="Moderator Diagram" /></td>
<td><img src="image4" alt="Moderator Diagram (Longitudinal Setting)" /></td>
<td>Yes</td>
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Second, as discussed in previous sections, non-cognitive skills affect children’s achievement and development positively and good predictors to academic success in school (Alexander, Entwisle, and Olson 2001; Claessens et al. 2009). Therefore, family SES can influence children’s achievement through influencing their non-cognitive skills (Table 1 top panel). In other words, current non-cognitive skills can serve a mediator of previous SES’s effects on later achievement, as will be shown in the analysis part. Though this role of mediator is not a central focus of this study\(^1\), it will propose methodological challenges in a longitudinal study like this, which I will discuss further in method section.

**Non-Cognitive Skills as a Moderator**

Besides as a mediator, non-cognitive skills may also work as a moderator and modify how family SES affects children’s achievement (Table 1 bottom panel). However, few studies before have examined this issue, which is the focal question of this article.

Theoretically, non-cognitive skills’ role as a moderator is supported by the theory of resource substitution, which posits that the existence of multiple resources can make outcomes less dependent on the presence of any specific resource, and that the presence of one type of resource may fill a gap due to the absence of another (Ross and Mirowsky 2006, 2011). Developed by Ross and Mirowsky, resource substitution theory was originally proposed to explain how multiple factors or resources work together to influence one’s health. In a nutshell, this theory posits that the effects of different resources on the outcome are interdependent, and an increase (or decrease) in one particular resource can decrease (or increase) the alternative resource’s effects on the outcome.

Given the above theoretical grounding and the fact that family SES and non-cognitive skills are both critical determinants of children’s development, it is likely that family SES and children’s non-cognitive skills work interactively and are two exchangeable resources for children’s achievement. In particular, having better non-cognitive skills could make up for academic disadvantage due to a lower family SES; and family SES is less important to the

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\(^1\) More detailed analysis of the mediation effects discussed in a separate article, as the I think it deserves more thorough analysis which may not be incorporated in this current article.
achievements of children who possess better non-cognitive skills. For instance, a child who has fostered a high motivation in learning and a well-developed self-control may make better use of the time and learning resources both in school and at home or community. Given these non-cognitive skills, this child’s academic achievement may less depend on his/her family’s socioeconomic resources, but is more positively influenced by these soft skills he/she has. Therefore, this child is likely to excel in school even if he/she is from a low SES family. Similarly, children with strong perseverance will make consistent efforts regardless of their surroundings and even when facing adversities. Thus, for children from low SES families, persistence will benefit their academic development and make up the disadvantage they may otherwise suffer from their families’ lack of financial resources and social capital.

As a matter of fact, there are plenty of anecdotes in our society where children coming from humble background achieve success and upward mobility by their own efforts and respectable characteristics such as perseverance, conscientiousness, motivation and self-control. Scientific studies also hint the possibility that non-cognitive skills may make up for the lack of family socioeconomic resources. For instance, in the Perry School Intervention Study, a group of students from disadvantaged background were selected to participate in an intervention program fostering non-cognitive skills such as planning, executing plans, and reviewing their work. Follow-up studies showed that these students not only improved in their cognitive ability, but also became more successful than their peers from similar background in terms of socioeconomic attainment in later life (Heckman, Moon, and Pinto 2010). Recent work by Shanahan and colleagues (2014) also suggest that non-cognitive skills, measured by the Big Five personality traits (neuroticism, extraversion, openness, agreeableness, and conscientiousness), moderate family SES effects on the social attainment process. In particular, being less neurotic, more agreeable, extraverted, conscientious, and imaginative can reduce the effects of family background on young adults’ education attainment, hourly wages and self-direction. In other words, better non-cognitive skills are more important for young adults from less-advantaged family background to obtain social attainment. This suggests that non-cognitive skills and family SES work interactively and are substitutable to certain extent in social attainment processes.
Moderated Effects in a Longitudinal Setting

Until now, few studies have systematically examined whether non-cognitive skills can moderate family SES’s effects on children’s achievement, and even less have examined this issue from a longitudinal or developmental perspective. However, these are important questions as they enhance our knowledge of how and when non-cognitive skills work as a moderator during children’s early life course, which carries strong policy implications. In this current study, I incorporate two developmental stages to accommodate the possibility that there may be difference across children’s developmental periods, and to better assess non-cognitive skills’ role as a moderator. I hypothesized that non-cognitive skills will reduce family SES’s effects on achievement. In particular, family SES effects on achievement are smaller for those who have better non-cognitive skills, and larger for those who have fewer non-cognitive skills.

METHODS

Testing whether non-cognitive skills will moderate family SES’s effects on achievement in a longitudinal setting face several methodological challenges which cannot be addressed by conventional method. In this section, I will first present the conceptual model used to address the scientific questions that are the focus of this article. Then, I discuss why the conventional regression method fails to provide good estimates in such a model. Third, I introduce the structure nested mean model (SNMM), and explicate how it helps to overcome the limitations of the conventional methods.

Defining Moderated SES’s Effects on Achievement in a Longitudinal Setting

Stylized Figure 1 shows the conceptual model used to design the models that follow. The central focus of this study is to estimate: whether and how family SES effects on achievement in early adolescence depend on children’s evolving non-cognitive skills during two developmental stages: early childhood and early adolescence. In Figure 1, D represents the demographic background variables, which are time invariant (for example, age upon the entry of kindergarten, gender, and race). C₀ and C₅ represent all the time-varying covariates measured at kindergarten entry and fifth grade (for example, family structure, number of siblings, etc.). NC₀ and NC₅ are
non-cognitive skills measured at kindergarten entry and fifth grade, respectively. SES\textsubscript{1} and SES\textsubscript{8} are family SES measured at first grade and eighth grade. Y\textsubscript{8} is children’s math or reading achievement in early adolescence, measured at 8\textsuperscript{th} grade. As shown in the graph, this study focuses on two developmental stages: (1) early childhood, here specified as the period around kindergarten to first grade, and (2) early adolescence, here specified as the period from around fifth to eighth grade.

**Figure 1.** Conceptual Framework: Causal Relationship between Pre-treatment time-invariant Covariates, Time-Varying Treatments, Moderators, Confounders, and Outcome: Selection on Prior Confounders and Potential Moderators

Note: (1) \(SES\textsubscript{1}\) and \(SES\textsubscript{8}\) are family SES at two time points (1\textsuperscript{st} Grade and 8\textsuperscript{th} Grade). (2) Y\textsubscript{8} is students’ achievement in 8\textsuperscript{th} Grade. (3) C\textsubscript{0} and C\textsubscript{5} are pre-SES time-varying confounders at Kindergarten and 5\textsuperscript{th} Grade respectively. (4) \(NC\textsubscript{0}\) and \(NC\textsubscript{5}\) are non-cognitive skills measured at kindergarten entry and fifth grade and are focal prior SES moderators. (5) \(U\textsubscript{a}\) and \(U\textsubscript{b}\) represents unobserved factors. (6) D are the time-invariant demographic and background covariates.

To analyze the moderated effects of SES by non-cognitive skills, we first need to estimate SES’s effects on achievement. Borrowing the framework of potential outcomes (Holland 1986; Rubin 1974) and treating SES as a treatment, I define SES’s effects on achievement as the direct effects and the focal interest to this study is thus the moderated direct
effects. The direct effect refers to the changes in achievement that is directly affected by any changes in family SES and not mediated by other covariates. Thus, the direct effects of early-childhood SES on achievement is formally defined as: \( DE_{SES_1} = E(Y(ses_1, ses_8) - Y(ses_1^*, ses_8)) \). The direct effects of early-adolescence SES on achievement is formally defined as: \( DE_{SES_8} = E(Y(ses_1, ses_8^*) - Y(ses_1, ses_8)) \). (Sobel 2008; Wang and Sobel 2013) In the equations, \( SES_1 \) and \( SES_8 \) denote children’s family SES measured at first 1st grade and 8th grade respectively. \( Y \) is the early-adolescence achievement measured at 8th grade. The direct effects of early childhood family SES (\( DE_{SES_1} \)) tell us how 8th grade achievement changes if we change family SES in a child’s early childhood (\( SES_1 \)) from \( ses_1 \) to \( ses_1^* \) without changing the child’s family SES during early adolescence. Similarly the direct effects of \( SES_8 \) (\( DE_{SES_8} \)) tell us how 8th grade achievement changes if we change family SES from \( ses_8 \) to \( ses_8^* \) during a child’s adolescence without changing his/her family SES in early childhood.

The focal interest to this study is two sets of moderated direct causal effects: one is during early childhood, and the other is during early adolescence. I incorporate them into the previously defined direct effects and formally define the two sets of moderated effects as below:

\[
\mu_1(NC_0, SES_1) = E(Y(ses_1, ses_8) - Y(ses_1^*, ses_8)|NC_0) \quad (1)
\]

\[
\mu_2(NC_5(SES_1), SES_8) = E(Y(ses_1, ses_8^*) - Y(ses_1, ses_8)|NC_0, SES_1, NC_5(SES_1)) \quad (2)
\]

In Equation (1), \( NC_0 \) is the non-cognitive skills measured at kindergarten fall, which is the baseline of this survey. This equation defines the focal effects during early childhood. Specifically, it gives the direct effect of early childhood family SES on 8th grade’s achievement within subgroups of prior non-cognitive skills (\( NC_0 \)) at kindergarten-entry. In other words, this equation summarizes the achievement changes in 8th grade if we change a child family SES in early childhood from \( ses_1 \) to \( ses_1^* \) without changing his/her family SES during early adolescence, and how such changes in achievement vary among children with different non-cognitive skills.

The second equation summarizes the focal effects during adolescence. It estimates the direct effect of family SES in early adolescence on achievement within levels of previous non-cognitive skills at 5th grade (\( NC_5(SES_1) \)). \( \mu_2 \) captures the achievement changes in early adolescence if we change children’s family SES from during their adolescence from \( ses_8 \) to \( ses_8^* \) without changing their family SES in early childhood, and how such difference depend on
children’s earlier non-cognitive skills measured at 5th grade ($NC_5$). As I have discussed earlier, non-cognitive skills can be influenced by previous family SES. Thus, in Equation (2), non-cognitive skills is expressed as a function of $SES_1$ by $NC_5(SES_1)$.

I further use linear function to parameterize the two sets of direct and moderated direct effects discussed above.

```
Early Childhood:
\[
\mu_1(NC_0, SES_1) = SES_1 \cdot (\gamma_0 + \gamma_1 NC_0) = \gamma_0 SES_1 + \gamma_1 NC_0 \cdot SES_1 \quad (3)
\]

Early Adolescence:
\[
\mu_2(NC_5(SES_1), SES_8) = SES_8(\gamma_3 + \gamma_4 NC_5(SES_1)) = \gamma_3 SES_8 + \gamma_4 NC_5(SES_1) \cdot SES_8 \quad (4)
\]
```

In these equations, $\gamma_0$ and $\gamma_3$ are the average direct effect of family SES on achievement in early childhood (1st grade) and early adolescence (8th grade) respectively if $NC_5$ and $NC_8$ have value of mean zero. $\gamma_1$ and $\gamma_4$ are the parameters with key interest as they represent whether and how non-cognitive skills would moderate family SES’s effects on achievement during the two focal developmental stages. Specifically, if $\gamma_1 = 0$ (or $\gamma_4 = 0$), it means non-cognitive skills do not moderate family SES’s effects on later achievement during early childhood (early adolescence). If $\gamma_1 > 0$ (or $\gamma_4 > 0$), it means non-cognitive skills magnify family SES’s effects on achievement during early childhood (early adolescence). If $\gamma_1 < 0$ or ($\gamma_4 < 0$), it suggests non-cognitive skills reduce family SES’s effects on achievement during early childhood (early adolescence).

**Model Specification and Problems of Conventional Methods in a Longitudinal Setting**

To address the conceptual question described in Figure 1 by a linear model, the conventional regression method would be to estimate model (5).

\[
E(Y_8|NC_0, SES_1, NC_5, SES_8, C_0, C_5, D) = \beta_0 + \beta_1 NC_0 + (\beta_2 + \beta_3 NC_0)SES_1 + \beta_4 NC_5 + \overbrace{\frac{(\beta_5 + \beta_6 NC_5)SES_8 + C_0 + C_5 + D}{}^{\mu_1}} \quad (5)
\]
In the equation, \( NC_0 \) and \( NC_5 \) are time-varying non-cognitive skills, which are potential moderators of family SES effects on achievement, measured at kindergarten entry and 5th grade. \( C_0 \) and \( C_5 \) are time-varying demographic control variables such as parents’ marital status, employment and so on. \( D \) is the time-invariant demographic control variables such as race, gender and so on. \( SES_1 \) is family SES in early childhood (measured at first grade), and \( SES_8 \) is family SES in early adolescence (measured at 8th grade). \((\beta_2 + \beta_3 NC_0)SES_1\) and \((\beta_5 + \beta_6 NC_5)SES_8\) correspond to previously defined \( \mu_1 \) and \( \mu_2 \) (Equation (3) and (4)). Thus, \( \beta_2 \) and \( \beta_5 \) are the average direct effects of family SES during two developmental stages. \( \beta_3 \) and \( \beta_6 \) measure how family SES effects on achievement vary for children with different prior non-cognitive skills.

However, by directly conditioning on time-varying variables such as non-cognitive skills, estimates provided in this conventional regression model are biased for causal interpretation for two reasons (Figure 2). First, it gives rise to the problem of over-control of intermediate pathways. As discussed earlier, non-cognitive skills during adolescence (\( NC_5 \)) is an intermediate variable as it is influenced by previous family SES in early childhood and can mediate its effects on achievement. Thus the part of \( \mu_1 \) in Equation (5), which involving parameters \( \beta_2 \) and \( \beta_3 \), fail to capture the effect of early childhood family SES (\( SES_1 \)) on young adolescence achievement (\( Y_8 \)) that operates through children’s non-cognitive skills during early adolescence (\( NC_5 \)). This violates the prior definition of the direct and moderated direct effects of family SES, and fails to answer the focal research question of this study. Second, conditioning on \( NC_5 \) also introduces the collider-stratification bias. As shown in Figure 2, conditioning on \( NC_5 \) induces an association between prior early childhood family SES (\( SES_1 \)) and unobserved determinants of \( Y_8 \), which yields biased estimates (Elwert and Winship 2014; Greenland 2003; Pearl 1995, 2003).

Similar problems arise with directly controlling for other non-focal time-varying covariates such as parents’ employment status, family structure, marital status, and so on. As illustrated by Figure 2, these characteristics (e.g. \( C_5 \)) are affected by previous family SES (e.g. \( SES_1 \)) and can mediate its effects on later achievement. Moreover, these covariates can also confound future family SES’s effects on achievement as they may affect family’s SES in the future (e.g. \( C_5 \) confounds \( SES_8 \)’s effects on achievement). Thus, by including those variables directly into the conventional regression model will introduce problems such as over-control and collider bias as well.
Figure 2. Problems with Conventional Regression: Over-control and Collider Stratification from Conditioning on Time-varying Confounders and Moderators

Note: (1) $SES_1$ and $SES_8$ are family SES at two time points (1st Grade and 8th Grade). (2) $Y_8$ is students’ achievement in 8th Grade. (3) $C_0$ and $C_5$ are pre-SES time-varying confounders at Kindergarten and 5th Grade respectively. (4) $NC_0$ and $NC_5$ are non-cognitive skills measured at kindergarten entry and fifth grade and are focal prior SES moderators. (5) $U_a$ and $U_b$ represents unobserved factors.

In sum, these complicated methodological issues pose challenge to separate out how non-cognitive skills moderate family SES’s effects on achievement in a longitudinal setting. Thus, to answer the questions in this study, alternative methods are necessary.

**Estimation with Structural Nested Mean Model**

I use Structure Nested Mean Model (SNMM) to tackle both methodological problems raised above. To illustrate how SNMM can help to overcome the problems of over control and collider bias in the longitudinal setting, I will use the focal variable of non-cognitive skills as an example. In general, SNMM formally relates $\mu_1(NC_0, SES_1)$ and $\mu_2(NC_5(SES_1), SES_8)$ to the conditional mean of the potential outcomes (Robins 1994), which is important to estimating these effects in the regression context. It decomposes the conditional expectation of the outcomes...
into several additive terms including the moderated family SES’s effects, $\mu_1, \mu_2$ (as defined earlier by Equation (3) and (4)), and a set of “nuisance” functions which capture the association, both causal and non-causal, of the moderators with the outcome (Almirall et al. 2013; Almirall, Ten Have, and Murphy 2010; Robins 1994, 1999, 2000; Wodtke, Geoffrey T., Felix Elwert n.d.).

In the form of an equation, SNMM is summarized by equation (6)

$$E(Y_8(SES_1, SES_8)|NC_0, NC_5(SES_1)) = \beta_0 + \epsilon_1(NC_0) + \mu_1(NC_0, SES_1) + \epsilon_2(NC_0, SES_1, NC_5(SES_1)) + \mu_2(NC_5(SES_1), SES_8) \quad (6)$$

$$\epsilon_1(NC_0) = E(Y_8(0,0)|NC_0) - E(Y_8(0,0)) \quad (7)$$

$$\epsilon_2(NC_0, SES_1, NC_5(SES_1)) = E(Y_8(SES_1, 0)|NC_0, NC_5(SES_1)) - E(Y_8(SES_1, 0)|NC_0) \quad (8)$$

In Equation (6), the intercept $\beta_0 = E(Y_8(0,0))$ is the grand mean of achievement with family SES in early childhood and early adolescence equal to zero, which is the reference value. Functions of $\mu_1(NC_0, SES_1)$ and $\mu_2(NC_5(SES_1), SES_8)$, defined as Equation (3) and (4), capture the direct and the focal moderated direct causal effects. $\epsilon_1(NC_0)$, defined by Equation (7), is the association between early childhood non-cognitive skills ($NC_0$) and the achievement in 8th grade, had the child spent both his/her early childhood and adolescence in a family with SES equal to 0. $\epsilon_2(NC_0, SES_1, NC_5(SES_1))$, as defined by Equation (8), is the association between early adolescence non-cognitive skills ($NC_5$) and achievement at 8th grade had the children with non-cognitive skills $NC_5(SES_1)$ spent early childhood in a family with SES equal to $SES_1$ and then early adolescence in a family with SES equal to 0.

In the Structure Nested Mean Model, the functions of $\epsilon_1$ and $\epsilon_2$ are designed to capture the associational effects of the intermediate time-varying variables (e.g. non-cognitive skills) on the final outcome (e.g. 8th grade achievement), which are not the focal interest of the study, and are thus called “nuisance” functions. Intuitively, replacing the time-varying variables by the nuisance functions in the model will break the linkage between prior treatment (e.g. $SES_1$) and following intermediate variable (e.g. $NC_5$) (as shown in Figure 2 and Figure 3), and thus solve the problem of over-control and collider bias by directly conditioning on these variables (e.g. $NC_5$).
Implementing SNMM in regression involves two stage of regression analysis, which is also termed as Regression-with-Residuals (RWR) (Almirall et al. 2013, 2010). In the first stage of regression, we model each of the time-varying covariates conditional on the observed past and obtain the estimated residuals, which are the nuisance functions. For instance, I regress the non-cognitive skills in early childhood on itself, and non-cognitive skills in adolescence on prior family SES and non-cognitive skills in early childhood (Equation (9)-(10)). Based on the regression, I obtain the residuals (Equation (11)-(12)). The residuals are the nuisance parts to be included in the SNMM.

\[
E(NC_0) = \alpha_0 \quad (9)
\]

\[
E(NC_5|NC_0, SES_1) = \gamma_0 + \gamma_1 NC_0 + \gamma_2 SES_1 \quad (10)
\]

Note: (1) \(SES_1\) and \(SES_8\) are family SES at two time points (1st Grade and 8th Grade). (2) \(Y_8\) is students’ achievement in 8th Grade. (3) \(C_0\) and \(C_5\) are pre-SES time-varying confounders at Kindergarten and 5th Grade respectively. \(NC_0\) and \(NC_5\) are non-cognitive skills measured at kindergarten entry and fifth grade and are focal prior SES moderators. (4) \(\delta(C_5) = C_5 - E[C_5|C_0, SES_1, NC_0]\). (5) \(NC_0\) is prior treatment moderator at kindergarten, \(\delta(NC_5) = NC_5 - E[NC_5|NC_0, SES_1, C_0]\). (6) \(U_a\) and \(U_b\) represent unobserved factors.
Children's Non-Cognitive Skills and the Effects of Family SES on Academic Achievement

\[ NC_0^r = NC_0 - \hat{E}(NC_0) \] (11)

\[ NC_5^r = NC_5 - \hat{E}(NC_5) \] (12)

The second stage is to regress the final outcome of achievement on two family SES measurements, interactions between non-cognitive skills and family SES, and the residualized non-cognitive skills to obtain the estimates. The model is specified following Equation (6). That is, I estimate a model as below:

\[
E(Y_8|NC_0, SES_1, NC_5, SES_8) = \beta_0 + \eta_1 NC_0^r + \beta_1 SES_1 + \beta_2 SES_1 \ast NC_0 + \eta_2 NC_5^r \\
+ \beta_3 SES_8 + \beta_4 SES_8 \ast NC_5
\] (13)

The \( \beta_k \) coefficients in Equation (9) are the estimated average direct effects of family SES on achievement and how these effects are moderated by children’s non-cognitive skills in two developmental stages respectively. The \( \eta_k \) coefficients represent the association between non-cognitive skills and the final outcome of the achievement in early adolescence. Different from conventional regression methods (Equation (5)), this two-stage Regression-with-Residual (RWR) replaces non-cognitive skills \( (NC_k) \) with the residualized non-cognitive skills \( (NC_k^r) \). The residualized non-cognitive skills \( (NC_k^r) \) serve as the nuisance functions in the SNMM. It breaks down the pathway between non-cognitive skills and previous family SES, thus eliminate the problem of over-control and collider bias.

I use RWR in this study to overcome the methodological problems raised by conditioning on time-varying variables. To better deal with other non-focal time-varying covariates, I use the approach of Covariate-Adjusted Regression-with-Residuals (CA-RWR) introduced by Wodtke and Almirall’s recent work (2015). Specifically, in the first stage, I estimate the residuals of focal variable of non-cognitive skills and all other non-focal time-varying covariates or confounders by Equation (14) to (21).

\[ E(NC_0) = \alpha_0 \] (14)

\[ E(C_0) = \alpha_1 \] (15)

\[
E(NC_5|C_0, NC_0, SES_1) = \gamma_0 + \gamma_1 C_0 + \gamma_2 NC_0 + \gamma_3 SES_1
\] (16)
Children’s Non-Cognitive Skills and the Effects of Family SES on Academic Achievement

\[ E(C_5|C_0, NC_0, SES_1) = \eta_0 + \eta_1 C_0 + \eta_2 NC_0 + \eta_3 SES_1 \]  
(17)

\[ \delta(NC_0) = NC_0 - \hat{E}(NC_0) \]  
(18)

\[ \delta(C_0) = C_0 - \hat{E}(C_0) \]  
(19)

\[ \delta(NC_5) = NC_5 - \hat{E}(NC_5|C_0, NC_0, SES_1) \]  
(20)

\[ \delta(C_5) = C_5 - \hat{E}(C_5|C_0, NC_0, SES_1) \]  
(21)

In the second stage, I estimate the SNMM specified as Equation (22).

\[ E(Y_8|NC_0, C_0, SES_1, NC_5, C_5, SES_8) = \beta_0 + \eta_1 \delta(NC_0) + \beta_1 SES_1 + \beta_2 SES_1 * NC_0 + \eta_2 \delta(NC_5) + \beta_3 SES_8 + \beta_4 SES_8 \]  
\[ * NC_5 + \beta_5 \delta(C_0) + \beta_6 SES_1 * NC_0 + \beta_7 \delta(C_5) + \beta_8 SES_8 * C_5 \]  
(22)

There are three assumptions to estimate the SNMM model with observed data (Almirall et al. 2010; Robins 1994; Wodtke, Geoffrey T., Felix Elwert n.d.). The first is that the mean of “nuisance” function equal to zero, conditional on the past. This assumption is about the specification of the nuisance functions. To test the robustness of the results, I tried extensive specifications of the nuisance functions in the sensitivity analysis. The second assumption is consistency. Specifically, it states that the observed outcome is consistent with one of the conceptualized potential outcomes. The third assumption is sequential ignorability. It states that: \( Y_6(SES_1, SES_8) \perp SES_1|NC_0 \) and \( Y_6(SES_1, SES_8) \perp SES_8|NC_0, SES_1, NC_5 \). In words, it assumes that at each time point, there exist no unobserved variables that directly affect selection into different family SES and the outcome achievement, other than prior measured covariates and prior family SES, as shown in Figure 2.

Though sequential ignorability is met by design in experimental studies, where treatment can be randomly assigned at each time point, it requires data on all the potential predictors of family SES and achievement to satisfy in an observation study like this. I thus conduct a sensitivity analysis to assess how the potential violations of these this assumption may change the results and present the results in the appendix.
DATA AND MEASURES

To assess my research questions, I use data from Early Childhood Longitudinal Studies, Kindergarten Class of 1998-99 (ECLS-K), a nationally representative study designed to assess social-group differences in U.S. children’s social-emotional and cognitive development. The survey, conducted by the National Center for Education Statistics (NCES), used a three-stage stratified sampling procedure in following a group of selected children from school entry through 8th grade. Data were collected from children and their families, teachers, and schools on children's cognitive, social, emotional, and physical development. In addition, information was included on children's home environment, home educational activities, school environment, classroom environment, classroom curriculum, and teacher qualifications. The analytic sample in this article is restricted to children who took the assessment of math or reading ability in 8th grade. This yields a sample of 9224 for children who were assessed via a math test, and 9165 for children who were assessed via a reading test.

Table 2 summarizes the descriptive statistics for the variables used in this study. The dependent variable is achievement measured by children’s math and reading test scores in 8th grade, when they were around 13-14 years old. I used the standardized math and reading scores provided by ECLS-K. These standardized scores measure how children did in terms of mathematic or reading ability compared with their peers. The standardized score has a mean of 50 and a standard deviation around 10.

Time-Varying Covariates

Family SES is measured with an index constructed by NCES. This is a composite measurement based on mother and father’s education, occupations, and family income, with each component equally weighted. It is further standardized with a mean of 0 and a standard deviation of 1 across the sample being surveyed (NCES 2002). In this study, I use family SES when children were in first grade to measure SES in early childhood and family SES in 8th grade to measure SES in early adolescence. I choose using a composite measurement of SES over using several separate measurements on multiple dimensions of family’s SES because the composite measurement facilitates the quantitative analysis of how non-cognitive skills may moderate SES’s effects on achievement.

If we use several measurements on different aspects of family SES, it will make the model and computation very complicated as there will be interaction between each of these aspects and the non-cognitive skills, as well as the interactions between each of these aspects with other time-varying covariates.
### Table 2. Descriptive Statistics of Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
<th>% Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time-invariant Covariates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Months upon Entry of Kindergarten</td>
<td>68.48</td>
<td>4.36</td>
<td>8.63</td>
</tr>
<tr>
<td>Gender</td>
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<td>0.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Race</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>0.10</td>
<td>0.31</td>
<td>0.18</td>
</tr>
<tr>
<td>Hispanic</td>
<td>0.17</td>
<td>0.38</td>
<td>0.18</td>
</tr>
<tr>
<td>Asian</td>
<td>0.06</td>
<td>0.23</td>
<td>0.18</td>
</tr>
<tr>
<td>Other</td>
<td>0.05</td>
<td>0.22</td>
<td>0.18</td>
</tr>
<tr>
<td>Multi-kindergarten (=1)</td>
<td>0.15</td>
<td>0.36</td>
<td>0.08</td>
</tr>
<tr>
<td><strong>Immigration Generation (Native as the Reference Group)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st Generation</td>
<td>0.01</td>
<td>0.07</td>
<td>1.70</td>
</tr>
<tr>
<td>2nd Generation</td>
<td>0.25</td>
<td>0.44</td>
<td>1.70</td>
</tr>
<tr>
<td><strong>Language Spoken at Home</strong></td>
<td>0.87</td>
<td>0.34</td>
<td>3.28</td>
</tr>
<tr>
<td><strong>Mother's Age at Birth</strong></td>
<td>29.36</td>
<td>5.75</td>
<td>14.07</td>
</tr>
<tr>
<td><strong>Mother's Marital Status at Birth</strong></td>
<td>0.76</td>
<td>0.43</td>
<td>4.11</td>
</tr>
<tr>
<td><strong>Time-Varying Covariates</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Early Childhood</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Siblings</td>
<td>1.46</td>
<td>1.15</td>
<td>11.97</td>
</tr>
<tr>
<td>Intact Family (=1)</td>
<td>0.81</td>
<td>0.39</td>
<td>11.97</td>
</tr>
<tr>
<td>Mother is Fulltime Employed (=1)</td>
<td>0.46</td>
<td>0.50</td>
<td>13.78</td>
</tr>
<tr>
<td>Father is Fulltime Employed (=1)</td>
<td>0.92</td>
<td>0.28</td>
<td>27.40</td>
</tr>
<tr>
<td>Marital Status of Resident Parent(s)</td>
<td>0.77</td>
<td>0.42</td>
<td>4.70</td>
</tr>
<tr>
<td>Children's Non-cognitive Skills (Standardized)</td>
<td>0.12</td>
<td>0.96</td>
<td>8.89</td>
</tr>
<tr>
<td>Family SES at First Grade</td>
<td>0.08</td>
<td>0.81</td>
<td>5.30</td>
</tr>
<tr>
<td><strong>Early Adolescence</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Siblings</td>
<td>1.55</td>
<td>1.13</td>
<td>7.21</td>
</tr>
<tr>
<td>Intact Family (=1)</td>
<td>0.78</td>
<td>0.41</td>
<td>3.84</td>
</tr>
<tr>
<td>Mother is Fulltime Employed (=1)</td>
<td>0.51</td>
<td>0.50</td>
<td>6.86</td>
</tr>
<tr>
<td>Father is Fulltime Employed (=1)</td>
<td>0.89</td>
<td>0.31</td>
<td>22.53</td>
</tr>
<tr>
<td>Marital Status of Resident Parent(s)</td>
<td>0.75</td>
<td>0.43</td>
<td>3.91</td>
</tr>
<tr>
<td>Children's Non-cognitive Skills (Standardized)</td>
<td>0.04</td>
<td>0.99</td>
<td>8.42</td>
</tr>
<tr>
<td>Family SES at 8th Grade</td>
<td>0.00</td>
<td>0.80</td>
<td>9.74</td>
</tr>
<tr>
<td><strong>Math Test Score (Standardized)</strong></td>
<td>51.46752</td>
<td>9.645363</td>
<td>0.14</td>
</tr>
<tr>
<td><strong>Reading Test Score (Standardized)</strong></td>
<td>51.5744</td>
<td>9.81092</td>
<td>0.78</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>9237</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Non-cognitive skills, of focal interest in this study, are constructed from the ECLS-K Social Rating Scales (SRS) as provided by the children’s teachers. This scale is adapted from the Social Skills Rating System (Gresham and Elliott 1990). At each wave of the survey, teachers were asked to use a frequency scale to report how often students exhibit a certain social skill or behavior (1 = never to 4 = very often), from which the ECLS constructed five SRS scales: Approaches to Learning, Self-Control, Interpersonal Skills, Externalizing Problem Behaviors, and Internalizing Problem Behaviors. In this analysis, non-cognitive skills are measured using an unweighted averaged composite of scales for Approaches to Learning, Self-Control, and Interpersonal Skills that is standardized across the analytical sample at each time point to ease interpretation. Specifically, this standardized composite measurement measures children’s behaviors and traits such as attentiveness, persistence, organization, ability to control behaviors, and skills in expressing emotions, forming and maintaining a good relationship with others.

Early childhood non-cognitive skills are those measured at entry to kindergarten, and early adolescence non-cognitive skills are measured at 5th grade by the survey.

Other time varying covariates include: number of siblings, intact family (living with both parents = 1), mother is full-time employed (=1), father is full-time employed (=1), marital status of resident parents (married=1). As discussed above, these time-varying covariates are not the main focus of the current study, but I include them in my models because they may work as time-varying confounders in the relationship between family SES, non-cognitive skills, and achievement.

**Time-Invariant Covariates**

As shown in Table 2, I also include demographic and other background information as time-invariant control variables. These include: child’s age in months when they entered kindergarten, gender (female = 1), race, whether the child is a second time kindergartener (second time = 1), immigrant generation (native =0 as the reference), language spoken at home (Non-English = 1), mother’s age at birth, mother’s marital status at birth (married = 0).

---

4 There are 24 items in total for SRS in kindergarten and first grade waves, and 26 items in third grade and fifth grade wave.

5 I conduct a Confirmatory Factor Analysis to examine the validity of such construct. The RMSEA for the model is 0.063 (with a 90% confidence interval 0.061 to 0.064), and the CFI is 0.962. Conventionally, a RMSEA less than 0.1 and CFI greater than 0.9 suggest a well fitted model.

6 A more detailed description of the constructed non-cognitive skills measurement is available in Appendix C.
Missing values are assumed to be missing at random (Allison 2002; Little and Rubin 2014). The magnitude of missing values differed across variables in the same wave as well as across waves for the same variable, and Table 1 presents the observations and missing patterns of the sample. I use multiple imputation strategy\(^7\) to deal with the missing covariates. Five data sets were imputed, using all the covariates in the analysis\(^8\). The results presented in the main text are based on the analysis on one of the five computed dataset.

**ANALYSIS AND RESULTS**

**Descriptive Statistics**

Table 2 presents the descriptive statistics of all the variables used in this study. Figure 4 shows the descriptive relationship between family SES and achievement by children’s non-cognitive skills during two developmental stages: early childhood (left part) and early adolescence (right part). This graph is plotted based on the observed data without any controls, and non-cognitive skills are categorized into three groups: high, medium and low. Specifically, the upper left graph depicts the relationship between family SES and mathematic achievement in 8\(^{th}\) grade (which is the outcome variable in this study) by children’s non-cognitive skills in early childhood; the bottom left graph depicts the relationship between family SES and reading achievement in 8\(^{th}\) grade by non-cognitive skills in early childhood; the upper right graph depicts the relationship between family SES and mathematic achievement by non-cognitive skills in early adolescence; and the right bottom graph depicts the relationship between family SES and reading achievement by non-cognitive skills in early adolescence. As we can tell from these four graphs, the relationship between family SES and achievement differs across children with different levels of non-cognitive skills. As is suggested by the variation in the slope of the line, the relationship between family SES and achievement is weaker among children with higher non-cognitive skills, and this is true for both mathematic and reading achievement and during both developmental stages of early childhood and early adolescence.

\(^7\) I use the ICE command in STATA (Royston, 2007) to deal with the imputation.

\(^8\) As will be discussed later in the sensitivity analysis, I repeat the analysis over all the five imputed data sets, the results are consistent and stable, with only slight difference in the estimates. I am thus presenting one sets of the results in the main text here.
**Figure 4.** Family SES and Achievement by Non-cognitive Skills in Two Developmental Stages

![Graph showing the relationship between Family SES and Achievement in early childhood and early adolescence.](Image)

Note: (1) NS is short for non-cognitive skills. (2) Loess smoothed curve is used.

**Non-cognitive Skills as a Mediator**

Table 3 describes how non-cognitive skills serve as a mediator of previous family SES’s effects on achievement. The results come from traditional regression method. In Model A and B, the outcome is mathematic test scores at 8th grade. Model A is the regression model with all the control variables but non-cognitive skills at 5th grade, and Model B is the full model with the non-cognitive skills at 5th grade. Model C and D is specified similarly to the first two models, but with the outcome as the reading test scores at 8th grade. As is suggested by the results, after including non-cognitive skills, family SES’s effects on math and reading achievement decrease.
This suggest that non-cognitive skills at 5\textsuperscript{th} grade is a mediator of 1\textsuperscript{st} grade family SES’s effects on achievement. Thus, as discussed in method section, traditional regression methods will unable to answer the question that whether and how non-cognitive skills will moderate family SES’s effects on achievement during adolescent, or how non-cognitive skills at 5\textsuperscript{th} grade will moderate 8\textsuperscript{th} grade family SES’s effects on achievement. Thus, I analyze the moderated effects of family SES by using Structural Nested Mean Model (SNMM). The results and the discussion are presented in the following section.

**Moderated Family SES’s effects by SNMM**

*Mathematic Achievement*

Table 4 presents the results from the SNMM, or regression-with-residual model. The coefficients before family SES represent the direct effects of family SES on 8\textsuperscript{th} grade achievement during either early childhood or early adolescence. The interaction term between family SES and non-cognitive skills tell whether and how family SES’s effects on achievement are moderated by non-cognitive skills within each of the two focal developmental stages.

Model 1 in Table 4 presents the estimates from the analysis with mathematic achievement as the outcome. As is shown, early-childhood family SES has a significant positive direct effect on later mathematic achievement in early adolescence, holding early-adolescence family SES constant. One standard deviation increase in early-childhood family SES increases later achievement in mathematics by 1.27 points.

Moreover, the significant coefficient before the interaction between family SES and non-cognitive skills during early childhood suggest that family SES effects vary across children with different prior non-cognitive skills. Specifically, as the interaction is negative ($\beta = -0.23$, $p<0.05$), it means that higher non-cognitive skills can substantially reduce the effects of family SES on achievement during this developmental period. One standard deviation increase in non-cognitive skills could lower family SES effects by 0.23 point, or around 18 percent of the total family SES effect. Figure 5 (a) shows the moderated early-childhood family SES effects in a graph. As we can tell from the graph, early-childhood SES effects on later math achievement decrease as children’s non-cognitive skills increase.
### Table 3. Family SES, Non-Cognitive Skills and Achievement in Early Adolescence

<table>
<thead>
<tr>
<th>Model</th>
<th>Mathematic Test Score (8th Grade)</th>
<th>Reading Test Score (8th Grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>Coef</td>
<td>Sig</td>
</tr>
<tr>
<td>Intercept</td>
<td>42.17</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>(1.75)</td>
<td></td>
</tr>
<tr>
<td>Family SES (1st Grade)</td>
<td>3.44</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>Non-Cognitive Skills (5th Grade)</td>
<td>2.08</td>
<td>***</td>
</tr>
<tr>
<td></td>
<td>(0.09)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>9224</td>
<td>9224</td>
</tr>
<tr>
<td>R^2</td>
<td>0.262</td>
<td>0.301</td>
</tr>
</tbody>
</table>

Notes: ~p<0.10, *p<0.05, **p<0.01, and ***p<0.001

### Table 4. Moderated Direct Effects of Family SES on 8th Grade Achievement by SNMM in Two Developmental Stages

<table>
<thead>
<tr>
<th>Model</th>
<th>Model 1: Mathematic Test Score</th>
<th>Model 2: Reading Test Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
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<tr>
<td>Intercept</td>
<td>50.75</td>
<td>1.56</td>
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<tr>
<td><strong>Early Childhood</strong></td>
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</tr>
<tr>
<td>Family SES</td>
<td>1.27</td>
<td>0.46</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.23</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Early Adolescence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family SES</td>
<td>2.79</td>
<td>0.43</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.42</td>
<td>0.43</td>
</tr>
<tr>
<td>N</td>
<td>9224</td>
<td>9165</td>
</tr>
</tbody>
</table>

Notes: Standard errors are based on 250 bootstrap samples. ~p<0.10, *p<0.05, **p<0.01, and ***p<0.001
For children with non-cognitive skills 3 standard deviations below the mean, a one standard deviation increase in family SES will improve the later mathematic achievement by around 1.96 points. In contrast, for children with non-cognitive skills 3 standard deviations above the mean, a one standard deviation increase in early-childhood family SES will improve later mathematic achievement by only 0.58 points. In sum, in the period of early-childhood, non-cognitive skills substantially weaken family SES’s effects on later mathematic achievement.

During the period of early adolescence, family SES effects on achievement are also significantly positive. As suggested by the lower part in Model 1, Table 4, a one standard deviation increase in family SES during this period will improve achievement in math by 2.79 points. Compared with the magnitude of the effects of early-childhood family SES, early-adolescence family SES effects on achievement in early adolescence are slightly greater.

In addition, the effects of family SES on later mathematic achievement depend on non-cognitive skills during this developmental period as well. The negative and significant coefficient of the interaction term in the model suggests that family SES effects are greater for children with lower non-cognitive skills and smaller for those with higher non-cognitive skills. In particular, a one standard deviation improvement in non-cognitive skills will reduce family SES effects on achievement by 0.42 points. Figure 5 (b) visualizes this moderated SES effect during early adolescence.

**Reading Achievement**

Model 2 in Table 4 presents the results for reading achievement, and the results are similar to those for mathematic achievement. First, during the period of early childhood, family SES effects on later achievement are significantly positive. One standard deviation improvement in family SES is associated with a 2.26 point improvement in reading achievement, holding family SES in early adolescence constant. Moreover, the coefficient of the interaction between family SES and non-cognitive skills is negative and marginally significant ($\beta=-0.2$, $p<0.1$), implying that non-cognitive skills moderate family SES effects on reading achievement in this developmental period. I use Figure 5 (c) to visualize the moderated SES effects. As non-cognitive skills increase, the effects of early-childhood family SES on reading achievement decrease.
Second, during the period of early adolescence, family SES effects on reading achievement are also positive and significant: one standard deviation increase in family SES will result in a 2.6 point increase in reading achievement. Again, the size of SES effects varies by children’s non-cognitive skills, and the reading achievement of children with higher non-cognitive skills is less impacted by their family SES (Figure 5 (d)).

In sum, during both developmental periods of early childhood and early adolescence, family SES affects math and reading achievement positively, while at the same time, non-cognitive skills moderate family SES effects, such that family SES’s effects on achievement are weaker among children with higher non-cognitive skills.
Sensitivity Analysis

As mentioned earlier, the results from the SNMM are valid and unbiased if (1) the model specification (nuisance and the causal model) of the SNMM are correct (2) there are no unobserved confounding variables that will influence family SES and achievement at the same time. These two assumptions are strong, and failure to meet them may render the estimates and inference invalid. Thus, I conduct further sensitivity analyses to test the robustness of the reported results. Results from sensitivity analyses are included in the appendix.

First, I focused on the assumptions on the model specifications. Specifically, I experimented with a variety of model specifications for both the causal model and nuisance functions. Details are discussed in Appendix A with Table A1 summarizing the results. Results from these models suggest that the reported estimates are robust.

Second, I conducted sensitivity analyses to check for the assumptions of unobserved confounders. To test how the robustness of the results are influenced by the unobserved confounding variables affecting both family SES and the achievement in early adolescence, I measure and include an extensive set of confounders in the analysis. Moreover, I also formally investigated the robustness of the results to hypothetical unobserved confounding. I discussed details about this formal analysis in Appendix B. In short, the current results hold even when the confounding measures are very large.

Third, I explored the importance of missing data. To assess the sensitivity of the results to the missing data, I constructed 5 data sets by different multiple imputation, and replicate the main analysis over all the five imputed data sets. I also tested the models by using other strategies such as the list wise deletion method. The results from these analyses follow similar patterns to the ones presented in this paper, and only differ very slightly in the coefficient estimates. These analyses\(^9\) indicate that results presented in the main text are stable under different procedures for handling missing data.

\(^9\) Available upon request.
DISCUSSION AND CONCLUSION

The connection between family background and children’s educational achievement is a central topic to stratification and education scholarship in sociology and general social sciences. Family SES, an overall summary of family’s socioeconomic characteristics, has long been shown a significant predictor of children’s achievement. Though myriad studies have developed around whether and how family translates its socioeconomic resources into children’s educational achievement, very few studies have carefully investigated whether the effects of family SES on achievement are moderated by children’s evolving non-cognitive skills, or whether the moderation effects vary across children’s developmental stage.

Adopting a longitudinal and developmental perspective, this study asks the above questions and analyzes how family SES effects on educational achievement are moderated by children’s non-cognitive skills during two developmental stages: early childhood and early adolescence. Capitalizing on recent methodological developments, this study yields two major findings. First, consistent with the previous literature, I find that family SES in early childhood and early adolescence both have direct effects on children’s achievement measured in early adolescence. Second, this study further shows that non-cognitive skills can moderate family SES effects on subsequent achievement, an issue less investigated by previous studies. Specifically, during both developmental stages of early childhood and early adolescence, family SES’s effects on achievement are significantly weaker among children with higher non-cognitive skills.

Such moderation effects carry meaningful implications. For instance, they suggest that non-cognitive skills can make up for the disadvantage of having low family socioeconomic resources. However, children from lower SES families are also more likely to be the ones with lower non-cognitive skills (Reardon and Portilla 2011); they therefore suffer a double jeopardy from shortages in both family resources and these skills, which can amplify their academic disadvantage compared to their peers from higher SES families. In addition, as the non-cognitive skills can continuously moderate family SES’s effects on achievement over early childhood and early adolescence, a continuous lower non-cognitive skills will even exacerbate the achievement disadvantage.

These findings indicate the importance and potential benefits of enhancing non-cognitive skills for those seeking to improve low SES children’s achievement and reduce the SES-based
achievement difference. Specifically, the improvement of non-cognitive skills can have “double benefits” as it will not only benefit achievement directly as suggested by previous studies (e.g. Almlund, Heckman, Duckworth, & Kautz, 2011; Duckworth, Tsukayama, & May, 2010; Heckman, 2006), but will also reduce achievement disadvantage due to family background by weakening the effects of SES on achievement. Also, as the significance of non-cognitive skills emerge in one’s early childhood, it will be beneficial to cultivate those skills when a child is still young. All of these carry strong policy implications for efforts to enhance non-cognitive skills especially for children from lower SES background and in their early childhood.

This study contributes to the current literature and expands our understanding of stratification and education in several ways. First, recent findings from across social sciences strongly suggest that non-cognitive skills are critical to children’s development, as they will affect achievement and social outcomes directly (e.g. Almlund, Heckman, Duckworth, & Kautz, 2011; Duckworth & Seligman, 2006; Heckman, 2006). Results from this current study add further evidence to this argument, but also advance our understanding by showing that non-cognitive skills can modify family SES effects on achievement as well.

In addition, results from this study suggest that when we examine how family characteristics influence children’s development, such as educational achievement, we should consider how other characteristics of the child may moderate the effects of family SES. In other words, we should pay closer attention to the potential heterogeneous effects of family characteristics on children’s development, and examine how this will influence the stratification process.

As discussed in this study, to examine the moderation effects in a temporal and developmental setting presents many methodological challenges, most centrally because the moderator itself is a mediator, and it is influenced by another key covariate. Traditional regression methods fail to yield unbiased estimates and new methods are required. In this study, I use Structural Nested Mean Models to overcome the methodological challenges (Almirall et al. 2013, 2010; Wodtke and Almirall 2015). As many questions in the field of child development and stratification have similar framing, the methods and perspective in this article can be applied to other questions. For example, we can ask whether and how children’s non-cognitive skills will moderate school effects on education achievement during different developmental stages. Or, we
could ask whether and how school characteristics will moderate family effects on educational outcomes during different developmental stages.

Although this study expands the current literature on education stratification, it has several limitations. First, though ECLS-K data enables me to study the proposed question in a longitudinal setting, it does not have any information on children’s educational attainment after 8th grade. Thus, I am not able to test whether non-cognitive skills will moderate family SES effects on educational achievement in other periods of development, such as late adolescence or early adulthood, or on other outcomes, such as college graduation or total educational attainment.

Second, the two key factors in this study are children’s non-cognitive skills and family SES. Though I have included many other covariates capturing family characteristics in the analysis, they are not of focal interest. However, as mentioned earlier, family SES effects on achievement can also be moderated by other factors as well. Thus, it would be interesting to examine how other characteristics of children will modify the effects of family socioeconomic resources in the process of education attainment.

Third, I use a composite measurement of family SES to facilitate the examination of the focal question in this study. As family SES is a multi-dimensional concept, including multiple tangible and intangible resources, future studies can delve more into questions like what the specific types of resources’ effects are that non-cognitive skills can moderate.

Despite these limitations, this study provides strong evidence that non-cognitive skills will moderate family SES effects on children’s educational achievement. Specifically, family SES effects on achievement are greater among children with lower non-cognitive skills than among those with higher non-cognitive skills. As children from lower SES families are more likely to lack non-cognitive skills (in addition to lacking material resources associated with SES), this study implies that children from low SES background may suffer from a “double jeopardy” in terms of achievement. However, the findings also strongly suggest that enhancing the non-cognitive skills of low SES children will be of great benefit as it could help to make up the academic disadvantage deriving from disadvantaged family background.
References


Appendix A: Sensitivity Analysis on the Specification of Nuisance Functions

I investigate the sensitivity of the estimates to different specifications of the causal and nuisance functions of the Structural Nested Mean Models (SNMM). The results are presented in Table A1. Model A, B and C are focused on testing the sensitivity over different causal functions, and Model D, E, F are focused on testing on different specification of nuisance functions. W denote for the time-invariant demographic variables presented in Table 2 in the main text (e.g. gender, month upon kindergarten entry, language at home, mother’s age at birth, mother’s marital status at home, whether is second time kindergartener, immigrant status). C0 and C5 represent the time-varying variables in Table 2 and include number of siblings, family composition, mother’s employment status, father’s employment status, parents’ marital status. C0 are these variables measured at kindergarten entry, and C5 are these variables measured at 5th grade.

Model A is the base model, where the focal interaction is only between family SES and non-cognitive skills, and only the main effects of W, C0 and C5 are included. Model B extend Model A by allowing family SES’s effects to vary not only by prior-SES non-cognitive skills, but also other prior time-varying characteristics (C0 and C5). Model C further extend Model B by assuming that not only SES’s effects are moderated by time-varying characteristics and non-cognitive skills, but all the time-invariant variables’ effects vary across these variables. In particular, Model C is the model presented in the main text.

In Model D, the nuisance function is further specified to include the interaction term between the time-invariant variables. In Model E, the nuisance functions further include the interactions between all the variables in C0, which is all the interactions between the variables measured at kindergarten entry. Model F further include the interactions between all the variables in C5, which is all the interactions between variables measured at 5th grade.

As we can tell from all these models, the estimates are invariant and stay quite consistent, which suggests the robustness of the analysis and the results in this study.
Table A1. Two-state estimates with different specifications of SNMM nuisance functions (1)

<table>
<thead>
<tr>
<th>Model</th>
<th></th>
<th>Model</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mathematic Test Score</td>
<td>Reading Test Score</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td>50.91</td>
<td>1.60 ***</td>
</tr>
<tr>
<td><strong>Childhood</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family SES</td>
<td></td>
<td>1.94</td>
<td>0.25 ***</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.22</td>
<td>0.11 ~</td>
<td>-0.20</td>
</tr>
<tr>
<td><strong>Early Adolescence</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family SES</td>
<td></td>
<td>2.37</td>
<td>0.24 ***</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.41</td>
<td>0.11 ***</td>
<td>-0.37</td>
</tr>
<tr>
<td>main effects of W, C0, C5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|                        |          | Model                  |          |
|                        |          | C                      | D        |
|                        |          | Mathematic Test Score  | Reading Test Score | Coef | SE  | Coef | SE  |
|                        |          | Coef | SE                 | Coef | SE  | Coef | SE  |
| Intercept              |          | 50.75 | 1.44 ***            | 43.97 | 1.54 ***|
| **Childhood**          |          |                    |          |
| Family SES             |          | 1.27 | 0.46 **             | 2.26 | 0.45 ***|
| Family SES # Non-Cognitive Skills | -0.23 | 0.12 ~ | -0.20 | 0.12 ~ |
| **Early Adolescence**  |          |                    |          |
| Family SES             |          | 2.79 | 0.43 ***            | 2.60 | 0.43 ***|
| Family SES # Non-Cognitive Skills | -0.42 | 0.43 *** | -0.37 | 0.12 ***|
| B+ interaction between W and C0, C5 |          |          |
| C+ interaction between elements of W |          |          |
### Table A1. continued

<table>
<thead>
<tr>
<th>Model</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mathematic Test Score</td>
<td>Reading Test Score</td>
</tr>
<tr>
<td></td>
<td>Coef</td>
<td>SE</td>
</tr>
<tr>
<td>Intercept</td>
<td>64.48</td>
<td>10.48 **</td>
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<tr>
<td>Childhood</td>
<td></td>
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<tr>
<td>Family SES</td>
<td>1.64</td>
<td>0.50 ***</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.24</td>
<td>0.11 *</td>
</tr>
<tr>
<td>Early Adolescence</td>
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<tr>
<td>Family SES</td>
<td>2.70</td>
<td>0.45 ***</td>
</tr>
<tr>
<td>Family SES # Non-Cognitive Skills</td>
<td>-0.42</td>
<td>0.12 ***</td>
</tr>
</tbody>
</table>

Notes: Standard errors are based on 250 bootstrap samples. ~p<0.10, *p<0.05,**p<0.01, and ***p<0.001
Appendix B: Sensitivity Analysis on the Assumption of Unobserved Confounders

In this section, I implement a formal sensitivity analysis to test the robustness of the estimates to unobserved confounding, which is a violation of the sequential ignorability assumption. This may occur when there are unmeasured variables which influence both family SES and the achievement test scores.

Following Sharkey and Elwert (2011); Wodtke, Elwert, and Harding (forthcoming), I conduct a sensitivity analysis for time-varying family SES that models bias due to unobserved confounding as a function of potential outcomes (Brumback et al. 2004; Robins 1999, 2000). Specifically, I use a selection function to summarize the relationship between observed and counterfactual outcomes and then to compute bias-adjusted effect estimates. If inferences about the family SES’s effects on achievement do not change across a range of substantively reasonable confounding scenarios, as defined by different values of the selection function, I conclude that the results are robust to unobserved confounding.

In the first step of the analysis, I specified a selection function: $s(\alpha, \alpha') = (\alpha - \alpha')\alpha$, where $\alpha$ is a sensitivity parameter specifying the magnitude of bias due to unobserved confounding. As I estimate a linear SNMM in this study, I chose a linear model for unmeasured confounding correspondingly. In the model, $\alpha = 0$ implies no unobserved confounding of family SES. $\alpha > 0$ implies the type of confounding that children from lower SES families have lower SES achievement regardless of their family SES; and children from higher family SES have higher achievement regardless of their family SES. $\alpha < 0$ implies the type of confounding that children from lower SES families have higher SES achievement regardless of their family SES; and children from higher family SES have lower achievement regardless of their family SES. The selection function constrains the magnitude of hypothetical unobserved confounding to be the same across levels of observed covariates and moderators for computational simplicity. As this study sets in a longitudinal setting, I specified two selection functions (E1 is for the period of early childhood, E2 is for the early adolescence):

$$ s_0(\alpha_0, \alpha'_0) = (\alpha_0 - \alpha'_0) \quad (E1) $$

$$ s_5(\alpha_5, \alpha'_5) = (\alpha_5 - \alpha'_5) \quad (E2) $$

In the second step, I adjust the estimate for the average treatment effect of family SES in the time-varying context based on the above selection function (E1 and E2). First, I caudated the bias by equation:

$$ B = \sum_{t=0}^{5} \int_{A'_{t,\min}}^{A'_{t,\max}} (A_t - A'_t)\alpha_t P(A'_t) \quad (E3). $$

In this equation, $A$ and $A'$ denote particular values of family SES. $P(A')$ can be obtained by the density function of family SES, which I obtained through kernel modeling. The bias defined in E3 account for the total bias accumulated across developmental periods of early childhood and early adolescence. Second, I subtract the bias term from the observed outcome $Y$, and obtain a bias-adjusted outcome $Y^a = Y - B$. Next, I refit the SNMM using the adjusted outcomes, and this tiles bias-adjusted estimates for the effects of family SES on achievement. Selecting a range of plausible values for the sensitivity parameter $\alpha$ and estimating the bias-adjusted effects of
each of these values allow me to assess the robustness of the results to different degrees of unobserved confounding.

Figure A1 and A3 show the results from this sensitivity analysis for the effects of family SES’s effects on math (A1) and reading achievement (A3) during childhood and adolescent respectively. Figure A2 and A4 shows the results from this sensitivity analysis for the non-cognitive skills moderated effects of family SES on math (A2) and reading (A4) achievement during childhood and adolescent respectively. The parameter $\alpha$ is presented on the x-axis. $\alpha = 0$ means there is no unobserved confounding variable, and $|\alpha| = 1$ means unobserved variables are assumed to confound the effect of family SES’s effects on achievement to the same extent as all observed covariates already controlled in the analysis. Following Wodtke, Elwert and Harding’s work (forthcoming), I judge values of $|\alpha| > 1$ to be implausible unobserved confounding scenarios given that I have adjusted a large and relevant set of observed confounders, though I still reported the results in the graph.

As suggested by these plots, the estimates and the main substantive conclusions are robust to unobserved confounding. Across a wide range of values of $\alpha$, the direct effects of family SES on math and reading achievement during childhood and adolescence are both significant. In addition, these effects are moderated by children’s non-cognitive skills during both two focal developmental stages, and better non-cognitive skills will reduce family SES’s effects on achievement.
Figure A1. Sensitivity Analyses for Effects of Family SES on Children’s Mathematic Achievement under Various Assumptions about the Strengths of Unobserved Confounding Variables

Figure A2. Sensitivity Analyses for Moderated Effects of Family SES on Children’s Mathematic Achievement (Interaction between Family SES and Non-cognitive Skills) under Various Assumptions about the Strengths of Unobserved Confounding Variable
Figure A3. Sensitivity Analyses for Effects of Family SES on Children’s Reading Achievement under Various Assumptions about the Strengths of Unobserved Confounding Variables

Figure A4. Sensitivity Analyses for Moderated Effects of Family SES on Children’s Reading Achievement (Interaction between Family SES and Non-cognitive Skills) under Various Assumptions about the Strengths of Unobserved Confounding Variable
Appendix C: Detailed Description of Non-cognitive Skills Measurement\textsuperscript{10}

Non-cognitive skills measurements used in this study are constructed based on the Approaches to Learning, the Self-Control, and the Interpersonal Skills, which are offered in ECLS-K’s Teacher SRS.

The Approaches to Learning Scale measures behaviors that affect the ease with which children can benefit from the learning environment. It includes six items that rate the child’s attentiveness, task persistence, eagerness to learn, learning independence, flexibility, and organization.

The Self-Control Scale has four items that indicate the child’s ability to control behavior by respecting the property rights of others, controlling temper, accepting peer ideas for group activities, and responding appropriately to pressure from peers.

The five Interpersonal Skills items rate the child’s skill in forming and maintaining friendships, getting along with people who are different, comforting or helping other children, expressing feelings, ideas and opinions in positive ways, and showing sensitivity to the feelings of others.

\textsuperscript{10} From ECLS-K user guide.
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