European Child & Adolescent Psychiatry (2019) 28:795–805
https://doi.org/10.1007/s00787-018-1248-3

ORIGINAL CONTRIBUTION

Ecological model of school engagement and attention-deficit/hyperactivity disorder in school-aged children

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Received: 18 May 2018 / Accepted: 26 October 2018 / Published online: 2 November 2018

Abstract
School engagement protects against negative mental health outcomes; however, few studies examined the relationship between school engagement and attention-deficit hyperactivity disorder (ADHD) using an ecological framework. The aims were to examine: (1) whether school engagement has an independent protective association against the risk of ADHD in children, and (2) whether environmental factors have an association with ADHD either directly or indirectly via their association with school engagement. This cross-sectional study used data from the 2011–2012 National Survey of Children's Health, which collected information about children's mental health, family life, school, and community. The sample contained 65,680 children aged 6–17 years. Structural equation modeling was used to estimate the direct association of school engagement and ADHD and indirect associations of latent environmental variables (e.g., family socioeconomic status (SES), adverse childhood experiences (ACEs), environmental safety, and neighborhood amenities) and ADHD. School engagement had a direct and inverse relationship with ADHD ($\beta = -0.35$, $p < 0.001$) such that an increase in school engagement corresponds with a decrease in ADHD diagnosis. In addition, family SES ($\beta = -0.03$, $p = 0.002$), ACEs ($\beta = 0.10$, $p < 0.001$), environment safety ($\beta = -0.10$, $p < 0.001$), and neighborhood amenities ($\beta = -0.01$, $p = 0.025$) all had an indirect association with ADHD via school engagement. In conclusion, school engagement had a direct association with ADHD. Furthermore, environmental correlates showed indirect associations with ADHD via school engagement. School programs targeted at reducing ADHD should consider family and community factors in their interventions.

Keywords ADHD · School engagement · Ecological model

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is a common childhood mental disorder characterized by the chronic presence of inattention and/or hyperactivity–impulsivity causing impairment in daily functioning and development [1]. In the United States (US), the prevalence of ADHD in children aged 3–17 years is approximately 6.7% and appeared to show an increasing trend [2]. The number of parent-reported diagnoses of ADHD increased to 33% between 1997 and 2008 [2]. Several factors may be contributing to the increased prevalence such as increased awareness among parents and schools, promotion of screening and diagnosis, and advances in treatment of ADHD [2]. ADHD has an early age of onset and often tends to persist over time [3], [4]. It can also result in impairments across cognitive, developmental, academic, and health-related domains [3], [5–7]. Due to these factors, reducing the incidence and improving the course of disease for ADHD should be public health priorities.

The full etiology of ADHD is unknown. Genetic studies have estimated the mean heritability of ADHD at 76% [8]. Although these studies suggested that genetic variations play a major role, they also implied that environmental factors

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could contribute to the development of ADHD. As such, one of the ways to reduce the incidence of ADHD should include an examination of modifiable factors in the environments surrounding the child. The ecological model of health, which posits that the external environments where children interact bear significance on their healthy development, depicts these environments in layers from most proximal to most distal from the child [9]. Immediately outside of the family environment, children engage most often in the school and community networks. School represents an important social environment for children. American school-aged children spend approximately 32–33 h a week in school learning and modeling from teachers and peers [10]. Social bonds to schools can play an important role in influencing academic as well as health-related outcomes.

School engagement, a construct measuring the degree to which students feel invested and motivated in their school life [11], appears to have a protective relationship against negative outcomes such as emotional distress, suicidality, and low mood in teens [12], [13]. As a protective factor, school engagement moderates the risk of negative mental health outcomes [14]. In addition, there is also research signifying a promotive relationship (i.e., a direct relationship with the outcome [15]) between school engagement, or similar constructs, and positive behaviors. Studies emphasized that forming social bonds to prosocial institutions (such as schools) may increase prosocial behavior and decrease delinquency [16], [17].

Despite the evidence documenting the positive effects of school engagement on mental health, few studies have examined the protective effect of school engagement on ADHD. We know of one study that examined school attitudes and suspension rates among 130 Australian adolescents with ADHD [18]. Results demonstrated that ADHD students in their first year of high school reported being less motivated and connected and having higher suspension rate compared to state benchmarks. However, multivariable analysis revealed that having ADHD symptoms was not predictive of student attitudes to school. This result was corroborated by prospective studies which found that school engagement predicts mental health symptoms among school-aged children, not necessarily the other way around [19], [20]. Further, Zendarski and colleagues did not consider the contribution of community characteristics that may affect the relationship between school engagement and ADHD.

Findings from previous works showed that school engagement is influenced by individual factors as well as family and community factors including family socioeconomic status (SES), adverse childhood experience (ACE), environment safety, and neighborhood amenities [21–27]. In addition, ACEs and low SES have been associated with increased odds of ADHD in children [28–31]. The relationships among family and community variables with ADHD become more complex as to whether these factors are contributing to the development of ADHD either directly or indirectly through their known associations with school engagement.

In summary, little research exists that examined the relationship between school engagement and ADHD, especially with a model inclusive of family and community factors that may contribute to the diagnosis of ADHD whether directly or indirectly through school engagement. The primary aim of the current study was to examine whether school engagement has an independent protective association against the risk of ADHD in children aged 6–17 using a population-based sample in the US. The second aim was to examine whether environmental factors have an association with ADHD either directly or indirectly via their association with school engagement.

Methods

Study sample and design

Data were drawn from the 2011–2012 National Survey of Children's Health (NSCH), which was funded by the Maternal and Child Health Bureau (MCHB) and conducted by the National Center for Health Statistics (NCHS) [32]. The 2011–2012 NSCH used a state-level sample design to collect health information for representative samples of children aged 0–17 years from all fifty states and the District of Columbia. Landline and cell phone numbers were sampled from each state, and then called and screened for the presence of a resident child under age 18. If multiple children resided in the household, one child was randomly selected to be the survey's participant. Survey's respondents were parents with knowledge about the sampled child's health. The NSCH collected information about physical and emotional health of children as well as information about medical homes, school life, family interactions, and neighborhood qualities [32]. Data for the 2011–2012 NSCH were collected between February 28, 2011 and June 25, 2012 with a total of 95,677 completed interviews. The national interview completion rates for the landline and cell phone samples were 54.1 and 41.2%, respectively [32]. Our study focused on the sample of 65,680 children aged 6–17 who attended school and provided data on school engagement.

Figure 1 maps the hypothesized relationships among school engagement, ADHD, and environmental factors. The hypothesized relationships are inspired by the ecological model and based on existing literature supporting the associations among neighborhood characteristics (e.g., amenities and safety), family characteristics (e.g., SES and ACE), and school engagement as mentioned above. The variables in circle represent latent factors, which are not directly observed but rather indicated by a group of measured variables (in

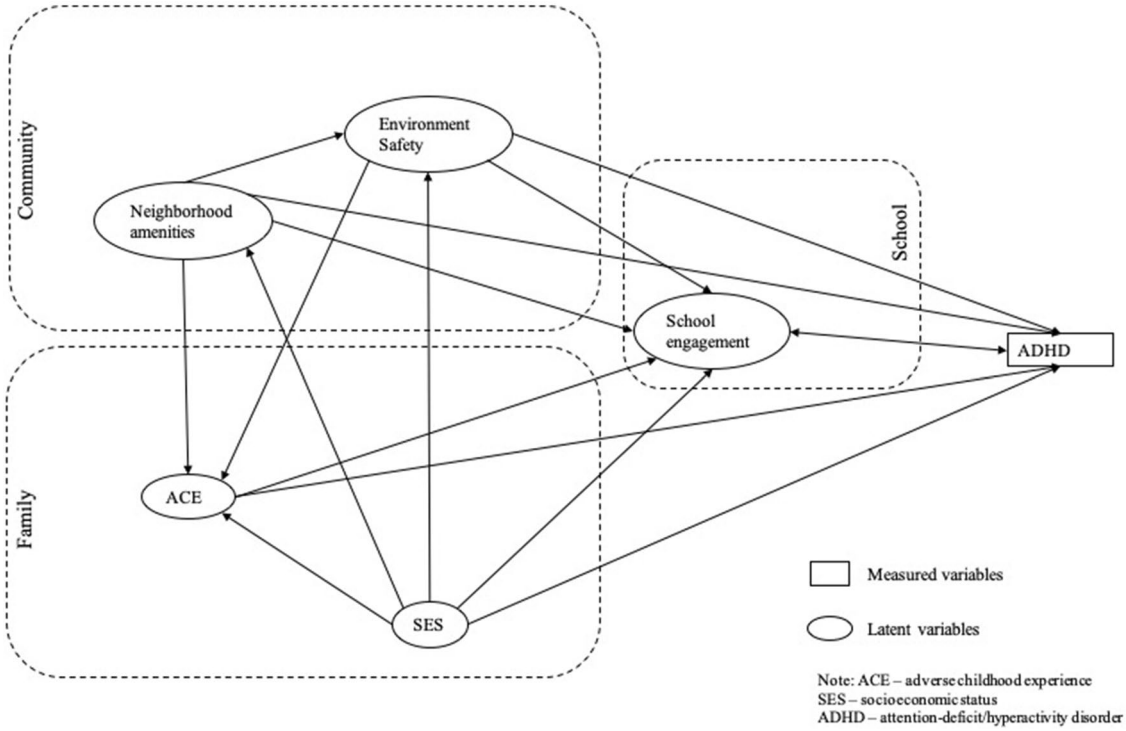

Fig. 1 Hypothesized measurement and structural models linking environmental correlates to ADHD

rectangles). The employment of certain measured variables to indicate a latent factor depends on existing knowledge and designs of the NSCH. For example, the NSCH selected the nine events depicted to measure ACEs. The indicators for SES were household income, parent education and employment, and child's insurance as we thought this might also represent the child's SES level. This conceptual model requires an analysis plan that can afford the examination of latent variables, multiple dependent variables, and direct and indirect relationships among variables. We propose the use of confirmatory factor analysis and structural equation modeling (SEM) for our analysis plan.

Measurement of observed variables

Current diagnosis of ADHD in the 2011–2012 NSCH was measured by asking parents "if a doctor or other health care provider ever told you that [selected child] had the condition" and "does [selected child] currently have ADHD?" Positive responses to both questions affirmed that the child has a current diagnosis of ADHD. A negative response to either question resulted in a negative outcome. A previous study found that ADHD prevalence based on parent report of provider diagnosis proved comparable to that based on medical records [33].

Other measured variables in our model served as control variables: child's age; sex; race and ethnicity, categorized as non-Hispanic White, non-Hispanic black, Hispanic, and multiracial/other; and current diagnosis of conduct problems, categorized as yes or no. Conduct problems have been shown to be associated with both school engagement and ADHD, and were, therefore, included in the model [34], [35].

Measurement of latent variables

In our model, the latent variables were school engagement, family SES, ACE, environment safety, and neighborhood amenities. The NSCH measured school engagement using two questionnaire items asking parents whether their child "cares about doing well in school" and whether "[he/she] does all required homework" during the past month. Responses for the two items were rated on a Likert scale ranging from never, rarely, sometimes, usually, to always.

Family SES was indicated by parental education, categorized as less than high school, high school graduate, or more than high school; parent employed for at least 50 weeks out of past 52 weeks, categorized as yes or no; annual household income, categorized as < 100% federal poverty level (FPL), 100–199% FPL, 200–399% FPL, or 400% or more FPL; and child's health care coverage, categorized as yes or no. ACE was represented by nine hardships including financial stress, having lived with a divorced or separated parent, having lived with a parent who died, having lived with a

parent who served time in jail or prison, having witnessed domestic violence, having been a victim of or witnessed violence in the neighborhood, having lived with anyone with mental health problems, having lived with anyone who had a substance use problem, and having experienced racial/ethnic discrimination.

Environment safety was indicated by two items measuring perceived safety in the child's community or neighborhood and school. Parents were asked "How often do you feel [selected child] is safe in your community or neighborhood?" and "How often do you feel [he/she] is safe at school?" Responses ranged on a scale from never to always. Neighborhood amenities were represented by the presence of sidewalks, a park, a recreational center, or a library. Each item had a yes or no response.

Statistical analysis

Descriptive statistics were estimated using SAS statistical software, version 9.4 [36] and SEM was conducted using Mplus [37]. The survey's complex designs were accounted for in both statistical programs. SEM is a multivariate technique capable of examining several independent and dependent variables simultaneously as well as incorporating latent and measured variables in the model [38]. It also allows for correlation or covariance among a set of variables. In addition, reciprocal effects between key variables can be estimated with cross-sectional data using SEM to better understand their directionality. Although this technique provides a viable alternative to using longitudinal data, causal inference is cautioned with non-experimental data [38]. As the model that we specified based on theory and published research included those aforementioned elements, SEM was an appropriate analysis technique for our study aim.

SEM was carried out in two steps. First, a measurement model was used to specify the latent variables and their measured indicators. Standardized loading coefficients of each measured indicators on their respective constructs were estimated. Second, a structural model specifying the relationships among our latent variables and outcome of ADHD was fitted using probit regression and robust-weighted least square means and variance-adjusted (WLSMV) estimation. Control variables (child's age, sex, race and ethnicity, and current diagnosis of conduct problems) with a significant effect ($p \leq 0.05$) were included in the final structural model. Total direct and indirect effects for latent variables on ADHD were also estimated. In supplemental analysis, the reciprocal effects between school engagement and ADHD were estimated for a better understanding of the directionality between these variables in our data. In addition, a subgroup analysis using only children with ADHD was conducted using the same measurement and structural model specifications with two changes. Parents of children with a current diagnosis of ADHD were also asked to rate the children's ADHD symptoms as mild, moderate, or severe. For the subgroup analysis examining school engagement and ADHD severity, the outcome of symptom severity was dichotomized into mild and moderate/severe because the 'severe' group had too few observations to stand as a lone category. The control variables now included ADHD medication status categorized as yes or no.

Indices used to assess model fit included the Root Mean Square Standard Error of Approximation (RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI). RMSEA values ≤ 0.05 indicate a good fit, ≤ 0.08 a reasonable close fit, and ≥ 0.10 a poor fit [38], [39]. For both CFI and TLI, values ≥ 0.95 are considered good fit [39]. The model Chi-square (χ^2) was not used because in very large sample sizes, even small differences between our model and data could result in statistically significant χ^2 values [38]. Additional parameters to the model suggested by the model indices were considered to enhance model fit based on two criteria: (1) substantial modification index and (2) theoretical justification [39].

Results

Descriptive analysis

Table 1 shows weighted characteristics of the observed variables. In this sample, the proportion of children aged 6–17 years with a current diagnosis of ADHD was 10.0%.

Table 1 Weighted characteristics of observed variables, $n = 65{,}680$

Variables	Weighted percentage
Current diagnosis of ADHD	
Yes	10.0
No	90.0
Current diagnosis of conduct problems	
Yes	3.7
No	96.3
Child's age	
6–11	49.4
12–17	50.6
Child's sex	
Male	51.2
Female	48.8
Child's race/ethnicity	
White, non-Hispanic	53.7
Black, non-Hispanic	14.2
Hispanic	22.3
Multiracial/other, non-Hispanic	9.7

A smaller percentage (3.7%) had a current diagnosis of conduct problems. There were similar distributions between the two age groups; 49.4% aged 6–11 years compared to 50.6% aged 12–17 years. The distribution of male was 51.2%. The racial and ethnic distribution was mostly non-Hispanic white (53.7%) followed by Hispanic (22.3%), non-Hispanic black (14.2%), and multiracial/other (9.7%).

Table 2 provides weighted characteristics of measured indicators. For the latent variable of school engagement, the majority of children reported usually or always caring about doing well in school (86.1%) and doing all required homework in the past month (87.0%). For the latent variable SES, about 33.2% of parents had a high school degree and 45.1% had more than a high school education. The majority of parents (84.9%) were employed in the last year. The household income distribution was as follows: 20.7% were < 100% below FPL, 21.4% 100–199% above FPL, 28.9% 200–399% above FPL, and 29.1% 400% or more above FPL. Furthermore, about 94.1% of children had some type of health care coverage.

For the latent variable ACEs, the most frequent experiences were financial hardship (experienced by 25.8% of children) and living with a divorced or separated parent (25.1%). Less frequent experiences were living with anyone who had a substance use problem (13.2%), witnessing or being a victim of neighborhood violence (11.5%), living with anyone with a mental health problem (10.1%), witnessing domestic violence (8.9%), and living with a parent who served time in jail or prison (8.1%). The least frequent experiences were racial/ethnic discrimination (5.6%) and having a parent who died (4.1%).

The majority of children lived in neighborhoods or communities that were usually or always safe (86.9%) and went schools that parents felt were usually or always safe (92.7%). Furthermore, most children lived in neighborhoods that afforded parks (83.6%), sidewalks (75.9%), recreational centers (69.2%), and libraries (89.1%).

Measurement model

The initial measurement model specifying the latent variables provided a reasonably good fit (RMSEA = 0.02; CFI = 0.92; TLI = 0.91). Using the modification indices, additional parameters were added to improve the model fit. Covariances between community safety and discrimination, neighborhood violence, and financial hardship were added. Covariances between sidewalks and parks and between living with a parent with a mental health problem and parental education were also added. Financial hardship was allowed to cross load on ACE and SES. After adding these parameters, the model fit improved (RMSEA = 0.01; CFI = 0.98; TLI = 0.97) and the standardized loading coefficients were all statistically significant ($p < 0.001$).

Structural model

The structural model included the measurement model specifying the latent variables and structural equations specifying the relationships among the latent variables and the outcome. The final model provided a good fit to our data (RMSEA = 0.01; CFI = 0.96; TLI = 0.95). Standardized loading coefficients are reported in (Fig. 2) and standardized path coefficients are reported in (Fig. 3) for ease of visualization. The standardized loading coefficients showed that, for example, a higher level of household income was associated with a higher level of family SES.

Similarly, the standardized path coefficient for school engagement, for instance, can be interpreted such that a higher level of school engagement was associated with a lower probability of having a current ADHD diagnosis, and this association was statistically significant ($p < 0.001$). One of our other latent variables, ACE, also showed a direct association with ADHD diagnosis ($\beta = 0.08$; $p = 0.001$).

Environment safety ($\beta = 0.23$; $p < 0.001$) had a positive association with school engagement, while ACE ($\beta = -0.28$; $p < 0.001$) and SES ($\beta = -0.15$; $p < 0.001$) had negative associations with school engagement. Neighborhood amenities had a small positive association with school engagement ($\beta = 0.04$; $p = 0.025$). SES was associated with environment safety ($\beta = 0.26$; $p < 0.001$), neighborhood amenities ($\beta = 0.30$; $p < 0.001$), and ACE ($\beta = -0.27$; $p < 0.001$). Furthermore, environment safety had a negative association with ACE ($\beta = -0.12$; $p < 0.001$).

Table 3 shows the standardized indirect effects (here, we refer to statistical effects not necessarily causal effects) of latent variables and ADHD diagnosis. All possible indirect pathways depicted in Fig. 3 were examined and reported in Table 3. Total direct effects (if applicable) equal those reported in Fig. 3. For example, SES did not have a direct effect on ADHD and so the direct effect estimate is not available for SES in Table 3. ACE had a direct effect on ADHD and its coefficient estimate and p value in Table 3 ($\beta = 0.08$; $p = 0.001$) are the same as those reported in Fig. 3. Total indirect effects represent the cumulative effect of all potential indirect pathways from one variable to the outcome. For example, SES had a direct effect on all other latent variables including school engagement, which had a direct effect on ADHD. All potential indirect pathways from SES to ADHD were, therefore, estimated. SES carried a total indirect effect on ADHD ($\beta = -0.03$; $p = 0.002$) mostly via ACE and school engagement. ACE ($\beta = 0.10$; $p < 0.001$) and neighborhood amenities ($\beta = -0.01$; $p = 0.025$) had indirect effect on ADHD via school engagement. Furthermore, environment safety had an indirect effect on ADHD ($\beta = -0.10$; $p < 0.001$) via ACE and school engagement.

In supplemental analysis, the model fitting the reciprocal effects of school engagement and ADHD (not shown)

Table 2 Weighted characteristics of measured indicators for latent variables, $n = 65{,}680$

Variables	%
School engagement	
[S.C.]* cares about doing well in school	
Never	1.2
Rarely	1.9
Sometimes	10.8
Usually	21.6
Always	64.5
[S.C.] did all required homework	
Never	1.3
Rarely	1.9
Sometimes	9.8
Usually	22.2
Always	64.8
Socioeconomic status	
Parent education	
Less than high school	21.7
High school graduate	33.2
More than high school	45.1
Caregiver's employment	
Yes	84.9
No	15.1
Household income	
< 100% below FPL^	20.7
100–199% above FPL	21.4
200–399% above FPL	28.9
400% or more above FPL	29.1
Child's health care coverage	
Yes	94.1
No	5.9
Adverse childhood experiences	
Hard to get by on family's income	
Never/rarely hard	74.2
Somewhat often/very often hard	25.8
Lived with a parent or guardian who got divorced or separated after [S.C.] was born	
Yes	25.1
No	74.9
Lived with a parent or guardian who died	
Yes	4.1
No	95.9
Lived with a parent or guardian who served time in jail or prison after [S.C.] was born	
Yes	8.1
No	91.9
Witnessed domestic violence	
Yes	8.9
No	91.1
Victim of violence or witnessed any violence in [his/her] neighborhood	
Yes	11.5
No	88.5
Lived with anyone who was mentally ill	
Yes	10.1
No	89.9

Table 2 (continued)

Variables	%
Lived with anyone who had a problem with alcohol or drugs	
Yes	13.2
No	86.8
Experienced racial/ethnic discrimination	
Yes	5.6
No	94.4
Environment safety	
School safety	
Never	0.6
Sometimes	6.7
Usually	25.4
Always	67.3
Community safety	
Never	2.0
Sometimes	11.0
Usually	31.6
Always	55.3
Neighborhood amenities	
Parks/playgrounds	
Yes	83.6
No	16.4
Sidewalks/walking paths	
Yes	75.9
No	24.1
Recreational center	
Yes	69.2
No	30.8
Library	
Yes	89.1
No	10.9

*Selected child, ^federal poverty level

revealed that ADHD did not have a significant direct effect on school engagement ($\beta = -0.03$; $p = 0.711$). Furthermore, in the subgroup analysis of only children with ADHD (not shown), school engagement continued to have a direct effect on ADHD severity regardless of medication status ($\beta = -0.18$; $p < 0.001$). SES rather than ACE showed a direct effect on ADHD ($\beta = -0.17$; $p < 0.001$) in this model.

Discussion

In this study, a new model examining the relationship between school engagement and ADHD using an ecological framework was developed and tested using SEM. The model was tested using a national representative sample of school-aged children in the US and provided a good fit based on fit indexes. An ecological framework encouraged the inclusion of factors from external environments, such as family, school, and community, in the study of ADHD. These environments and their interactions with each other, in addition to biological factors, provided a more comprehensive understanding of the development of ADHD in children. In addition, the use of SEM allowed for the examination of the complex relationships among these latent environmental factors and their contribution to ADHD diagnosis. It also allowed for the examination of directionality among key variables using cross-sectional data.

Results from the structural model demonstrated that school engagement had an inverse relationship with ADHD such that an increase in level of school engagement corresponds to a decrease in the probability of having ADHD diagnosis. Supplemental analysis further revealed that among children currently diagnosed with ADHD, an increase in level of school engagement results in a decrease in parent-reported severity of ADHD regardless of medication status. The directionality of the findings supported

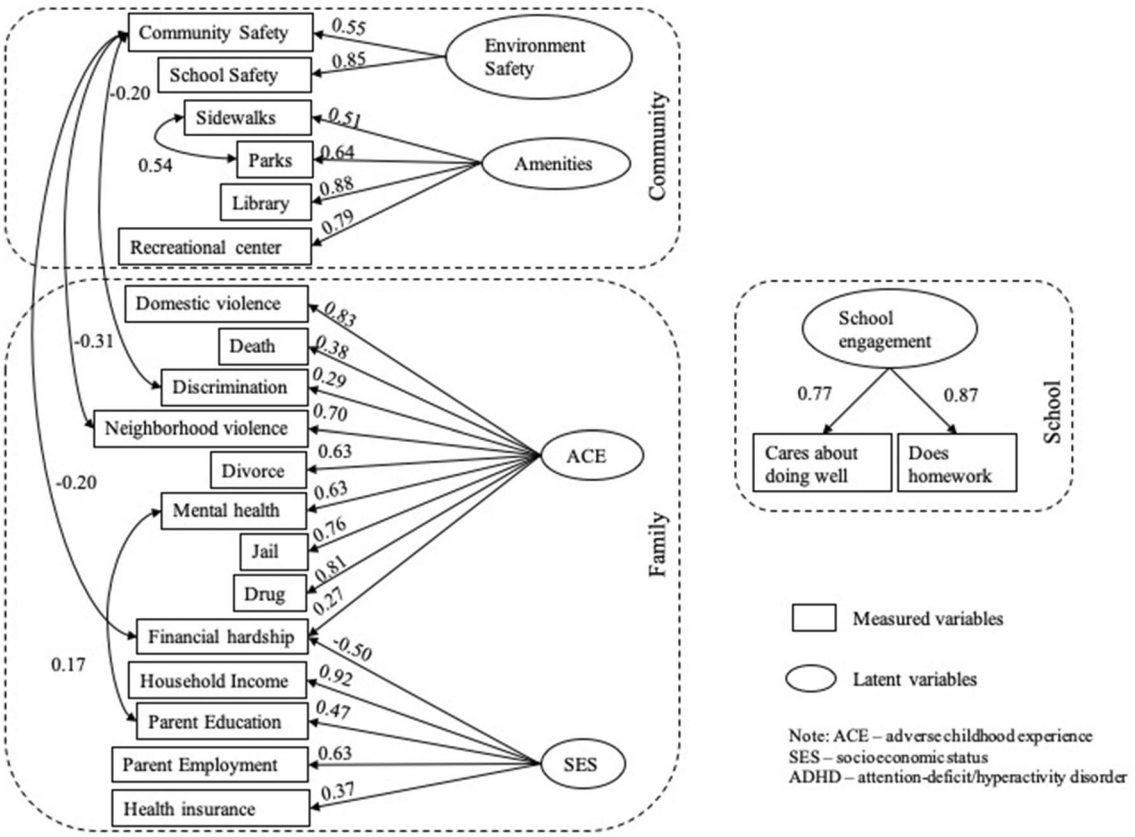

Fig. 2 Standardized loading coefficients of measured indicators (all associated p values < 0.001), including added parameters to improve model fit

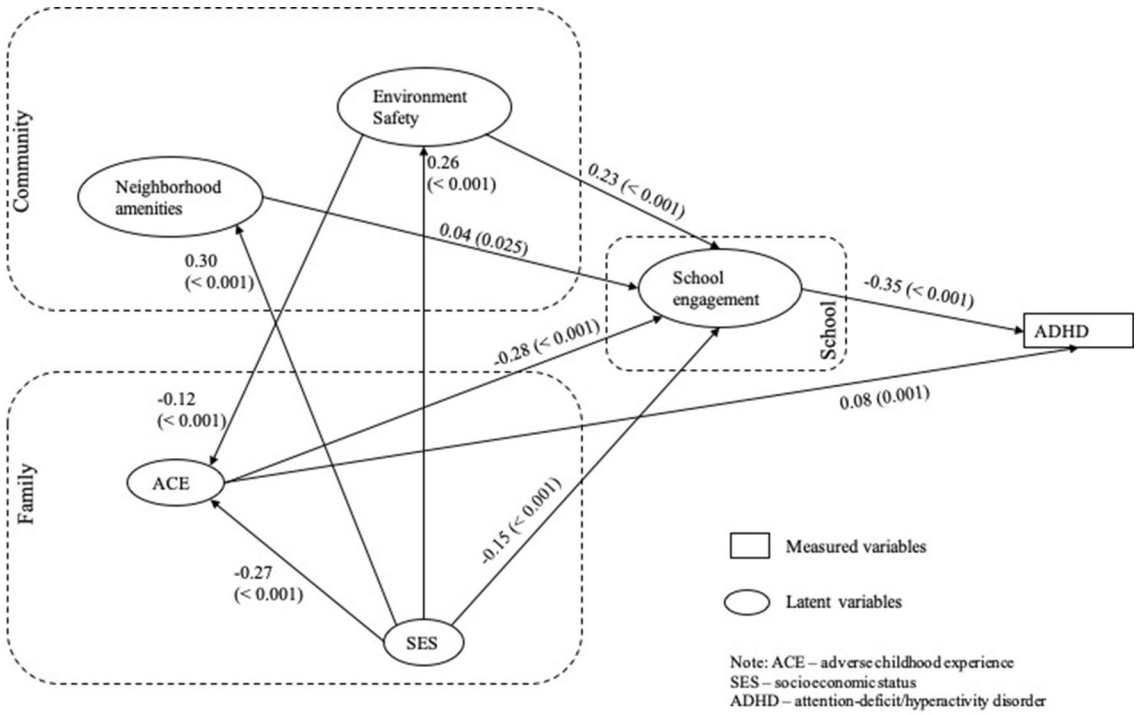

Fig. 3 Standardized path coefficients of latent variables (p values)

Table 3 Standardized path coefficients of latent variables (*p* values)

	β	*p*
Effects from SES to ADHD		
Total effect	−0.03	0.002
Total direct	–	–
Total indirect	−0.03	0.002
Specific indirect effects		
ADHD ← ACE ← SES	−0.02	0.001
ADHD ← engaged ← SES	0.05	< 0.001
ADHD ← ACE ← safety ← SES	−0.00	0.003
ADHD ← engaged ← amenities ← SES	−0.00	0.027
ADHD ← engaged ← ACE ← SES	−0.03	< 0.001
ADHD ← engaged ← safety ← SES	−0.02	< 0.001
ADHD ← engaged ← ACE ← safety ← SES	−0.00	< 0.001
Effects from ACE to ADHD		
Total effect	0.18	< 0.001
Total direct	0.08	0.001
Total indirect	0.10	< 0.001
Specific indirect effects		
ADHD ← engaged ← ACE	0.10	< 0.001
Effects from neighborhood amenities to ADHD		
Total effect	−0.01	0.025
Total direct	–	–
Total indirect	−0.01	0.025
Specific indirect effects		
ADHD ← engaged ← amenities	−0.01	0.025
Effects from safety to ADHD		
Total effect	−0.10	< 0.001
Total direct	–	–
Total indirect	−0.10	< 0.001
Specific indirect effects		
ADHD ← ACE ← safety	−0.01	0.003
ADHD ← engaged ← safety	−0.08	< 0.001
ADHD ← engaged ← ACE ← safety	−0.01	< 0.001

our hypothesis that school engagement may be protective against ADHD diagnosis and symptom. This hypothesis was based on existing literature which emphasized that forming social bonds to prosocial institutions (such as schools) may increase prosocial behavior, decrease delinquency, and reduce the risks of negative mental health outcomes [12], [13], [16], [17]. The causal effect between low school engagement and ADHD diagnosis cannot be established using our cross-sectional data, but rather the findings strongly suggest that school engagement may be one of the environmental protective factors in the diagnosis of ADHD and warrants further research. In addition, we also found other environmental pathways that can potentially influence the diagnosis of ADHD.

Our study found a direct association between ACE and ADHD, supporting a growing body of literature that supports an association between ACEs and increased odds of ADHD in children [28–30]. However, the path coefficients in this study suggested that ACEs have a smaller effect on ADHD compared to school engagement. In addition, environment safety and neighborhood amenities were not associated with ADHD, which is supported by previous research [40]. Rather environment safety and neighborhood amenities contribute indirectly to ADHD through their associations with school engagement as indicated by their significant effects on school engagement in our model. The direct relationships between environment safety, neighborhood amenities, ACE, and family SES with school engagement agreed with findings from our and others' previous work [21–27]. The regression coefficients showed that SES, ACE, and environment safety all had a greater effect on school engagement than neighborhood amenities. Furthermore, examining the total effects of latent variables on ADHD demonstrated that school engagement, ACE, and environment safety have greater influences on ADHD than SES and neighborhood amenities.

Our results did not find a significant direct association between family SES and ADHD. A systematic review of fifteen studies examining SES and ADHD in children was able to meta-analyze results from four of the fifteen studies [31]. Results showed that low SES was associated with higher odds of ADHD (odds ratios = 2.21, 95% confidence interval = 0.22–22.13). The large confidence interval, however, suggested that the data were not sufficient for estimating the true relationship between SES and ADHD. In addition, the meta-analysis did not include studies that used continuous measures or a score-based SES measure. Therefore, while our findings showed that SES contributes directly to ACE, environment safety, neighborhood amenities, and school engagement, the relationship between SES and ADHD is still unclear.

There are limitations in our study. One is the manner in which questions were asked. For example, the question about neighborhood amenities asked parents whether selected amenities are available in the community to their children, which may not necessarily reflect the utilization of these amenities by children. As such, interpretation about the relationship between neighborhood amenities and school engagement or ADHD should be made with caution. However, no studies to our knowledge attempted to account for environmental factors when studying school engagement and ADHD. Our findings, therefore, provide preliminary insights into the relationship between having neighborhood amenities, school engagement, and ADHD.

Second, the cross-sectional nature of the NSCH limits inferences about causality between our key variables. However, the analysis using SEM allowed us to examine the directionality of key variables using cross-sectional data. Third, the low response rates for the landline and cell phone

samples can potentially bias the results if those who did not respond were inherently different than those who answered the survey. However, sampling weights attempted to adjust for the low response rates by making the data representative of all non-institutionalized children in the US. Regardless of these limitations, the study developed and tested a new conceptual model mapping the relationships between environmental correlates, school engagement, and ADHD in a nationally representative sample of school-aged children.

Our findings suggest that improving school engagement might reduce the development of ADHD symptom and diagnosis in children. In addition, the results also indicate that family and community factors might be potential pathways for intervention in the course of ADHD development indirectly via school engagement. School programs aimed at improving students' school engagement can benefit from the inclusion of family and community factors as part of their intervention. Path coefficients also indicate that improving environment safety, reducing ACEs, and family SES may have greater impact on improving school engagement than neighborhood amenities. In addition, addressing issues related to SES can improve almost all other factors in the model. Future research is needed to expand the ecological model of school engagement and ADHD, for instance, by including a genetic component. Additional data, such as measuring the genetic risk for ADHD development in a large sample, would allow research to further expand the ecological model to understand upstream factors that increase risk for ADHD development for those with genetic risk and the potential role of community and school factors that may mitigate or elevate those risks. In a greater context, the examination of modifiable environmental factors using an ecological model can provide insight into the potential contribution of school and community life to other mental health outcomes, not just specifically ADHD.

Acknowledgements This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. On behalf of all authors, the corresponding author states that there is no conflict of interest.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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