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The Association Between Socioeconomic Status and Cognitive Development in Children Is Partly Mediated by a Chaotic Home Atmosphere

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ABSTRACT

There are socioeconomic-status (SES) differences in cognitive development. Various factors have been proposed that might explain this association, and one of these factors is the home environment. The present study examined a chaotic home atmosphere as a potential mediator of the association between parental SES and cognitive development. A nationally representative sample of children in the United Kingdom was studied when children were 3 years (n = 15,590), 5 years (n = 13,802), and 7 years old (n = 12,661). At each wave, the children completed multiple cognitive tests, and parents provided information on their SES (income, education, and occupation) and the home atmosphere. Mediation effects were tested with longitudinal structural equation modeling. Direct relations between parental SES and cognitive ability were partly mediated by the home atmosphere. The proportion of mediation was 16% for the change in cognitive ability predicted by parental SES. This study suggests that a chaotic home atmosphere might partly explain the association between parental SES and cognitive development.

Introduction

There are socioeconomic-status (SES) differences in cognitive development: Children whose parents are poorer, are less educated, and work in occupations of lower status tend to show lower cognitive ability (Bradley & Corwyn, 2002). In this study, we addressed the question of how SES influences cognitive development by examining the home atmosphere as a potential mediator.

Socioeconomic status and cognitive ability

Socioeconomic status is a widely studied theoretical concept that captures a person's social standing within society and their access to financial, human, and social capital (Bradley & Corwyn, 2002). Socioeconomic status is often operationalized by variables such as income, education, and occupation that are used as indicators of a latent SES variable (Krieger, Williams, & Moss, 1997). Children who are born into lower-SES households tend to

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perform worse on tests of cognitive ability (McLoyd, 1998). This tendency is of practical interest because childhood cognitive ability has been associated with a wide range of prospective outcomes, such as educational success, career advantages, a higher income, better health, and longevity (Deary & Batty, 2007; Strenze, 2007). Thus, if children from lower-SES backgrounds tend to lag behind in cognitive development, they are more likely to become disadvantaged adults (Najman et al., 2004).

Whereas some of this transmittance of cognitive ability and SES can be attributed to genetic effects (Asbury & Plomin, 2014), there is ample evidence of environmental (nongenetic) effects on cognitive ability that might be partly explained by SES (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009; Beckett et al., 2006; Hart, Petrill, Deckard, & Thompson, 2007; Petrill, Pike, Price, & Plomin, 2004). Shared environmental effects on cognitive ability account for more than 30% of the variance in cognitive ability in childhood (Davis, Haworth, & Plomin, 2009; Haworth et al., 2010; Plomin, Fulker, Corley, & DeFries, 1997), and there is evidence from twin studies that parental SES might explain around 10% of these shared environmental influences (Hart et al., 2007; Petrill et al., 2004). To understand the environmental association between SES and cognitive ability, it is crucial to examine *how* SES affects cognitive development by identifying mediator mechanisms.

Mediators explaining the association between socioeconomic status and cognitive development

Most previous research on the association between SES and cognition (e.g., Christensen, Schieve, Devine, & Drews-Botsch, 2014; Yeung, Linver, & Brooks-Gunn, 2002) has been cross-sectional and has rarely accounted for preexisting associations. To estimate the strength of the association between SES and cognitive change, longitudinal studies are required—or alternatively, studies that can control for parental cognitive ability or estimate genetic and environmental effects by using twin, family, or molecular-genetic designs are required.

In a literature search for studies that accounted for preexisting differences in cognitive ability while examining potential mediator mechanisms, we found nine studies. Table 1 summarizes studies that controlled for children's previous cognitive ability, while Table 2 summarizes studies that controlled for parental cognitive ability. No studies were found that directly controlled for genetic influences (e.g., by using a twin, family, or molecular genetics design). Details on the methods of the literature search are reported in Appendix A ("Literature Search Protocol").

Two general pathways through which SES may affect cognitive development have been proposed (Guo & Harris, 2000): the "parental socialization" model and the "financial capital" model. The parental socialization model proposes that lower SES impacts parents' ability to interact and socialize with their children in a manner that promotes cognitive development, whereas the financial capital model focuses on material resources that aid in cognitive development and are less available for lower-SES individuals. Most mediation studies identified in the literature search were theoretically coherent with the parental socialization model, because they examined parenting factors such as parenting quality, style, and investment. They all revealed that parenting partially mediates the association between SES and cognitive ability (Dickerson & Popli, 2016; Guo & Harris, 2000; Linver,

Table 1. Studies on mediators explaining socioeconomic-status (SES) differences in cognitive development during childhood while controlling for the child's previous cognitive ability.

Citation	Sample Size, Data Set, and Country	Age at Waves	Design	Previous Cognitive Ability	Predictor (SES Measure)	Mediators	Cognitive Outcomes	Main Findings
Lugo-Gil and Tamis-LeMonda (2008)	*n* = 2,089 low-income families, Early Head Start Research and Evaluation Study, United States	14 m 24 m 36 m	SEM, cross-lagged paths between variables	Cognitive ability previous waves	Family resources (mother's education, mother's reading frequency, income, father's residency)	Parenting quality: maternal supportiveness (sensitivity, cognitive stimulation, positive regard), mother–child interaction task	Bayley MDI	Effect of family resources on cognitive ability fully mediated by parenting quality
Mistry et al. (2008)	*n* = 1,459 low-income families, EHS Research and Evaluation Study, United States	14 m 24 m 36 m	SEM, mediation model	Cognitive ability baseline	Mother's education, income-to-needs ratio, welfare cash assistance	Parental investment: maternal supportiveness (sensitivity, cognitive stimulation, positive regard), language/literacy environment	Bayley MDI	Effect of SES on cognitive outcomes fully mediated by parental investment
Noble et al. (2015)	*n* = 179, United States	9/15 m 15/21 m	Mediation analysis	Regressed cognitive change scores between waves	Parents' education, income-to-needs ratio	Critical life events, learning and literacy environment, parental warmth	Preschool Language Scale, Visual Paired Comparison Task	Language/literacy environment and parental warmth mediate SES effect on language but not memory; no mediation effect on critical life events.
Von Stumm (2012)	*n* = 4,512 growing up in Scotland, Scotland	3 y 5 y	Cross-lagged mediation model	Cognitive ability previous waves	Parents' occupation and education, household income	Main meal (slow vs. fast food)	BAS: naming vocabulary and picture similarity	Meal type mediates SES effect on cognitive ability for vocabulary but not picture similarity.
National Institute of Child Health and Human Development (2005)	*n* = 1,364, United States	24 m 36 m 54 m Kindergarten, first grade, second grade	Mediation effects on growth curves	Change in cognitive ability	Income groups (poverty in infancy, poor after infancy, chronically poor, never poor)	Childrearing environment: parenting quality and child care characteristics (quantity and quality)	Bayley (24 m), Bracken & Reynell (3 m), PLS-3 (54 m), WJ subtests (54 m, first grade, second grade)	Parenting but not childcare significant mediator between poverty and cognitive development
Dickerson & Popli (2016)	*n* = 19,000, UK Millennium Cohort Study	9 m 3 y 5 y 7 y	SEM, mediation model	Cognitive ability in previous waves	Poverty (net equivalent income < 60% below median)	Parental investment: home learning variables, social/routine activities, parenting style	Denver (9 m), BAS subtests (3 y, 5 y, 7 y), Bracken (3 y), NFER (7 y)	Poverty adversely affects parental investment, which in turn affects cognitive development.

Note. Lugo-Gil and Tamis-LeMonda (2008) and Mistry et al. (2008) reported very similar analyses using the same data set.

Note. m = months; y = years; SEM = Structural equation modeling; MDI = Mental Development Index; BAS = British Ability Scales; PLS = Preschool Language Scale; WJ = Woodcock Johnson; NFER = National Foundation for Educational Research.

Table 2. Studies on mediators explaining socioeconomic-status (SES) differences in cognitive development during childhood while controlling for parent IQ.

Citation	Sample Size, Data Set, and Country	Age at Waves	Design	Parent IQ	Predictor (SES Measure)	Mediators	Cognitive Outcomes	Main Findings
Byford, Kuh, & Richards (2011)	*n* = 1,690 National Survey of Health and Development, UK	4 y 8 y	Regression analysis, path model analysis	Parent's IQ at age 8 years (same tests as child)	Parent highest education/ training qualification 29 y, occupational status of "head of household"	Parenting: Cognitive stimulation/ intellectual environment, coercive discipline, parental interest school, aspiration, affection	Word reading, sentence completion, vocabulary	Parenting, particularly intellectual environment, mediates association between SES and children's cognitive ability.
Guo and Harris (2000)	*n* = 1,735 National Longitudinal Survey of Youth, US	*Not given, all children born to female sample aged 27 y to 34 y at last wave*	Cross-sectional mediation model	Mother's cognitive ability	Poverty: proportion of years since birth lived below poverty line	Cognitive stimulation, parenting style, physical environment, child health, child care quality	Peabody: Reading Recognition/ Comprehension, Mathematics Assessment, Picture Vocabulary	Cognitive stimulation, parenting style, physical environment, and child health at birth mediate SES effects on cognitive ability; later child health and child care quality do not.
Linver et al. (2002)	*n* = 493, low-birth-weight premature infants, United States	3 y 5 y	Cross-sectional mediation model combining outcomes at different ages to one factor	Maternal receptive verbal ability	Family income	Maternal emotional distress, parental authoritative and authoritarian behavior (mother– child interactions), provision of cognitively stimulating activities	Stanford-Binet Intelligence Scale Form L-M (3 y) Wechsler Preschool and Primary Scale of Intelligence (5 y)	Relation between SES and cognitive ability mediated by provision of stimulating experiences in the home, not mediated by maternal distress and parenting style.
Jenkins, Woolley, Hooper,& De Bellis (2014)	*n* = 102, US	4 y–18 y	Path model analysis	Biological parental IQ	Income, education, occupation, health status, health insurance access, food security, housing conditions, education, and labor market access	Parental stress: marital conflict, parenting stress, depressive symptoms and maternal history of psychiatric disorders	Wechsler: Vocabulary, Matrix Reasoning	None of the family stress components mediated the effect of SES on child IQ.

Note. NFER = National Foundation for Educational Research; m = months; y = years.

Brooks-Gunn, & Kohen, 2002; Lugo-Gil & Tamis-LeMonda, 2008; Mistry, Biesanz, Chien, Howes, & Benner, 2008; National Institute of Child Health and Human Development, 2005; Noble et al., 2015). However, Noble et al. (2015) found a statistically significant mediation effect of parenting for only one of the two studied cognitive outcomes possibly due to a relatively small sample size (n = 179). Another study looked at parental stress and found no mediation effect (Jenkins, Woolley, Hooper, & De Bellis, 2014). Again, this finding may have been due to a sample size that was too small (and thus underpowered) to detect potentially modest effects (n = 102).

The pathway proposed by the financial capital model is quite intuitive, because there is a direct link from SES to certain resources that might shape the home environment (e.g., wealthier families are more likely to be able to afford separate bedrooms, a quiet study space, and high-quality child care). However, fewer studies found in the literature search focused on material resource-oriented mediator variables: Two of the included studies examined child care quality and quantity (Guo & Harris, 2000; National Institute of Child Health and Human Development, 2005) but found no mediation effect; one study found a small mediation effect for whether a child's main meal usually consisted of slow or fast food (Von Stumm, 2012). Additionally, in one of the studies, the physical home environment mediated the association between SES and cognitive ability (Guo & Harris, 2000). Although there has only been one previous study examining the home environment as a potential mediator between SES and cognitive development, it is an important potential mediator that is in line with the financial capital model and one that has previously been proposed in the theoretical literature (Bradley & Corwyn, 2002; McLoyd, 1998). Lower-SES families are less likely to have the resources to afford appropriate housing and thus are more likely to live in more stressful, chaotic environments that are thought to impact cognitive development (Bradley & Corwyn, 2002). Lower-SES parents lack material and nonmaterial resources to provide a home environment that enables children to optimally develop their cognitive abilities (McLoyd, 1998).

Home atmosphere as a potential mediator

Mediating effects of housing conditions have previously been shown for the effect of SES on health outcomes and socioemotional development, but there has been limited previous research for the effect on cognitive development (Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005; Thomson, Petticrew, & Morrison, 2001). In the literature search, only one study was identified that examined housing conditions as a mediator between SES and cognitive development by studying the physical home environment (measured as how safe, tidy, clean, and light a visiting interviewer rated the child's home; Guo & Harris, 2000). In a model that simultaneously included parenting factors and the child's health as mediators, the physical home environment still independently explained 7% of the association between SES and cognitive ability.

However, aside from the physical environment, there is more to the home environment that may play a role in mediating the relation between SES and cognitive development. The concept of a "chaotic" home atmosphere captures factors beyond the previously studied interviewer-rated physical home environment visit with the inclusion of variables such as how much noise, crowding, and traffic are experienced within the home (Matheny, Wachs, Ludwig, & Phillips, 1995). This concept indicates to what extent a home is calm

enough to enable children to live and learn without disturbances. A more chaotic home atmosphere is a promising, previously unstudied mediator mechanism, because previous evidence has supported separate links between SES and the home atmosphere and the home atmosphere and cognitive development.

First, previous studies have shown a clear link between SES and a chaotic home atmosphere: Lower-SES homes are likely to be more overcrowded and in less safe, cheaper, and noisier neighborhoods (Saegert & Evans, 2003). Furthermore, people in lower-SES homes were less likely to be able to afford maintenance, proper insulation, and other means that create a calm atmosphere (Evans, 2004; McLoyd, 1998). Additionally, children from lower-SES backgrounds were confronted with less routine, predictability, and structure in their home lives (Matheny et al., 1995). In a previous study with 339 9-year-old children, there was a medium-sized correlation (r = .30, p < .001) between households' income-to-needs ratios and a chaotic home atmosphere (Evans et al., 2005).

Second and importantly, a chaotic home atmosphere has been related to children's cognitive development, and this association has existed beyond genetic effects (Hart et al., 2007; Petrill et al., 2004; Pike, Iervolino, Eley, Price, & Plomin, 2006). In a UK study with 7,781 twin pairs aged 3 and 4 years old, chaos at home explained about 10% of the shared environmental variance and 6% of the total variance of verbal and nonverbal cognitive ability (Petrill et al., 2004). A U.S. study examining 350 twin pairs revealed comparable proportions of explained variance and additionally showed that a chaotic home atmosphere accounted for some of the longitudinal stability of cognitive ability that cannot be attributed to genetics (Hart et al., 2007). Additionally, in a longitudinal study that included 1,123 children in poor regions of the United States, household disorganization predicted early language development. Importantly, household disorganization continued to account for unique variance in predicting early language development even when the partial mediator of "observed parenting" was included in the model (Vernon-Feagans, Garrett-Peters, Willoughby, & Mills-Koonce, 2012).

The present study

The aim of this study was to examine whether a chaotic home atmosphere explains part of the association between SES and cognitive development. The research question was: Does a chaotic home atmosphere partly explain the changes in children's cognitive ability predicted by parental SES? In an additional analysis, we explored whether a chaotic home atmosphere partly explained the longitudinally stable association between SES and cognitive ability. We addressed these questions by employing a structural equation modeling approach in a large longitudinal sample.

Methods

Participants and procedure

The sample consisted of members of the Millennium Cohort Study (Centre for Longitudinal Studies, 2012a, 2012b, 2015), a population-representative survey following the lives of 18,818 children born in the United Kingdom in 2000 and 2001. To date, the sample has been

followed up in five waves. Children from disadvantaged and ethnic-minority backgrounds were intentionally oversampled because these populations are typically hard to reach. Governmental records of child benefits (a benefit with almost universal coverage) were used to identify eligible children, who were then sampled by electoral ward. Trained interviewers visited the families at their home addresses to conduct data collection at each wave. The data used in this study were obtained through face-to-face interviews with the caretakers and cognitive assessments with the children. Further information on the cohort, sampling, and data collection has been reported elsewhere (Chaplin Grey, Gatenby, Simmons, & Huang, 2010; Connelly & Platt, 2014). The data can be accessed via the UK Data Service and is managed by the Centre for Longitudinal Studies.

In the current study, data were analyzed from when children were about 3 years old (M_{age} = 3;2, SD = 2.52 months), which was used as the baseline in this study (Wave 2, n = 15,590); 5 years old (M_{age} = 5;3, SD = 3 months), which was used as the first follow-up (Wave 3, n = 13,802); and 7 years old (M_{age} = 7;3, SD = 3 months), which was used as the second follow-up (Wave 4, n = 12,661). At all included waves, about half of the cohort members were male (51%). For families with twins (n = 246) and triplets (n = 10), only one randomly chosen child per family was included. Table 3 shows the sample size for each variable at each included wave.

Measures

Parental socioeconomic status

A latent variable indicating parental SES at baseline was derived as indicated by the variables of equivalized household income and maternal and paternal education and occupation (factor loadings for each variable are shown in Table 3). The ***equivalized household income*** was calculated using modified Organisation for Economic Co-operation and Development (OECD) scales that set a family's need relative to those of a childless couple, while taking into account the number and age of family members (see Hansen, 2010, p. 85, for detailed information on the calculations). The income measure was positively skewed and thus was log-transformed. ***Education*** was measured by asking the cohort member's parents about their academic and vocational qualifications and classifying them according to the National Vocational Qualification (NVQ) level (Rosenberg, 2012). The NVQ levels rank from 1 to 5, with Level 1 indicating academic or vocational qualifications on the same level as a General Certificate of Secondary Education (*GCSE) level below Grade C* and Level 5 indicating academic or vocational qualifications on the same level as *postgraduate qualifications* (for more detailed descriptions of each level, see Rosenberg, 2012, p. 33). Level 0 indicates no academic or professional qualification. ***Parents' occupational class*** was grouped into three levels (Level 1 = *higher occupations*, Level 2 = *intermediate occupations*, Level 3 = *lower occupations*) according to the National Statistics Socioeconomic Classification (Rose, Pevalin, & O'Reilly, 2005). The scores were reversed for the analyses, so a higher score indicated a higher occupational class. For unemployed or stay-at-home parents, this information was not available. Thus, the available sample size for parental occupational class (shown in Table 3) was smaller than for the other variables. Only information on the education and occupation of the cohort members' biological parents was included in the analyses, and information on potential other respondents (e.g., foster parents) was not included. At

Table 3. Overview of variables, descriptives, and factor loadings.

Age	Category	Variable	Sample Size	Mean (Standard Deviation)	Factor Loadings Model 1
3 y	Parental Socioeconomic Status	Equivalized Income £/w	15,317	328.24 (218.52)	.72
		Occupation Mother	7,771	2.07 (0.84)	.68
		Occupation Father	9,155	2.07 (0.88)	.62
		Education Mother	14,889	2.49 (1.45)	.71
		Education Father	10,942	2.65 (1.47)	.69
	Cognitive Ability Child	BAS Naming Vocabulary	14,564	73.20 (17.97)	.69
		Bracken Color	14,762	6.82 (4.04)	.75
		Bracken Letters	14,691	1.71 (2.65)	.33
		Bracken Numbers	14,604	2.88 (3.68)	.51
		Bracken Size	14,481	4.50 (2.80)	.61
		Bracken Comparisons	14,219	2.47 (2.3)	.45
		Bracken Shapes	13,855	6.22 (4.07)	.75
	Home Atmosphere	Really Disorganized	15,447	3.79 (0.96)	.57
		Cannot Hear Yourself Think	15,447	3.57 (0.99)	.80
		Calm Atmosphere	15,447	3.63 (0.85)	.58
5 y	Parental Socioeconomic Status	Equivalized Income £/w	13,674	353.72 (219.00)	—
		Occupation Mother	7,742	2.06 (0.83)	—
		Occupation Father	8,600	2.11 (0.87)	—
		Education Mother	13,246	2.62 (1.45)	—
		Education Father	9,705	2.75 (1.47)	—
	Cognitive Ability Child	BAS Naming Vocabulary	13,576	107.46 (16.07)	.71
		BAS Picture Similarity	13,591	82.09 (11.93)	.46
		BAS Pattern Construction	13,368	88.34 (7.42)	.55
	Home Atmosphere	Really Disorganized	13,717	3.65 (1.05)	.51
		Cannot Hear Yourself Think	13,712	3.52 (1.00)	.82
		Calm Atmosphere	13,718	3.55 (0.88)	.59
7 y	Parental Socioeconomic Status	Equivalized Income £/w	12,481	388.27 (228.17)	—
		Occupation Mother	7,759	2.07 (0.83)	—
		Occupation Father	7,533	2.15 (0.86)	—
		Education Mother	12,148	2.72 (1.44)	—
		Education Father	8,850	2.83 (1.49)	—
	Cognitive Ability Child	BAS Pattern Construction	12,362	116.37 (16.54)	.62
		BAS Word Reading	12,190	107.06 (29.97)	.68
		NFER Number Skills	12,426	18.39 (5.84)	.76
	Home Atmosphere	Really Disorganized	12,585	3.72 (1.06)	—

Note. Means and standard deviations were calculated for unstandardized variables. The variable calm atmosphere was reversed, so a higher value indicated a less chaotic atmosphere. Model 1 = mediation chaotic home atmosphere of SES association with change in cognitive ability. Factor loadings were standardized. BAS = British Ability Scales; £/w = pounds per week; NFER = National Foundation for Educational Research.

baseline, the biological mother was interviewed in 99% of cases, and the biological father was interviewed in 96% of cases.

Child's cognitive ability

A range of standard age-appropriate cognitive ability tests was administered to the children. At each time point, at least three different tests could be combined to a latent factor to measure general intelligence. The British Ability Scales (BAS) are a battery of standardized cognitive ability tests for children (Elliott, Smith, & McCulloch, 1997). The BAS Naming Vocabulary test measures expressive verbal ability, vocabulary, and language development. It was administered when the children were 3 and 5 years old. The BAS Pattern Construction test captures spatial problem solving, dexterity, and coordination. The cohort children completed it when they were 5 and 7 years old. The BAS Picture

Similarity test that measures nonverbal reasoning and problem solving was also administered when the children were 5 years old. The BAS Word Reading test assesses reading knowledge. The cohort children completed this test when they were 7 years old. The BAS tests showed a very good internal reliability (Cronbach's $\alpha_{\text{Naming Vocabulary}}$ = .75, Cronbach's $\alpha_{\text{Pattern Construction}}$ = .83, Cronbach's $\alpha_{\text{Picture Similarities}}$ = .81, Cronbach's $\alpha_{\text{Word Reading}}$ = .93; Russell, Ryder, Norwich, & Ford, 2015). Additionally, at age 3 years, five subtests of the Bracken School Readiness Test were used to assess children's basic understanding of the concepts of colors, numbers, letters, shapes, and size comparisons (Bracken, 2002). Finally, at age 7 years, a variant of the National Foundation for Educational Research Standard Progress in Mathematics Test was administered to assess children's numerical and analytic skills. All the cognitive ability test scores were *z* standardized and adjusted for children's sex and age in days at the time of assessment.

Chaotic home atmosphere

A shortened, adjusted version of the Confusion, Hubbub, and Order Scale (CHAOS; Matheny et al., 1995) was administered to the main respondent when children were 3 and 5 years of age. The adjusted scale consisted of three statements (*"You can't hear yourself think in your home"; "The atmosphere in your home is calm"* [reverse-scored]; and *"It's really disorganized in your home"*). These three statements correlated most highly (all greater than r = .60) with the full-length CHAOS. The third statement was amended (original: *"It's a real zoo in your home"*). The shortened scale showed acceptable internal consistency with Cronbach's alpha = .68 at the baseline observation and Cronbach's alpha = .67 at the first follow-up. The external and construct validity of the CHAOS have been reported elsewhere (Matheny et al., 1995). Respondents were asked to indicate their agreement with the statements on a 5-point Likert scale (1 = *strongly agree*; 5 = *strongly disagree*). The responses were *z* standardized. The indicators were then combined with a latent variable. At age 7 years, only the statement, *"It's really disorganized in your home"* was included in the parent interview.

Parenting competence

In a post-hoc sensitivity analysis, the home atmosphere variables were adjusted for self-reported parenting competence, measured as part of the parenting interview with the following question: *"The next question is about how you feel about being a parent. For the next statement, choose your response from the choices 1 to 5. I feel that I am: 1 = not very good at being a parent, 2 = a person who has some trouble being a parent, 3 = an average parent, 4 = a better-than-average parent, and 5 = a very good parent."*

Analyses

Descriptive statistics were computed using R (R Core Team, 2013); a heterogeneous correlation matrix using pairwise complete observations was computed using the *polycor* package (Fox, 2010). We specified the research question and analysis strategy prior to conducting any analyses. Longitudinal structural equation modeling was performed using the software MPlus Version 7 (Muthén & Muthén, 1998–2015). The significance of the indirect effects was tested using the *lavaan* package in R (Rosseel, 2011). To address the main research question (whether a chaotic home atmosphere mediates the change in

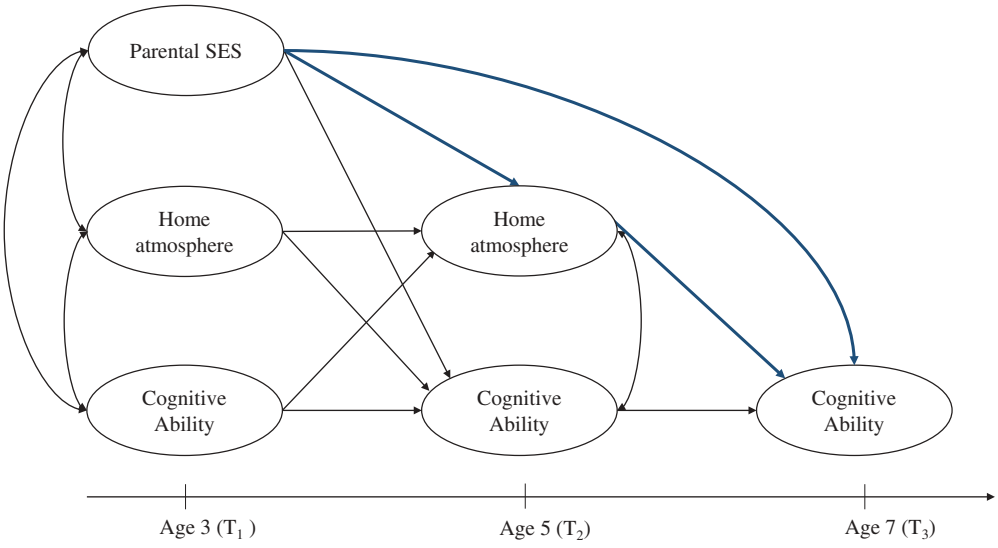

Figure 1. Illustration of Model 1 constructed to address Research Question 1. Mediation paths in **bold**.

cognitive ability predicted by SES), a longitudinal mediation model with autoregressive and cross-lagged paths was computed (see Figure 1). For the additional analysis (whether home atmosphere mediates the longitudinally stable association between SES and cognitive ability), a mediation analysis was performed with second-order latent trait variables (see Appendix B) Figure A1. For all models, model fit was assessed using chi-square, the Comparative Fit Index (CFI), the Tucker-Lewis Index (TLI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). Guidelines for testing mediation via structural mediation models were followed (Iacobucci, Saldanha, & Deng, 2007), and the statistical significance of the indirect effects was tested using bootstrapped 95% confidence intervals. Furthermore, the proportion of the effect of SES on cognitive ability that was explained by chaos in the home (the proportion of mediation) was calculated using the following formula (Iacobucci et al., 2007):

$$\frac{\hat{a} \times \hat{b}}{\hat{a} \times \hat{b} + \hat{c}'} \tag{1}$$

The indirect path from SES through a chaotic home atmosphere to cognitive ability was calculated as the product of the path from SES to the home atmosphere $\hat{a}$ and the path of the home atmosphere on cognitive ability $\hat{b}$ and was divided by the sum of the indirect path and the mediated direct path from SES to cognitive ability $\hat{c}'$.

The data set was split in half at random, and the models were constructed using half of the sample and were then tested using the other half to avoid overfitting of the model and to test whether the results were replicable. There were various data missing due to an attrition of 19% from baseline (age 3 years) to the second follow-up (age 7 years), nonapplicability of certain questions (e.g., nonemployed individuals), and single missing items (sample sizes for each variable are in Table 3). To make use of all available data, full

information maximum likelihood estimation was used, as recommended by Schafer and Graham (2002).

Results

Descriptive statistics and factor loadings for each variable are shown in Table 3. Table 4 shows a correlation matrix for all variables at baseline. The replication of results across sample halves was successful (the results were highly similar across the halves), and thus, the results reported in the following are for the full sample. The path weights for each half of the sample can be found in Appendix C (Figures A3 and A4).

Does chaos mediate the relation between socioeconomic status and cognitive change?

Preliminary analyses showed that SES was extremely stable across the waves (autoregressive coefficient from age 3 years to age 5 years, $\beta[SE] = .98\ (.001)$, $p < .001$, and from age 5 years to age 7 years, $\beta[SE] = .999\ (.001)$, $p < .001$). Thus, SES at baseline (age 3 years) was included in the model as a time-constant variable. First, a model was constructed to assess whether SES predicted changes in cognitive development (Model 1A, path weights in Table 5). For Model 1A, the model chi-square was significant, but alternative fit indices suggested a good model fit, $\chi^2(122) = 2{,}542.31$, $p < .001$, CFI = .967, SRMR = .027, TLI = .958, RMSEA = .36. There was a significant association between SES and cognitive development when controlling for previous cognitive ability at the first follow-up at age 5 years, $\beta(SE) = .16\ (.01)$, $p < .001$, and the second follow-up at age 7 years, $\beta(SE) = .05\ (.02)$, $p = .001$. To test the mediation of this association, chaotic home atmosphere was included in the model at baseline and the first follow-up. This final mediation model (Model 1) is illustrated in Figure 2, and the path weights for both Model 1 and Model 1A are summarized in Table 5.

For the mediation model (Model 1), the model chi-square was significant, but alternative fit indices suggested a good model fit, $\chi^2(229) = 3{,}230.29$, $p < .001$, CFI = .968, SRMR = .027, TLI = .961, RMSEA = .029. The estimates of the regression of SES at baseline on home

Table 4. Correlations at baseline (age 3 years).

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Parental SES														
(1) Equivalized Income	—													
(2) Occupation Mother	.43	—												
(3) Occupation Father	.41	.33	—											
(4) Education Mother	.49	.52	.37	—										
(5) Education Father	.46	.32	.50	.49	—									
Child Cognitive Ability														
(6) BAS Naming Vocabulary	.29	.16	.16	.30	.23	—								
(7) Bracken Color	.33	.20	.21	.31	.27	.53	—							
(8) Bracken Letters	.11	.08	.07	.12	.11	.19	.24	—						
(9) Bracken Numbers	.19	.12	.12	.20	.18	.30	.37	.50	—					
(10) Bracken Size	.22	.16	.15	.22	.19	.45	.44	.19	.31	—				
(11) Bracken Comparisons	.16	.12	.10	.14	.12	.33	.31	.19	.28	.44	—			
(12) Bracken Shapes	.28	.18	.19	.28	.24	.51	.55	.31	.44	.48	.83	—		
Home Atmosphere														
(13) Really Disorganized	.14	.07	.07	.11	.08	.04	.09	.01	.04	.08	.06	.08	—	
(14) Cannot Hear Yourself Think	.17	.14	.11	.18	.14	.09	.15	.06	.10	.11	.08	.14	.44	—
(15) Calm Atmosphere	.06	.04	.03	.05	.04	.02	.06	.05	.05	.06	.04	.05	.36	.46

Note. BAS = British Ability Scales; SES = socioeconomic status.

Table 5. Path weights of Model 1A (SES, cognitive ability) and Model 1 (SES, home atmosphere, cognitive ability).

Parameter	Unstandardized Path Estimate (SE)	Standardized Path Estimate (SE)
Model 1A without mediator		
Covariance T1 SES and Cognitive Ability	.77 (.02)	.60 (.01)
Autoregression Cognitive Ability T1 → T2	.72 (.02)	.71 (.01)
Autoregression Cognitive Ability T2 → T3	.71 (.02)	.80 (.01)
SES → Cognitive Ability T2	.21 (.02)	.16 (.01)
SES → Cognitive Ability T3	.06 (.02)	.05 (.02)
Model 1 with mediator		
Covariance T1 SES and Cognitive Ability	.22 (.01)	.60 (.01)
Covariance T1 SES and Home Atmosphere	.08 (.00)	.27 (.01)
Covariance T1 Home Atmosphere and Cognitive Ability	.08 (.00)	.20 (.01)
Covariance T2 Home Atmosphere and Cognitive Ability	.01 (.00)	.07 (.02)
Autoregression Cognitive Ability T1 → T2	.73 (.02)	.71 (.01)
Autoregression Cognitive Ability T2 → T3	.70 (.02)	.80 (.01)
Autoregression Home Atmosphere T1 → T2	.48 (.01)	.53 (.01)
SES → Cognitive Ability T2	.22 (.02)	.17 (.01)
SES → Cognitive Ability T3	.05 (.02)	.04 (.02)
SES → Home Atmosphere T2	.14 (.01)	.15 (.02)
Home Atmosphere T1 → Cognitive Ability T2	−.04 (.01)	−.03 (.01)
Cognitive Ability T1 → Home Atmosphere T2	*−.01 (.01)*	*−.02 (.01)*
Home Atmosphere T2 → Cognitive Ability T3	.06 (.01)	.05 (.01)
SES → Home Atmosphere T2 → Cognitive Ability T3	.01	.01

Note. Values printed in *italics* are not significant at $p < .05$. T1 = 3 years old; T2 = 5 years old; T3 = 7 years old; SE = standard error; SES = socioeconomic status.

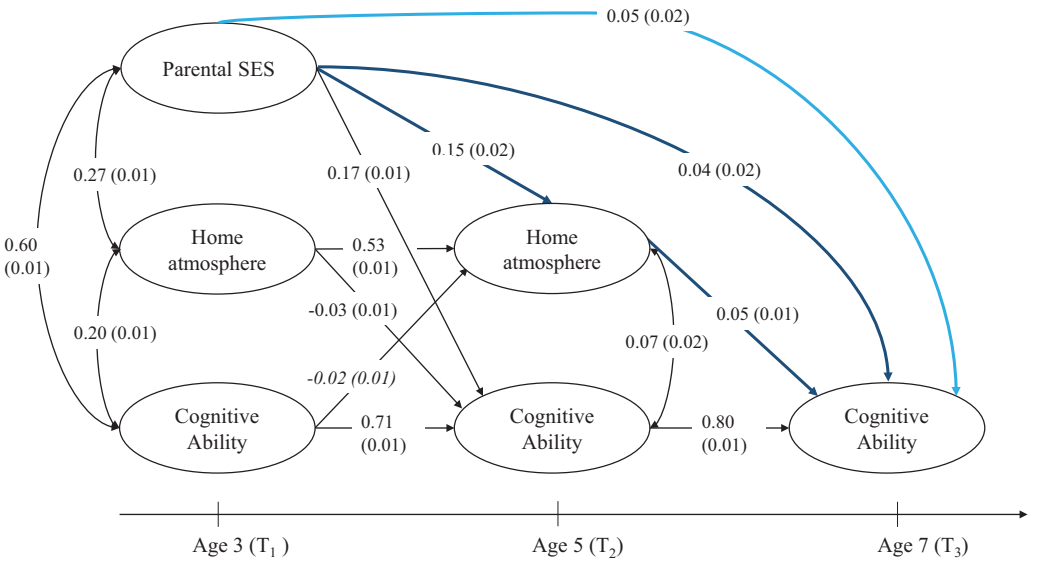

Figure 2. Model 1 with standardized coefficients and standard errors for mediation paths (printed in bold). Manifest variables and factor loadings are reported in Table 3 and Table 5. Direct path before including home atmosphere in **bold light** (Model 1A). Mediation paths in **bold dark**. Path weight printed in italics was not significant at $p < .05$. Model 1A resembles Model 1 without the home atmosphere variables.

atmosphere at the first follow-up, $\beta(SE) = .15\ (.02)$, $p < .001$, and of home atmosphere at the first follow-up on cognitive ability at the second follow-up, $\beta(SE) = .05\ (.01)$, $p < .001$, were both significant. The indirect coefficient was computed from these path weights by multiplying them together, $\beta = .15 \times .05 = .01$, and the p value derived using bootstrapping indicated that this indirect coefficient was significant ($p < .001$). Including the mediation variable attenuated the direct link from SES to cognitive ability at Wave 4, but the path was still significant, $\beta(SE) = .04\ (.02)$, $p = .008$, indicating a partial mediation. The percentage of the association between SES and cognitive development that was mediated by the home atmosphere (Iacobucci et al., 2007) was 16%. Although these results were consistent with the proposed mediation, there was one path weight that was in an unexpected direction: A more chaotic home atmosphere at baseline (age 3 years) predicted a stronger increase in cognitive ability at the first follow-up (age 5 years), $\beta(SE) = -.03\ (.01)$, $p = .004$.

Sensitivity and additional analyses

Several post-hoc analyses were performed to test the stability of results for the model. First, home atmosphere at baseline was excluded. Thus, general home atmosphere at age 5 years was examined as a mediator variable instead of the change in home atmosphere controlling for previous home atmosphere. Second, a model with a home atmosphere variable at each wave was constructed: The single item measuring home atmosphere at age 7 years was included in the analyses and regressed onto parental SES, cognitive ability at age 5 years and age 7 years, and home atmosphere at age 5 years. Both of these alterations to the model did not alter the finding that a chaotic home atmosphere partly mediated the relation between parental SES and cognitive change. Additionally, we performed a post-hoc sensitivity analysis exploring whether the associations were confounded by parenting competence by adjusting the home atmosphere variables for self-reported parenting competence at all waves. The indirect effect remained stable, with $\beta = .01$, $p = .003$. This finding indicated that the home atmosphere mediates the association between SES and cognitive development independent of (self-reported) parenting competence.

In a planned additional analysis, a latent state-trait model (Newsom, 2015) was constructed to examine associations between the stable aspects of SES, cognitive ability, and home atmosphere over time. Latent variables were derived from the manifest indicators for SES, cognitive ability, and home atmosphere at all three time points. These latent variables were used to compute second-order latent-trait variables that represent the stable aspects of the constructs. A mediation analysis was then conducted with these constructs. The strong direct association between SES and cognitive ability was slightly attenuated when the mediator variable of home atmosphere was included in the model. Home atmosphere was associated with both SES, $\beta(SE) = .22\ (.01)$, $p < .001$, and cognitive ability, $\beta(SE) = .05\ (.01)$, $p < .001$, and the indirect effect was significant, $\beta = .01$, $p = .001$. Thus, the home atmosphere partially mediated the association between SES and cognitive ability when we looked only at the stable aspects of the different constructs. However, the proportion of mediation was very small: 1.6%. Path weights for the full model and information on model fit can be found in Appendix B, Figure A2.

Discussion

This study examined whether a chaotic home atmosphere explains some of the association between SES and cognitive ability. There was a direct relation between SES and cognitive development, which was partially mediated by the home atmosphere in a model examining the change in cognitive ability predicted by parental SES (Figure 2). This finding suggests that a lower SES is associated with a disordered and chaotic home and in turn is related to lower cognitive ability.

In the main model, which explored longitudinal change in cognitive ability predicted by SES and mediated by the home atmosphere, the percentage of mediation (which indicated how much of the relation between SES and cognitive ability was explained by the mediator of home atmosphere) was 16%. As shown in Formula 1 in the Methods section, the percentage depended on both the size of the direct effect from SES on cognitive ability and the size of the indirect effect from SES through a chaotic home atmosphere on cognitive ability. The size of the direct effect in the main model was small: $\beta(SE) = .05\ (.02)$, $p = .001$. Therefore, the small indirect effect ($\beta = .01$, $z[SE] = 4.27\ [< .01]$, $p < .001$) still explained a relatively substantial amount of the direct effect. In the additional cross-sectional analysis, which addressed the potential for mediation between the time-stable factors of SES, home atmosphere, and cognitive ability, the direct effect was considerably larger ($\beta[SE] = .64\ [.01]$, $p < .001$). However, the indirect effect was small ($\beta = .01$, $z[SE] = 3.80\ [< .01]$, $p < .001$) and comparable in size to the indirect effect in the main model, and thus, it only explained a very small proportion of the large direct effect (1.6%).

Broadly, the results were coherent with previous research in the literature search (Tables 1 and 2) in showing there are environmental factors that mediate the association between parental SES and children's cognitive development. However, most of the previous studies mainly examined parenting factors (Dickerson & Popli, 2016; Guo & Harris, 2000; Linver et al., 2002; Lugo-Gil & Tamis-LeMonda, 2008; Mistry et al., 2008; National Institute of Child Health and Human Development, 2005; Noble et al., 2015). The current study adds to the literature because it looked at the home atmosphere as a potential explanatory mechanism. Although this mechanism has previously been proposed in the theoretical literature (Bradley & Corwyn, 2002, pp. 380–381), it was only examined in one previous study that fulfilled the criteria of our literature search (Guo & Harris, 2000). This previous study revealed a mediation effect for the physical home environment rated by an interviewer, while the current study focused on the home atmosphere as it was experienced by people living in the home. Taken together, the two studies suggest that both the objective and subjective home environment mediate the relation between parental SES and cognitive development.

Mechanisms of mediation

A variety of mechanisms might explain the association between SES and home atmosphere and between home atmosphere and cognitive development.

Lower-SES individuals may be less able to afford living in calmer homes. Furthermore, lower-SES parents may lack the educational and social resources to create a calm home. Thus, a chaotic home atmosphere may be a manifestation of a lack of access to resources. An additional explanation has been proposed by Davis-Kean (2005): Parents with lower education may have lower expectations of their children and thus put less effort into creating an

intellectually stimulating home atmosphere. The study that supported these claims was cross-sectional, and thus, the directionality of effects should be interpreted with care.

Another potential explanation for the association between home atmosphere and cognitive development may be that children living in chaotic homes suffer from chronically heightened stress levels that impair cognitive development. This potential explanation is supported by human and animal studies that have shown a negative link between chronic stress and cognitive development (Lupien, McEwen, Gunnar, & Heim, 2009). Furthermore, children growing up in calm homes may be more able to interact with their environment in cognitively stimulating ways (Petrill et al., 2004).

Strengths and limitations

We used a nationally representative, large longitudinal data set, and mediation effects were shown for both a model examining longitudinal change (thus controlling for preexisting differences) and for a model examining highly stable, reliable constructs (albeit with a small percentage of mediation). The data set was randomly split, and the results were replicated across the sample halves. The mediation models were built according to guidelines based on simulation studies. These simulation studies indicated that structural equation modelling mediation analyses are more accurate and more likely to detect existing patterns compared with regression analyses (Iacobucci et al., 2007). They also indicated that structural equation modelling mediation analyses should include at least three indicators per construct and the central mediation analysis should be estimated as a subset of a more extensive nomological network (Drolet & Morrison, 2001; Iacobucci et al., 2007). All constructs were measured as latent variables, which removed variable-specific measurement error from the analyses.

The main limitation of this study is that it did not directly control for genetic effects. More intelligent parents are likely to attain a higher SES (Deary et al., 2005) and thus less chaotic homes (Evans, 2004); as discussed earlier, they are also likely to have more intelligent children for genetic reasons (Haworth et al., 2010; Marioni et al., 2014). Controlling for preexisting cognitive differences in the main model of the current study accounted for associations between SES, housing, and cognitive ability at baseline originating from genetic effects but not for genetic effects on cognitive development over time. Children of more intelligent parents with higher SES and calmer homes may have shown a steeper increase in cognitive ability across the waves. The observed relation between SES and cognitive development would then originate from an underlying genetic association. However, previous genetically informative studies have supported the results of this study by pointing toward existing environmental effects: At least when examining SES and home atmosphere separately, both factors accounted for shared environmental effects on cognitive ability (Hanscombe, 2012; Hart et al., 2007; Petrill et al., 2004).

An additional limitation is that different measures of cognitive ability were used at each wave. This limitation may have resulted in somewhat different aspects of cognitive ability being measured at each time point. However, for each wave, at least three different cognitive ability tests were used, and all the tests were standardized and age-appropriate tests of cognitive ability that correlated well together. Furthermore, the latent cognitive ability variables derived at each wave all loaded strongly onto a common factor for the

additional analysis, which supports the claim that the cognitive ability variables at each wave were all likely to capture general intelligence.

Implications and future research

The effect sizes were relatively small. This finding was not surprising, because cognitive development is likely to be influenced by many different factors (Finkel & Pedersen, 2001), any of which are likely to contribute to the overall SES differences in cognitive ability (Guo & Harris, 2000). There are likely to be other housing-related aspects beyond the home atmosphere that influence cognitive development such as the physical home environment (Guo & Harris, 2000). Furthermore, the atmosphere at home has previously been related to cognitive development beyond SES (Hart et al., 2007; Petrill et al., 2004).

Housing issues that originate from lower SES have previously been shown to have detrimental effects on socioemotional development and health (Evans et al., 2005; Thomson et al., 2001). By studying cognitive development, this study revealed a further outcome associated with housing issues linked to SES. Future research should examine interventions to help lower-SES families create a calmer home atmosphere (e.g., interventions aimed at improving social housing or helping lower-SES families to create calm spaces in their homes). Intervention studies that employ randomized, controlled designs can back up results by allowing more certain conclusions about causes and effects. Additionally, they could offer policy implications regarding the possibility of reducing the SES gap in cognitive ability. Housing interventions that have a positive effect on health could be used to design comparable interventions targeting cognitive development (see Thomson et al., 2001, for a review). Additionally, future research could examine whether the home atmosphere not only acts as a mediator, but also a moderator by buffering or amplifying effects of SES on cognitive development.

Conclusion

This study suggests the home environment explains part of the association between SES and cognitive development. A chaotic home atmosphere explained 16% of the association between SES and cognitive change.

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Appendix A: Literature Search Protocol

Literature Search Protocol was written using the Prisma-P 2015 guidelines as an orientation (Moher et al., 2015; .

Aim: Find longitudinal studies on how the environment mediates socioeconomic differences in cognitive development during childhood.

Eligibility criteria:

- Study design: longitudinal (minimum time to follow-up = 1 year)
- Participants: children (birth–18 years old)
- Included measure of socioeconomic status (SES): education, occupation, or income
- Included environmental measure or intervention, examined this measure in relation to SES
- Included outcome measure of cognitive development, measured with a cognitive IQ test
- Controlled for baseline cognitive ability OR used twin design OR genetic markers OR cognitive ability of parents
- Study languages: English and German

Information sources:
Databases: PsychInfo and Google Scholar; search language was English.

Search strategy:
Scan reference list included studies and relevant reviews and who cited included studies.

Search terms:
(Cognitive development OR intelligence OR cognitive ability OR cognition OR IQ OR cognitive skill)
AND
(Environment OR environmental OR background OR non-genetic OR context OR nurture OR education OR school OR home)
AND
(Children OR child OR pupil OR adolescent OR youth)
AND
(Class OR socio-economic status OR socioeconomic status OR status OR SES OR social position OR socioeconomic position OR socio-economic position OR income OR wealth OR occupation)

Data management:
Downloaded all references that might be eligible in EndNote and then examined carefully for eligibility.

Reporting:
Summarized design and time to follow-up; examined factors, outcomes, and credibility of study (sample size, reliability measures) in a table to avoid selective review

Appendix B: Additional Analysis

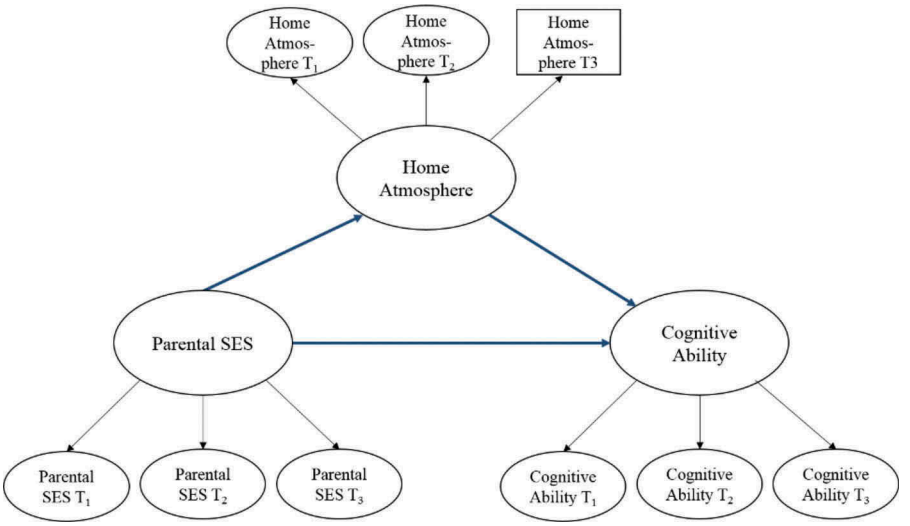

Figure A1. Illustration of Model 2, constructed to address additional research question. *Note.* T1 = age 3 years, T2 = age 5 years, T3 = age 7 years. Mediation paths are in **bold.**

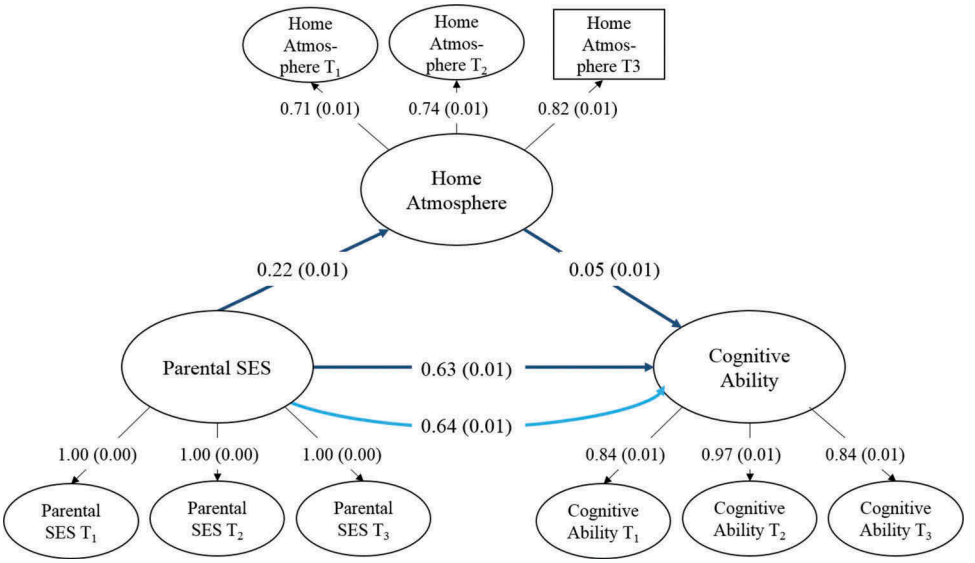

Figure A2. Model 2, latent-state trait model. Direct path before including home atmosphere in **bold light**. Mediation paths in **bold dark**. All paths are significant at $p < .05$. For manifest variables and path weights, see Table 4. All coefficients shown are standardized path weights and standard errors. Home atmosphere at T3 is a manifest variable, because only one item was available at this wave. *Note.* T1 = age 3 years, T2 = age 5 years, T3 = age 7 years.

Apart from a significant model chi-square, model fit indices indicated a good model fit: $\chi 2$ (522) = 8,882.43, p < .001, Comparative Fit Index = .971, standardized root mean square residual = .048, Tucker-Lewis Index = .967, root mean square error of approximation = .032.

Appendix C: Results for both sample halves

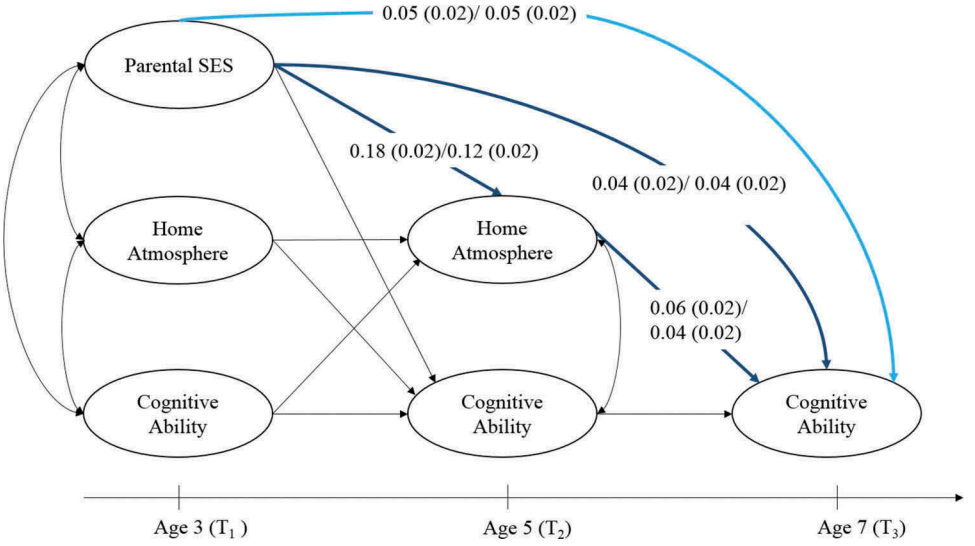

Figure A3. Model 1 for both sample halves (Half 1/Half 2) with standardized coefficients and standard errors for mediation paths (printed in **bold dark blue**). Direct effect before including home atmosphere (Model 1A) in **bold light blue**. Model 1A resembles Model 1 without the home atmosphere variables.

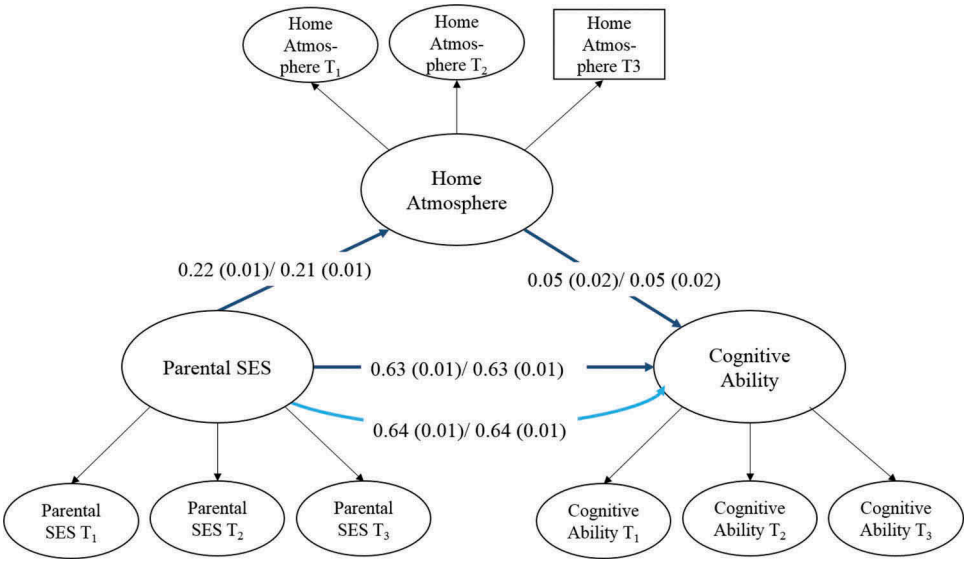

Figure A4. Model 2 main path weights for both sample halves (Half 1/Half 2), latent-state trait model, mediation paths printed in **bold dark blue**, direct effect before including home atmosphere in **bold light blue**. All paths are significant at $p \leq .05$. All coefficients shown are standardized path weights and standard errors. Home atmosphere at T3 is a manifest variable, because only one item was available at this wave. *Note*. T1 = age 3 years, T2 = age 5 years, T3 = age 7 years.