Contextual Effects of Neighborhoods and Schools on Adolescent and Young Adult Marijuana Use in the United States

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ABSTRACT: Little is known about the unique contribution of schools vs neighborhoods in driving adolescent marijuana use. This study examined the relative contribution of each setting and the influence of school and neighborhood socioeconomic status on use. We performed a series of cross-classified multilevel logistic models predicting past 30-day adolescent (N = 18 329) and young adult (N = 13 908) marijuana use using data from Add Health. Marijuana use differed by age, sex, race/ethnicity, and public assistance in adjusted models. Variance parameters indicated a high degree of clustering by school ($\sigma^2 = 0.30$) and less pronounced clustering by neighborhood ($\sigma^2 = 0.06$) in adolescence when accounting for both levels simultaneously in a cross-classified multilevel model. Clustering by school persisted into young adulthood ($\sigma^2 = 0.08$). Parental receipt of public assistance increased the likelihood of use during adolescence (odds ratio = 1.39; 95% confidence interval: 1.19-1.59), and higher parental education was associated with increased likelihood of use in young adulthood. These findings indicate that both contexts may be promising locations for intervention.

KEYWORDS: Marijuana, adolescence, emerging adulthood, contextual effects, school, neighborhood, cross-classified models, multilevel modeling

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Background and Aims

In 1996, California made history as the first state to pass medical marijuana legislation; substantial changes in US state-level marijuana policies have occurred since then.[1] As of the 2016 election, 8 states have retail marijuana; Washington, DC has legalized possession and cultivation; and 23 additional states have passed decriminalization and/or medical marijuana laws.[2] Although it has been hypothesized that the national trend toward loosening restrictions on marijuana would lead to increases in adolescent marijuana use,[3] national data do not confirm those expectations. The prevalence of past 30-day use among US high school students decreased to 23.4% in 2013, from 26.7% in 2009.[4,5] There are also a number of methodologically rigorous studies concluding that medical marijuana laws have not led to increases in adolescent marijuana use.[6-8] Given the rapid pace of policy change, continued monitoring of changes in the prevalence of adolescent marijuana use is a key public health priority.[9] Concern about the public health consequences of more liberal marijuana policies has stimulated epidemiologic research on marijuana use, and this work has highlighted large gaps in knowledge about how contextual and psychosocial factors are associated with adolescent marijuana, particularly in comparison with what is known about alcohol or tobacco use. Now more than ever, we need to identify how psychosocial factors affect risk for adolescent marijuana use[6] so as to provide a foundation for the development of effective prevention strategies.[10]

Socioeconomic status (SES) may be a key marker of risk for engagement in marijuana use. Defined as the "relative position of a family or individual on a hierarchical social structure, based on access to or control over wealth, prestige, resources, and power,"[11] SES is a strong predictor of health status throughout the life course; SES in adolescence has implications for future adult health and behaviors.[11–14] Specifically, low SES in childhood increases risk for several adolescent risk behaviors, including cigarette smoking, poor nutrition, and sedentary behavior.[15] The nature of the association between SES and marijuana use is unclear.[15-17] The best evidence suggests that the association is not linear and varies by age, sex, and race/ethnicity.[16-18] Summary data from the Monitoring the Future study show that low parental education is associated with higher use among 8th graders but not among 12th graders. Those data also indicate that the associations between family SES and marijuana use are stronger among whites as compared with blacks or Hispanics.[19] Finally, although low SES (eg, poverty) is typically associated with poor health outcomes, research shows that high family SES may be a marker of risk for adolescent marijuana use.[20]

Socioeconomic status does not operate solely at the level of adolescents or their families. Several researchers have noted the importance of investigating how "contextual" SES—ie, the SES of the contexts in which adolescents are embedded—relates to health and behavior. There is an insufficient body of research available that describes how contextual SES relates to adolescent marijuana use and that is the focus on this study. We used cross-classified multilevel modeling (CCMM)[21] to estimate the influence of the school and neighborhood contexts simultaneously and to incorporate contextual measures of SES. The CCMM approach is superior to hierarchical multilevel modeling when examining nonhierarchical contexts. Hierarchical multilevel modeling overestimates the importance of contexts under consideration (eg, schools) when cross-classified contexts that are salient (eg, neighborhoods) are eliminated from the model.[21]

To address gaps in knowledge about the association between SES and marijuana use, we examined the extent to which individual-level, school-level, and neighborhood-level SES in adolescence were associated with marijuana use in adolescence and young adulthood. We used CCMM to estimate the independent and joint influence of schools and neighborhoods on use, whereas also examining individual-level effects. This study had 2 aims. First, we estimated the level of variation in marijuana use in schools and neighborhoods: (1) cross-sectionally, among a national sample of 12- to 19-year olds and (2) longitudinally, when the same respondents were 24- to 32-year olds. In the longitudinal analysis, we nested respondents in the neighborhood they resided in and school they attended as adolescents and estimate their risk for marijuana use in adulthood. This enabled us to determine the extent to which clustering at the school and neighborhood levels persists into adulthood.[22] Second, we examined the association between SES at the family, school, and neighborhood levels in adolescence with (1) adolescent marijuana use and (2) marijuana use in young adulthood. Data are from the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative longitudinal survey of adolescents in the United States.[23]

Methods

Data source

Add Health is a school-based sample of adolescents who were in grades 7 to 12 when first interviewed in 1994-1995 (Wave I). The sampling strategy consisted of a systematic random sample of high schools and "feeder" schools (ie, middle schools whose students matriculate into the selected high school). A total of 132 schools participated, which was 79% of those sampled. An in-school survey was completed by 90 118 students, and 20 745 students participated in an additional, detailed in-home interview (75.6% and 79.5% of eligible students, respectively). During the in-home interview, 85% of students' caregivers (usually the mother) were also interviewed (85%, n = 17 760).[23-25]

We used Wave I data from the in-school survey, in-home interview, and the parent questionnaire. Individual-level data were drawn from the 20 745 youth who completed the in-home survey. Respondents whose caregivers had not completed the parent survey were retained in the sample. We excluded those who were missing information on: school (n = 660), marijuana use (n = 402), other individual-level predictors or covariates (n = 845), school-level demographics (n = 493), or neighborhood-level demographics (n = 16). Our analytic sample included 18 329 students nested in 128 schools and 2255 neighborhoods (ie, census tracts) for the cross-sectional analysis. Data from the Wave IV in-home interview (collected in 2008-2009) were used to explore the longitudinal effects of school and neighborhood on marijuana use in young adulthood for 13 908 participants who were not missing any variables at Wave I and for whom there was data available on past 30-day marijuana use at Wave IV.

Measures

Marijuana use. The primary outcome variable was past 30-day marijuana use at Wave I. Respondents indicated the frequency of marijuana use in the past 30 days, which we recoded to create a binary outcome. Past 30-day marijuana use in young adulthood at Wave IV was constructed in a similar manner.

Socioeconomic status. We used 2 indicators of SES: receipt of public assistance as a proxy for poverty and parental educational attainment as a graded indicator of status. The individual-level indicators for family receipt of public assistance (eg, enrollment in the Aid to Families with Dependent Children program) and parental educational attainment were constructed from the parent report, if available, and from the adolescent participant report if a parent did not provide information. We used parent report of educational attainment to develop a 4-level variable representing the highest level of parent education among all resident caregivers. The categories were as follows: (1) did not complete high school, (2) graduated from high school (including completion of an equivalency test), (3) attended college, and (4) completed college.

For both indicators (ie, receipt of public assistance and parental education), we created analogous variables at the school and neighborhood levels. Individual reports of receipt of public assistance from the total in-school sample were aggregated by school to construct a school-level measure of the percentage of students receiving public assistance. The school-level measure of parental education was constructed to reflect the proportion of students in that school with at least 1 parent who had completed college, aggregated to the school-level from individual responses to the in-school survey. Data on neighborhood-level SES public assistance and educational attainment come from 2 variables from the 1990 US Census: percentage of families currently receiving public assistance, and the percentage of residents (>25 years old) with a college degree or above.

Demographic factors. We included sex, age, and race/ethnicity as covariates. Self-reported race and ethnicity were used to construct a single variable with the following categories: white, black/African American, Hispanic, Asian/Pacific Islander, Native American, other, and multiracial.

Statistical analysis

Initially, we present descriptive statistics on individual-level demographic and SES factors overall and by Wave I and Wave IV past 30-day marijuana use. Differences in marijuana use by demographic factors were examined using chi-square tests. Descriptive and bivariate statistics were computed using SAS (version 9.4; Cary, NC, USA).

In the remaining analyses, we use cross-classified multilevel logistic regression models to examine: (1) between-level variation (random effects) in past 30-day marijuana use during adolescence and young adulthood and (2) individual-level, school-level, and neighborhood-level predictors of past 30-day marijuana use (fixed effects) in adolescence and young adulthood. In addition to the predictors discussed above, age, race/ethnicity, and sex were included in the models as covariates. Models were fit using MLwiN (version 2.29; Birmingham, UK) with the STATA (version 13; College Station, TX, USA) package runmlwin.[26] Multilevel and cross-classified multilevel models automatically adjust for sample size of schools and neighborhoods, downweighting the importance of schools and neighborhoods with small sample sizes so that they do not bias estimates of random effects. The software uses Bayesian estimation procedures and Markov Chain Monte Carlo methods with noninformative priors and a Metropolis-Hastings sampling algorithm allowing for simultaneous modeling of nonhierarchically nested contexts. The deviance information criterion (DIC) was used to assess model fit with lower values indicating better model fit.[27–30] Odds ratios and 95% credible intervals (CIs) are presented for fixed effects, parameter estimates and standard errors for intercepts, and variance estimates and 95% CIs for random effects.

Model building proceeded in several steps. First, we examined the independent contributions of neighborhood and school contexts (separately) on the outcome using 2-level hierarchical null (or unconditional) models. These models were fit by including individuals nested within either the school or the neighborhood level. Next, school and neighborhood contexts were examined simultaneously by allowing for cross-classification of the 2 contexts and compared with the single-context only models to verify that cross-classification was necessary in these analyses. Subsequent models incorporated this cross-classification of school and neighborhood. Specifically, a series of 4 models were fit to predict past 30-day marijuana use during adolescence (Wave I): (1) individual-level predictors and covariates, (2) individual predictors and covariates plus school-level demographics, (3) individual predictors and covariates plus neighborhood-level demographics, and (4) all individual-level, school-level, and neighborhood-level predictors and covariates. A similar series of 4 models were fit predicting past 30-day marijuana use during young adulthood (Wave IV) including Wave IV age as a covariate.

Results

Description of sample

Among the 18 329 respondents included at Wave I, there were 2760 unique combinations of school and neighborhood. The data structure was fully cross-classified; adolescents attending the same school resided in multiple neighborhoods, and adolescents residing in the same neighborhood often attended different schools in the same neighborhood. The median number of students per school was 117.5 (range: 18-1588, n = 128 schools; Table 1). In total, 45% of neighborhoods (n = 1017) had only 1 respondent, and the median number of adolescents per neighborhood was 2 (range: 1-267, n = 2255 neighborhoods). There was a median of 1 school per neighborhood (range: 1-3) and a median of 13.5 neighborhoods per school (range: 1-224).

Table 2 presents descriptive statistics for the sample, as well as prevalence estimates for past 30-day marijuana use during adolescence (Wave I) and young adulthood (Wave IV) overall, and by demographic factors. In total, 51% of respondents were white, 49% were men, and the mean age at Wave I was 15.6 (SD: 1.7). Also, at Wave I, 32% had a parent with a college degree and 10% reported receiving public assistance.

The past 30-day prevalence of marijuana use at Wave I was 14.2% and 15.9% at Wave IV (Table 2). Use was higher among men compared with women at both time periods. The prevalence of use increased with age at Wave I and decreased with age at Wave IV. At Wave I, Native American and multiracial respondents had the highest rates of use (32% and 19%), whereas Asians had the lowest (9%). The prevalence for all other groups ranged between 12% and 15%. Native American and multiracial respondents also had the highest rates of use in young adulthood (18% and 23%), but they were not substantially higher than for the other groups (range: 9%-17%). Across all schools, the median percentage of students reporting past 30-day marijuana use was 11% (range: 0%-34%). Figure 1 presents a histogram of school percentage of students reporting past 30-day use indicating a wide degree of variation in marijuana use at the school level. Across neighborhoods, the median

Table 1. School-level and neighborhood-level socioeconomic status: Add Health, Wave I (1994-1995) (N = 18 329).

	MEDIAN	RANGE
School level (n = 128)		
No. of respondents	117.5	18-1588
% college degree	28.3	5.5-91.2
% public assistance	7.2	0.0-45.4
Neighborhood level (n = 2255)		
No. of respondents	2	1-267
% college degree	20.3	0.0-82.5
% public assistance	7.3	0.0-67.5

Table 2. Past 30-day marijuana use, by demographic factors: Add Health, Wave I (1994-1995; N = 18 329), and Wave IV (2008-2009; N = 13 908).

	WAVE I		WAVE IV	
	TOTAL (N = 18 329)	PAST 30-DAY USE (N = 2610)	TOTAL (N = 13 908)	PAST 30-DAY USE (N = 2214)
Age (Wave I), y				
≤14	5163 (28%)	371 (7%)	4352 (31%)	805 (18)
15-16	6912 (38%)	1116 (16%)	5187 (37%)	816 (16%)
≥17	6524 (34%)	1123 (17%)	4369 (31%)	593 (14%)
Sex				
Male	9062 (49%)	1459 (16%)	6493 (47%)	1322 (20%)
Female	9267 (51%)	1151 (12%)	7415 (53%)	892 (12%)
Race/ethnicity				
White	9306 (51%)	1385 (15%)	7390 (53%)	1224 (17%)
Black	3751 (20%)	457 (12%)	2806 (20%)	476 (17%)
Asian/Pacific Islander	1176 (6%)	103 (9%)	778 (6%)	71 (9%)
Hispanic	3064 (17%)	464 (15%)	2185 (16%)	280 (13%)
Native American	102 (1%)	33 (32%)	67 (<1%)	12 (18%)
Other	159 (1%)	19 (12%)	107 (1%)	18 (17%)
Multiracial	771 (4%)	149 (19%)	575 (4%)	133 (23%)
Public assistance				
Yes	1748 (10%)	294 (17%)	1220 (9%)	197 (16%)
No	16 581 (90%)	2316 (14%)	12 688 (91%)	2017 (16%)
Parent education				
<High school	2328 (13%)	332 (14%)	1655 (12%)	186 (11%)
High school graduate	4778 (26%)	666 (14%)	3596 (26%)	551 (15%)
Some college	5390 (29%)	835 (15%)	4152 (30%)	726 (17%)
College graduate	5833 (32%)	777 (13%)	4505 (32%)	751 (17%)

All *P* values testing for association between demographic and socioeconomic characteristics and past 30-day marijuana use were <0.05 (not shown). Parent education represents the parent with the highest level of educational attainment. Age categories at Wave IV were the following: ≤27, 28 to 29, and ≥30-31 years.

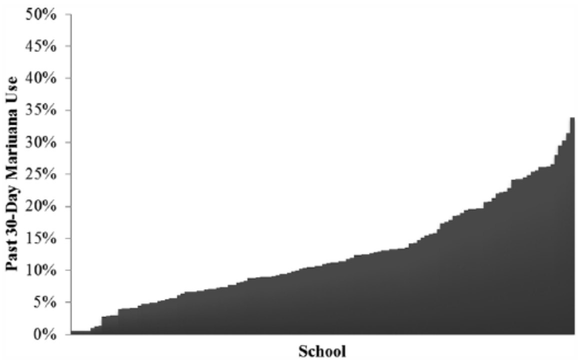

Figure 1. Percentage of students reporting past 30-day marijuana use by school (n = 128 schools): Add Health, Wave I (1994-1995) (N = 18 329).

percentage of respondents reporting marijuana use was 0% (range: 0%-100%).

Table 3 presents fixed and random effects for the school-only, neighborhood-only, and cross-classified null models. Results from the single-context models would seem to indicate that there is similar variability at the school level or neighborhood level when the other context is not considered. Between-school variance in the school-only model was 0.46 (95% CI: 0.32-0.64), compared with the between-neighborhood variance estimate of 0.33 (0.24-0.42) for the neighborhood-only model. However, considering both contexts simultaneously in the cross-classified model shows that most of the between-level variability in marijuana smoking is at the school level $(\sigma^2_{\text{school}} = 0.43)$, whereas the between-neighborhood variance is diminished $(\sigma^2_{\text{neighborhood}} = 0.06)$ after accounting for school level. This reinforces the necessity of conducting CCMM in this study, and cross-classification was used in all subsequent models.

Cross-sectional analysis examining marijuana use during adolescence

Table 4 presents fixed and random effects from the 4 logistic CCMMs of Wave I marijuana use. Model 1 included individual-level predictors and covariates only. Adding individual-level fixed effects to the null cross-classified model (from Table 3) mildly attenuated between-school variance $(\sigma^2_{\text{school}} = 0.30)$ with minimal effect on neighborhood-level variance $(\sigma^2_{\text{neighborhood}} = 0.06)$. Receiving public assistance, male sex, and older age are associated with an increased odds of past 30-day marijuana use. Relative to whites, blacks, and Asian/Pacific Islanders demonstrated lower odds of marijuana use, whereas Native American and multiracial respondents demonstrated higher odds of marijuana use. There was no association between parental education and recent marijuana use.

Table 4 also presents Models 2 to 4, which include individual predictors and covariates along with: school-level factors (model 2), neighborhood-level factors (model 3), and both school-level and neighborhood-level factors (model 4). Trends in individual covariates persist after adjusting for school-level and neighborhood-level demographics. Importantly, no school-level or neighborhood-level indicators of SES covariates were associated with marijuana use.

Two sets of post hoc analyses were conducted to explore these results further.

First, we performed additional sensitivity analyses on the fully adjusted cross-sectional Wave I outcome in adolescence to examine the effect of neighborhood size on our ability to estimate the variance parameters. One potential concern was that having many neighborhoods in the sample with small sample size might bias our estimates of the neighborhood-level variance despite the automatic downweighting of neighborhoods with small sample size in the CCMM estimation. We performed the following 2 sensitivity analyses: (1) dropping any neighborhoods with only 1 respondent (dropping n = 1017 neighborhoods; N = 1017 participants) and (2) dropping any neighborhoods with fewer than 5 respondents (dropping n = 1660 neighborhoods; N = 2693 participants). We present the variance parameters and 95% CIs for these sensitivity analyses and the original analysis (model 4; Table 4) in Supplemental Table 1. Excluding neighborhoods with only 1 respondent yielded similar variance parameters at the school ($\sigma^2 = 0.28$) and neighborhood ($\sigma^2 = 0.06$) in the fully adjusted model predicting adolescent marijuana use. Excluding neighborhoods with fewer than 5 respondents also yielded similar results $(\sigma^2_{\text{school}} = 0.28; \sigma^2_{\text{neighborhood}} = 0.04)$. Both the neighborhood and school variance parameters are robust to excluding small neighborhoods despite many neighborhoods having only 1 respondent.

Second, we explored the meaningfulness of the cross-sectional school-level variance result $(\sigma^2_{\text{school}} = 0.30)$. The school-level variance parameter describes the variation between schools in the magnitude of the school-level effects. In other words, assuming a causal interpretation, attending a certain school may increase or decrease the likelihood of a given adolescent using marijuana. This "school effect" for each school can be estimated after the model is fit. These posterior estimates of the random effects are also known as empirical Bayes estimates or best linear unbiased predictions (BLUPs). Calculating BLUPs and then comparing their magnitude with other significant fixed effects can therefore help us to understand the meaningfulness of the school-level variance results. In this case, we compare the magnitude of the BLUPs from the cross-sectional fully CCMM (model 4; Table 4) to the magnitude of the fixed effects for female sex and receipt of public assistance. As noted above, female sex is protective against marijuana use in Wave I, and on the log odds scale, this difference is −0.28. Of the 128 schools in the sample, 67 (52.3%) have a school effect (BLUP) of this magnitude or larger (in terms of absolute values). Receipt of public assistance is associated with increased odds of marijuana use in Wave I, and on the log odds scale, this difference is 0.32. Of the 128 schools, 61 (47.7%) have a school effect of this magnitude or larger. These are substantial and meaningful differences between schools in the "school effect." In approximately half of schools, attending those schools is associated with a greater impact on student likelihood to use marijuana than public assistance or female sex.

Table 3. Null models of variation in past 30-day marijuana use across school and neighborhood contexts: Add Health, Wave I (1994-1995) (N = 18 329).

	MODEL		
	SCHOOL ONLY	NEIGHBORHOOD ONLY	CROSS-CLASSIFIED
Fixed effect estimates			
Intercept (SE)	−2.09 (0.07)	−1.91 (0.03)	−2.08 (0.07)
Random effect estimates			
Neighborhood	—	**0.33 (0.24-0.42)**	**0.06 (0.03-0.12)**
School	**0.46 (0.32-0.64)**	—	**0.43 (0.31-0.60)**
DIC fit statistic	14 328	14 640	14 306

Parameter estimate (standard error) is reported for intercepts for fixed effects; variance parameters (95% credible intervals) are reported for random effects. Deviance information criterion (DIC) is a measure of model fit. Two-sided tests were performed for fixed effects; 1-sided tests were performed for random effects. Statistically significant effects are printed in bold (P<0.05).

Longitudinal analyses examining marijuana use in young adulthood

Cross-classified models predicting marijuana use at in young adulthood are presented in Table 5. In Wave IV, male sex was still associated with elevated odds of past 30-day marijuana use, but the effect of age was reversed, with older age being associated with decreased odds of use. Compared with whites, Asian/Pacific Islanders remained less likely to use marijuana, whereas multiracial participants remained more likely to do so. Although parent education was not associated with marijuana use in Wave I, it was statistically significant in young adulthood. Adults whose parents had at least a high school degree had higher odds of marijuana use than those whose parents had not completed high school. By contrast, family receipt of public assistance—which was a significant predictor of use in Wave I—was not predictive of marijuana use by Wave IV.

Similar to the Wave I models, school-level and neighborhood-level SES were not significant predictors of Wave IV marijuana use. Importantly, the random effect at the school level persisted into Wave IV. The school-level variance parameter for schools was reduced from 0.31 in Wave I to 0.08 in Wave IV (ie, more than 25% of the school-level clustering remain), indicating that young adults' marijuana use was similar to those with whom they attended school in adolescence. The neighborhood-level variance parameter, which initially in Wave I was 0.04, was attenuated to 0.01 in Wave IV.

Discussion

The purpose of this work was to examine the effects of school and neighborhood context on marijuana use and to estimate whether contextual SES was associated with use. We used cross-classified multilevel models to simultaneously examine the contextual effects of both school and neighborhood on marijuana use cross-sectionally (ie, in adolescence) and longitudinally (ie, in young adulthood). Of the 2 contexts, schools explained more variability than neighborhoods in marijuana use, with school-level variance being approximately 4 times that of the neighborhood. There are substantial and meaningful differences between schools in the "school effect." In approximately half of schools, attending those schools is associated with a greater impact on student likelihood to use marijuana than public assistance or female sex. This finding reinforces the importance of the school setting in existing prevention programming.[31]

We also found that school clustering persisted to a significant degree into young adulthood. The ongoing importance of schools may be due to adolescence being a "sensitive period" when lifelong behavioral patterns are established.[32,33] Regardless of the underlying mechanism, these findings indicate the potential for school-level or neighborhood-level interventions in adolescence to exert ongoing effects into young adulthood. Examining persistence of school-level and neighborhood-level clustering is still highly novel, with only 1 study we are aware of examining the persistence of school-level clustering (of weight-status outcomes).[22]

Findings indicate that marijuana use is common among adolescents regardless of SES, and that none of the school-level or neighborhood-level SES indicators were associated with marijuana use. Taken alongside the existing literature on SES and marijuana use, our results underscore the complex relationship between SES and marijuana use. The association between SES (individual and contextual) and marijuana use may be different for behavioral outcomes, such as early pregnancy and cigarette use, for which low SES is a strong marker of risk. In addition, the prevalence of marijuana use may be similar across levels of contextual SES, as it is across levels of individual SES. This limited variability makes it difficult to estimate the association between the 2 variables. A promising approach for future research may be to examine within-group differences in marijuana use among populations with different levels of SES.

Limitations

This study has several limitations that should be noted. The analysis was based on a nationally representative sample of adolescents selected for participation through school-based

Table 4. Cross-classified multilevel models predicting past 30-day marijuana use: Add Health, Wave I (1994-1995) (N = 18 329).

	MODEL			
	MODEL 1: INDIVIDUAL	MODEL 2: INDIVIDUAL, SCHOOL	MODEL 3: INDIVIDUAL, NEIGHBORHOOD	MODEL 4: INDIVIDUAL, SCHOOL, AND NEIGHBORHOOD
Fixed effect estimates				
Intercept (SE)	−4.66 (0.19)	−5.17 (0.21)	−4.89 (0.25)	−5.22 (0.53)
Individual level				
Age	**1.19 (1.17-1.22)**	**1.20 (1.17-1.23)**	**1.20 (1.18-1.24)**	**1.19 (1.14-1.23)**
Female	**0.76 (0.70-0.83)**	**0.76 (0.70-0.82)**	**0.76 (0.69-0.83)**	**0.76 (0.69-0.83)**
Public assistance	**1.37 (1.17-1.58)**	**1.37 (1.16-1.58)**	**1.38 (1.18-1.62)**	**1.39 (1.19-1.59)**
Parent education				
Less than high school	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
High school graduate	1.04 (0.90-1.21)	1.05 (0.91-1.22)	1.06 (0.91-1.22)	1.07 (0.91-1.23)
Some college	1.14 (0.98-1.34)	1.14 (0.98-1.32)	1.16 (0.98-1.33)	1.17 (1.00-1.34)
College graduate	0.99 (0.85-1.16)	0.98 (0.84-1.15)	1.00 (0.84-1.16)	1.00 (0.85-1.17)
Race/ethnicity				
White	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Black	**0.85 (0.73-0.98)**	**0.83 (0.71-0.97)**	**0.85 (0.74-0.99)**	**0.83 (0.71-0.98)**
Asian/Pacific Islander	**0.41 (0.32-0.51)**	**0.40 (0.31-0.50)**	**0.41 (0.31-0.52)**	**0.40 (0.31-0.52)**
Hispanic	1.07 (0.91-1.25)	1.06 (0.91-1.25)	1.08 (0.92-1.24)	1.07 (0.91-1.24)
Native American	**2.48 (1.50-3.87)**	**2.37 (1.45-3.69)**	**2.46 (1.48-3.81)**	**2.42 (1.46-3.77)**
Other	0.71 (0.42-1.13)	0.70 (0.39-1.10)	0.71 (0.42-1.14)	0.70 (0.41-1.08)
Multiracial	1.28 (1.03-1.54)	1.27 (1.02-1.56)	1.28 (1.05-1.55)	1.27 (1.03-1.56)
School level				
% college degree	—	1.01 (1.00-1.02)	—	1.01 (1.00-1.02)
% public assistance	—	1.01 (1.00-1.03)	—	1.02 (1.00-1.03)
Neighborhood level				
% college degree	—	—	1.00 (1.00-1.01)	1.00 (1.00-1.01)
% public assistance	—	—	1.00 (0.99-1.01)	1.00 (0.99-1.01)
Random effect estimates				
Neighborhood	**0.04 (0.02-0.08)**	**0.07 (0.04-0.12)**	**0.05 (0.03-0.09)**	**0.06 (0.02-0.16)**
School	**0.31 (0.22-0.43)**	**0.29 (0.19-0.40)**	**0.29 (0.20-0.42)**	**0.30 (0.20-0.43)**
DIC fit statistic	14 075	14 073	14 082	14 083

Odds ratios (95% credible intervals [CIs]) are reported for fixed effects (2-sided tests); variance parameters (95% CIs) are reported for random effects (1-sided tests). Parameter estimate and standard error (SE) are reported for intercepts. DIC refers to deviance information criterion, a measure of model fit. Statistically significant effects are printed in bold ($P < .05$).

sampling. Due to the sampling strategy, the number of adolescents per school was much greater than per neighborhood, with a large number of neighborhoods having only 1 individual. This raises the possibility that findings are a reflection of sampling design. However, examinations of other outcomes in Add Health using cross-classified modeling have demonstrated meaningful effects at both school and neighborhood, which suggest that the findings are unlikely an artifact of the sampling strategy.[21,34,35] In addition, sensitivity analyses excluding neighborhoods with only 1 respondent and excluding

Table 5. Cross-classified multilevel models predicting past 30-day marijuana use in young adulthood (Wave IV; 2008-2009) based on adolescent predictors (Wave I; 1994-1995), Add Health (N = 13 908).

	MODEL			
	MODEL 1: INDIVIDUAL	MODEL 2: INDIVIDUAL, SCHOOL	MODEL 3: INDIVIDUAL, NEIGHBORHOOD	MODEL 4: INDIVIDUAL, SCHOOL, AND NEIGHBORHOOD
Fixed effect estimates				
Intercept (SE)	0.96 (0.43)	0.83 (0.25)	0.41 (0.37)	0.59 (0.29)
Individual level (Wave I)				
Age (Wave IV)	**0.91 (0.89-0.93)**	**0.91 (0.90-0.92)**	**0.93 (0.91-0.95)**	**0.92 (0.90-0.94)**
Female	**0.52 (0.47-0.57)**	**0.51 (0.47-0.56)**	**0.52 (0.47-0.57)**	**0.52 (0.47-0.56)**
Public assistance	1.14 (0.97-1.34)	1.14 (0.96-1.36)	1.13 (0.95-1.34)	1.13 (0.94-1.34)
Parent education				
Less than high school	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
High school graduate	**1.30 (1.07-1.54)**	**1.30 (1.07-1.55)**	**1.26 (1.05-1.52)**	**1.30 (1.08-1.55)**
Some college	**1.47 (1.24-1.72)**	**1.45 (1.22-1.75)**	**1.41 (1.17-1.68)**	**1.45 (1.22-1.75)**
College graduate	**1.42 (1.18-1.72)**	**1.39 (1.15-1.68)**	**1.35 (1.10-1.64)**	**1.38 (1.12-1.67)**
Race/ethnicity				
White	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)	1.0 (ref.)
Black	1.15 (0.99-1.30)	1.12 (0.97-1.28)	1.12 (0.97-1.29)	1.11 (0.96-1.29)
Asian/Pacific Islander	**0.49 (0.37-0.63)**	**0.49 (0.37-0.63)**	**0.49 (0.37-0.62)**	**0.48 (0.36-0.63)**
Hispanic	0.88 (0.75-1.04)	0.88 (0.74-1.04)	0.87 (0.73-1.02)	0.87 (0.73-1.03)
Native American	1.11 (0.52-1.99)	1.08 (0.50-1.93)	1.11 (0.51-2.04)	1.08 (0.53-1.91)
Other	0.99 (0.54-1.57)	0.98 (0.57-1.60)	0.98 (0.55-1.57)	0.98 (0.55-1.61)
Multiracial	**1.49 (1.20-1.81)**	**1.47 (1.18-1.83)**	**1.47 (1.17-1.81)**	**1.47 (1.17-1.78)**
School level				
% college degree	—	1.00 (0.99-1.01)	—	1.00 (0.99-1.01)
% public assistance	—	1.01 (0.99-1.02)	—	1.00 (0.99-1.01)
Neighborhood level				
% college degree	—	—	1.00 (0.99-1.01)	1.00 (0.99-1.01)
% public assistance	—	—	1.01 (0.99-1.01)	1.01 (1.00-1.02)
Random effect estimates				
Neighborhood	0.01 (0.00-0.03)	**0.06 (0.03-0.11)**	**0.05 (0.02-0.12)**	**0.02 (0.01-0.06)**
School	**0.08 (0.05-0.13)**	**0.07 (0.03-0.12)**	**0.07 (0.03—0.12)**	**0.08 (0.04-0.13)**
DIC fit statistic	11 818	11 817	11 816	11 821

Odds ratios (95% credible intervals [CIs]) are reported for fixed effects (2-sided tests); variance parameters (95% CIs) are reported for random effects (1-sided tests). Parameter estimate and standard error (SE) are reported for intercepts. DIC refers to deviance information criterion, a measure of model fit. Statistically significant effects are printed in bold ($P < .05$).

neighborhoods with fewer than 5 respondents yielded similar results to the main analysis. These results indicate that estimates of variance parameters are robust to extremes in neighborhood size.

Another limitation is the age of the data, particularly Wave I data, which were collected in the mid-1990s. We opted to use Add Health because it comprises a large, nationally representative sample of adolescents and has information about their schools and neighborhoods. It is one of very few data sets available to examine our specific research questions. In addition, the fact that the data are from the mid-1990s enables us to establish the effects of adolescent social environments and sociodemographic risk factors on today's adults—ie, those born when marijuana use was at its highest (late 1970s) and who have witnessed changes in the legal status of marijuana. The longitudinal impacts of contexts and risk factors on a more recent cohort are important, but will not be visible for a number of years.

Conclusions

This study also adds to the current literature by examining the longitudinal impact of school and neighborhood on marijuana use into young adulthood. Results suggest that there are school and neighborhood contributions to the likelihood of marijuana use during adolescence, along with small but persistent contextual effects predicting marijuana use into young adulthood. Future research is need to further elucidate mechanisms through which schools and neighborhoods influence marijuana use as markers of SES in this analysis indicated no relationship with marijuana use. However, this study demonstrates the salience of schools and neighborhoods as predictors of marijuana use, particularly in adolescence, indicating that these contexts may provide unique opportunities for targeted interventions or policy change.

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Author Contributions

CEM, ECD, and TKR conceived and designed the study and analysis. CEM analyzed the data and wrote the first draft of the manuscript. CEM, RMJ, ECD, TKR, and CRE contributed to the writing of the manuscript; agree with manuscript results and conclusions; and made critical revisions and approved final version. CEM and RMJ jointly developed the structure and arguments for the paper.

Disclosures and Ethics

As a requirement of publication, author(s) have provided to the publisher signed confirmation of compliance with legal and ethical obligations including but not limited to the following: authorship and contributorship, conflicts of interest, privacy and confidentiality, and (where applicable) protection of human and animal research subjects. The authors have read and confirmed their agreement with the ICMJE authorship and conflict of interest criteria. The authors have also confirmed that this article is unique and not under consideration or published in any other publication, and that they have permission from rights holders to reproduce any copyrighted material. The external blind peer reviewers report no conflicts of interest.

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