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Residential Greenspace and Adolescent Outcome: Exploring Associations and Interactions with Peer Deviance

By

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Abstract

Greenspace is becoming a popular area of study in health research. Past research has linked greenspace and improved adult physical and mental health, but the research on children and adolescents remains mixed. This study explores the relationship between greenspace and adolescent outcomes, including antisocial behavior and depression. The role of peer group in this relationship was also examined. Survey data from a subset of an in-lab sample was used in this study, and public greenspace data was collected from satellite imagery. Pearson correlation tests between demographic variables, greenspace measures, and outcome variables were run, and multiple linear regression models were used to test the impact of greenspace on internalizing and externalizing outcomes. Results found that tree canopy is strongly related to demographic factors but is not significantly related to outcomes when these factors are present. Subgroups of each demographic variable and peer deviance were used to further explore associations. These analyses found for non-Black youth that greenspace was significantly, negatively related to depression. Furthermore, greenspace was related to outcomes on a significant level for youth in the high SES group. Greenspace was not found to be related to peer group deviance. This research provides evidence that greenspace is strongly related to socioeconomic factors and not directly related to outcomes. It may be that these factors are the link between greenspace and adolescent outcome.

INTRODUCTION

Greenspace is becoming a popular area of study in many different fields, especially as it pertains to health. At present, there are multiple theoretical pathways being studied for the role of greenspace and its effects. One theory, proposed by Ulrich (1983), states that people have a positive emotional response to nature, allowing them to transition from a stressful state to an unstressed state (Stress Reduction Theory). The Attention Restoration Theory claims that greenspace allows top-down, directed attention resources to be replenished (Kaplan & Kaplan, 1989). The Collective Restoration Theory (Hartig et al., 2021) focuses on greenspace being a place for social relationships to prosper, which lead to the effects found in studies. The varying theories from different disciplines illustrates how greenspace is being studied from a variety of perspectives. The different measures of greenspace further demonstrate this, from only including parks, to including any area that is green – such as cemeteries (Taylor & Hochuli, 2016).

There is considerable amount of literature on the impacts of greenspace on adults, with results generally supporting an association between greenspace and improved mental and physical health. In Wisconsin, researchers operationalized greenspace as percentage of vegetation coverage and tree canopy and found that more greenspace corresponded to better mental health outcomes in a sample of 2,479 adults, age 21-74 years, when controlling for confounders (Beyer et al., 2014).

In New Zealand, research on 3149 residents, aged 15 years and older, found that higher proportions of greenspace and access to useable greenspace were related to a decrease in anxiety and mood disorders (Nutsford et al., 2013). The pathway for greenspace and mental health was studied in Bulgaria, where research on 399 students (15-25 years old)

found that greenspace is linked to restorative quality, which is connected to physical activity and social cohesion, both of which improve mental health (Dzhambov, A., 2018). Greenspace in this study included anything larger than 500 square meters. However, due to children's period of development and sensitivity, there may be different relationships between children and greenspace than adults and greenspace. Effects may persist longer in children than adults due to the time in development.

Research on the relationship between greenspace and children's physical health has demonstrated a variety of benefits. One study, that consisted of 4,758 11- year-olds, found that children's working spatial memory is better for those who live in areas with more greenspace – vegetated areas larger than one hectare– compared to those who live in areas with less greenspace (Flouri et al. 2018). In Belgium, researchers compared 310 sets of twins in urban, suburban, and rural areas between 7 and 15 years old, and found that greenspace was associated with higher intelligence and decreased behavioral problems in urban areas only (Bijnens et al., 2020)**.** In Australia, longitudinal research from birth to age 13 on 10,095 children, found that quantity and quality of greenspace were related to better general health in children (Feng & Astell-Burt, 2017). Since effects were only seen in urban areas, it is hypothesized that greenspace does not impact suburban and rural kids, as greenspace in these areas may be in higher quantities and may be interacted with less as driving is more common.

Greenspace is also hypothesized to be a mediator between child wellbeing and stressors, such as family stress and health. Family stress is linked to asthma in children, but greenspace buffers this effect (Chen et al., 2017). Results based on 150 children (ages 9 to 17 years), demonstrated that as the quality of parent-child relationships improved,

greenspace became more related with better asthma outcomes in the children. In the United States, research on 34,350 children ages 6 to 17 years, found that impoverished children were more likely to not have parks near them (Reuben et al., 2020). Furthermore, fewer parks made it more likely for children to have less physical activity, use screens more, more likely to have inadequate sleep, be obese or overweight, and more likely to have a current ADHD diagnosis (Reuben et al., 2020).

There is less work on the relationship between children's mental health and greenspace; nonetheless, research has shown that greenspace is related to better child mental well-being and moderating ADHD symptoms (McCormick, 2017). An increase in greenspace is associated with a decreased risk of conduct-related behavior problems for 7-year-olds, and increased greenspace is associated with decreased risk of depression and anxiety for 12-year-olds (Madzia et al. 2018). This longitudinal study included 562 participants at the 7-year check-in and 313 participants at 12-year-olds. Greenspace was measured using normalized difference vegetation index (NDVI), a satellite-derived measure of greenspace. A four-year study on British children starting at birth found that children near more greenspaces had fewer internalizing behavioral difficulties, but the results were only significant for south Asian children, and not white children, when satisfaction with greenspace was controlled for (McEachan et al., 2018).

Longitudinal research on 6384 families, measuring children at ages 3,5, and 7 found that greenspace predicts emotional resilience, but does not generally relate to child adjustment (Flouri et al. 2014). Furthermore, three- to five- year-olds with lower socioeconomic status who lived in areas with more greenspaces had fewer emotional problems than their counterparts. It appears that sociodemographic factors play a role in

the relationship between greenspace and outcomes. The strength of the relationship between greenspace and child mental wellbeing may depend on the reporter for the child's state as well; researchers found a strong effect size for parent-reported wellbeing compared to children- and teacher-reported (Feng & Astell-Burt, 2017).

There is limited research on the relationship between greenspace and adolescents (Vanaken & Danckaerts, 2018). Adolescence is separate from childhood as adolescents spend more time outside of the home and with their peers than young children do, and how they spend this unstructured time is different. Children typically spending more of their unstructured time playing, while adolescents spend this time talking to peers (Larson, 2001). This has implications for greenspace research, as it may be that the greenspace provides a place for children to play and thereby improve their health, while adolescents engage with greenspace differently, and therefore are impacted differently.

Adolescence has lifelong implications on health, brain development, and personal capabilities, which are influenced by interactions with the outside world (Patton et al., 2016). Drug and alcohol use often begins in middle school and increases throughout high school (Donovan, 2004). During adolescence, peers have a strong influence on behavior, including substance use and delinquency (Conger & Rueter, 1996). Peer deviance is related to adolescents participating in deviant acts and other problem behaviors (Barnes et al., 2006; Kobayashi & Farrington, 2020). While adolescents are susceptible to their friends' delinquent behavior, how susceptible they are may vary by individual traits and how their friends' behavior is perceived (Slagt et al., 2015; Brendgen et al., 2001). Furthermore, natural public spaces have been identified as popular places for adolescents to engage in drug and alcohol use due to the lack of supervision (Mason, & Korpela, 2009).

One study, on 126 adolescents, found that greenspace moderates the relationship between peer influence and adolescent substance use, and that this relationship is stronger for adolescents in areas with greater greenspace (Mennis et al., 2021). Due to the importance of peer relationships and the impact of peer deviance, this research hypothesizes that peer groups can moderate the relationship between greenspace and adolescent outcome.

In this paper, we seek to understand the relationship between greenspace and adolescent behavior. As described above, greenspace will be analyzed as a moderating variable, one that can either have a positive effect – such as being a place to play – or a negative effect – such as being a place to engage in deviant behavior. We expect to find that greenspace is negatively correlated with rates of anxiety and depression in adolescents. Our second research question is if there is a difference in the relationship between greenspace and behavior throughout development. The final question being addressed by this research is if the relationship between greenspace and behavior is conditioned by an adolescent's peer group. We hypothesize that peer deviance moderates the relationship between greenspace and adolescent behavior. This study will add to the literature on children and their outcomes and contribute to the understanding of the role of greenspace in youth outcomes.

METHODS

Sample & Procedure

The sample of adolescents is a subset of a larger, community-based sample of 3,350 students from 16 schools in Cook and DuPage counties. In the current study sample, a

subset of youth and their primary caregivers came into the lab at the University of Chicago for a detailed assessment. The project received University of Chicago Biological Sciences Division Institutional Review Board approval. Data for the in-lab study were collected between 2011-2012. During the 3-4 hour in-lab visit, youth information on family, school, and peer characteristics and emotional and behavioral outcomes were measured using self-report. A parent or primary caregiver participated in a demographic interview, which collected data on income, their education level, family structure, and provided the family's exact address. This study targeted both youth and up to one sibling per family, resulting in a total of 378 youth from 241 families. Youths ranged in age from 8 to 19 years (mean = 14.07, SD = 1.75) and the sample was evenly divided across gender (47.65% male). More than half of the sample identified as Hispanic or non-Caucasian (18.8%) or Black (35.4%).

Information on greenspace was obtained through an existing public dataset. Data were constructed in a 2010 collaborative project between the University of Vermont Spatial Analysis Laboratory and the Chicago Metropolitan Agency for Planning. This project used object-based image analysis to create pixels representing meters^2 to define geographical areas in terms of physical environment. Each pixel was assigned to one of seven categories representing: tree canopy, grass/shrub, bare, buildings, roads, and other paved surfaces. We used information drawn from the 2010 geographic map to correspond to the dates in which data were collected from youth.

Measures

Youth Outcomes

Antisocial behavior was measured using 14 items assessing aggressive and delinquent behavior during the past 12 months. Example behaviors include "sold

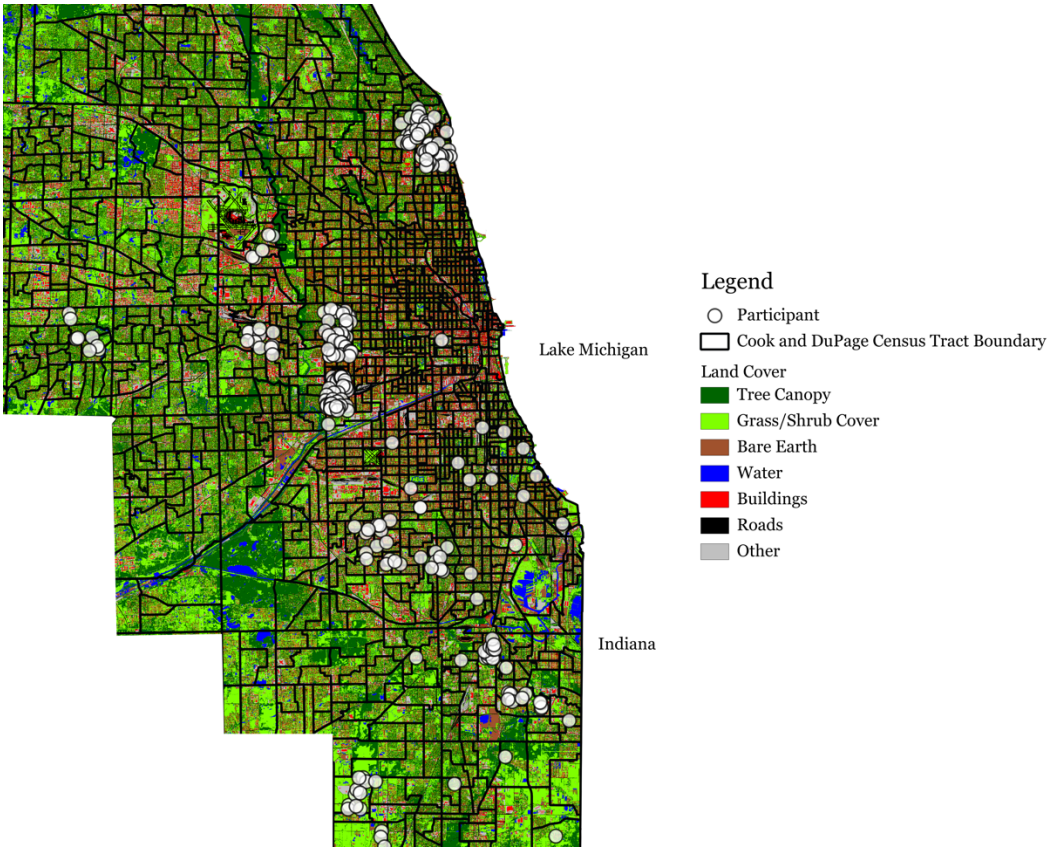
marijuana or other drugs" and "lied to your parents or guardians about where you had been or whom you were with". Youth indicated the frequency of each behavior, ranging from Never to 5 or more times. Each item was then recoded as yes or no. Items were then summed to create a composite of total antisocial behavior. A higher score indicates more antisocial behavior. The antisocial variable was winsorized to remove extreme values and reduce the impact of outliers.

Youth-reported depression was measured using the 20-item Center for Epidemiological Studies Depression Scale (Radloff, 1977). This four-point Likert scale ranges from 'never or rarely' to 'most of the time or all of the time'; the former being one point and the latter being four points. Example questions included how often youth felt depressed, and how often they had cried in the past seven days. Frequencies of all 20 items were averaged to create a single composite score. A higher score indicates higher levels of depression.

Greenspace

The addresses of each individual family were geocoded by census tract. Census tracts are statistical subdivisions of counties that range from 1200 to 8000 people. The optimal amount is 4000 people in each tract. The greenspace data was overlaid onto census tracts to create a map that assigns each pixel in a census tract to one of the seven mutually exclusive categories. The percentage of pixels belonging to each category within a given census tract was then calculated.

Figure 1. Geocoded map of Cook and DuPage Counties.



The World Health Organization's definition of greenspace is "all urban land covered by vegetation of any kind. This covers vegetation on private and public grounds, irrespective of size and function" (World Health Organization, 2017). Thus, we focused on tree canopy, grass and shrub cover, and bare earth in this paper

Covariates

The covariates for this study included youth age, race/ethnicity, gender, and family socioeconomic status. Age was measured by the study date minus the youth's birthdate. Gender and race and ethnicity were measured by youth self-report. Youth responses on the race and ethnicity questions were recoded into four mutually exclusive groups: 1) White/not Hispanic; 2) Hispanic; 3) Black/not Hispanic; and 4) and other race/ethnicity or

multiple races selected. The socioeconomic status of families was collected using the Hollingshead index. This two-factor index measures SES based on parental educational attainment and occupation. The higher the index score, the higher social status. Scores ranged from 8 to 66.

Peer Group Deviance

The child report of peer delinquency and substance use was measured using items adapted from similar scales used in prior research. Questions asked participants how many of their friends engaged in delinquent or substance use behaviors, such as lying, skipping school, and smoking cigarettes. A four-point scale was used for this measure, with a response of 1 meaning none, and a response of 4 meaning all of them. The peer deviance scale is the average frequency of peers across all behaviors. This variable was winsorized for analysis to reduce the impact of extreme outliers.

Data Analysis

Pearson correlation tests were run between all three measures of greenspace and youth outcomes. Multiple regression was used to examine associations between greenspace and outcome after controlling for age, age^2, gender, race and ethnicity, and socioeconomic status. Gender was coded as a dummy variable (male =1, female = 0) and race was recoded as minority (1) vs. white (0). Socioeconomic status and age were kept as continuous.

To explore whether relationships between greenspace and youth outcomes were moderated by demographic factors, Pearson correlation tests between greenspace and outcomes were run separately by subgroup. In these analyses, correlations were calculated for males and females, for youth in the three largest racial/ethnic groups (Non-Hispanic White, non-Hispanic Black, and Hispanic), age, and SES. Age was split into two groups: 9 to

13 years, and 14 years and older. Family socioeconomic status also became three groups: low (a score of 32 or lower), medium (33 to 56), and high (57 and higher).

Following the correlations, multiple regressions analyses were conducted separately by subgroup while controlling for other covariates. For example, a model was run among males in the sample, controlling for age, age^2, and family SES. This analysis addresses whether the relationship between greenspace and youth outcomes is stronger in some subgroups than others. These analyses were then followed up with regression models that included both the main effects of greenspace and covariates, as well as the statistical interactions between greenspace and each of the 4 demographic factors. Continuous variables of greenspace, age, age^{2,} and family SES were centered prior to creating interaction terms.

The same strategy above was used to analyze peer deviance. Peer deviance was split into three groups. Pearson correlations were calculated for each of the three subgroups, followed up by separate multiple regression models. A final model included greenspace, covariates, peer deviance, and the interaction between greenspace and peer deviance.

RESULTS

Sample Description

Out of the 378 participants, 361 (95.5%) had non-missing data on all outcomes and predicators and were included in the below analyses. The descriptive statistics of this sample are given in Table 1.

Table 1. Descriptive Statistics (*n=361).*

Variable	Values	Frequency	Percent
Sex	Female	189	52.35%
	Male	172	47.65%
Race	Non-Hispanic White	132	36.57%
	Hispanic (regardless of race)	68	18.84%
	Non-Hispanic Black	128	35.46%
	Other or multiple Race/Ethnicity	33	9.14%

Variable	Min	Max	Mean	SD
Age	9.56	19.19	14.07	1.75
SES	9.00	66.00	45.17	13.78
Peer Group Deviance	1.00	3.09	1.35	0.38
Antisocial Behavior	0.00	16.00	2.60	2.48
Depression	1.00	3.26	1.62	0.39

Note. Socioeconomic status was created using the Hollingshead index, which is based on parent education attainment level and current occupation. The score ranges from 8 to 66, which a higher score representing greater SES.

Greenspace

The N=361 youth came from a total of 233 individual families. Youth in the study lived in a variety of different cities (Table 2). The 33 families were distributed across 94 different census tracts.

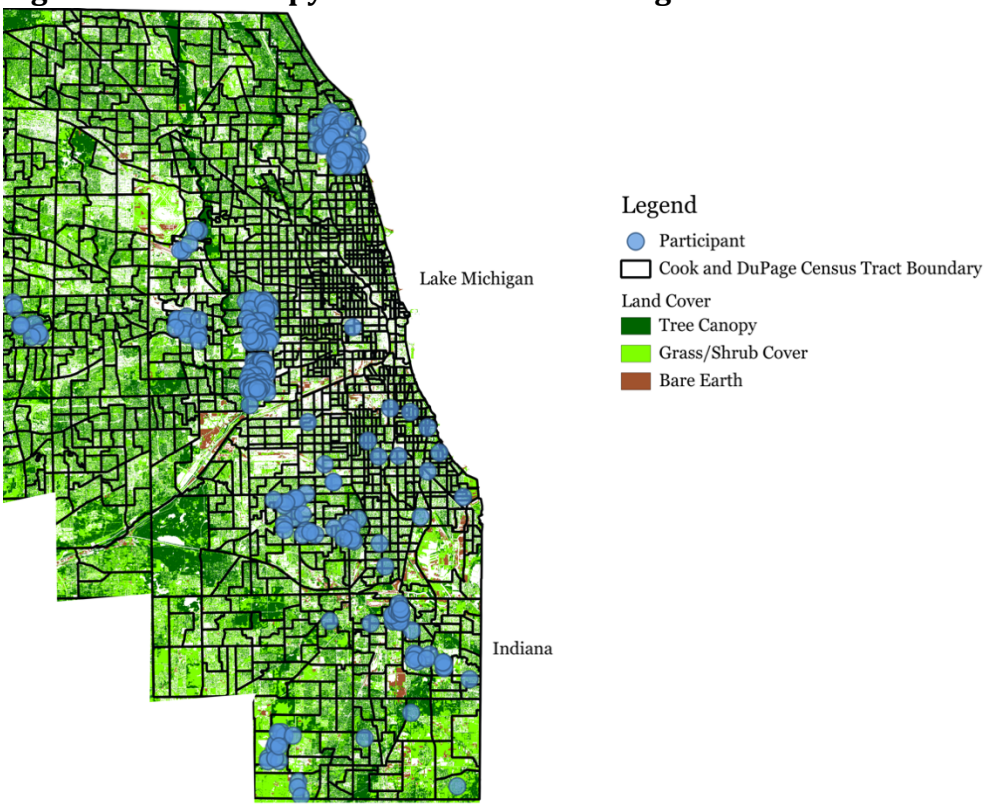
Table 2. Participants by City

City	Number of Participants
Bellwood	12
Berwyn	58
Chicago	32
Dolton	12
Evanston	65
Glen Ellyn	14
Matteson	18
Oak Lawn	25
Oak Park	53
Riverdale	14
South Holland	18

Note. Number of participants for cities represented in the study. Places that had 10 or more participants are shown, not representative of entire sample.

There was variation in amount of greenspace across census tract. Tree canopy ranged from 7.1% to 59.6% (mean=28.4%, SD=10.1%0. Land Cover ranged from 12.7% to 76.9% across tracts (mean=26.8%, SD=12.6%). Finally, bare earth had a low of zero percent and a high of 10.6% (mean = 1%, SD=2.2%). The range of tree canopy, shrub and grass, and bare earth across tracts is shown in Figure 2.

Figure 2. Tree Canopy across Cook and DuPage Counties



Note. Darker areas demonstrate higher concentration of that type of cover in area.

Correlations

Tables 3 presents the correlations between the three measures of greenspace, the two youth outcomes, and the demographic covariates. Socioeconomic status and minority race had a negative relationship, but none of the other covariates were related. Peer group deviance was inversely related to socioeconomic status, and positively related to minority race and age. Antisocial behavior was related to minority race, age, and peer deviance, but negatively related to SES. Depression was negatively related to SES and male gender, and had a positive relationship with minority, age^2, peer group deviance, and antisocial behavior.

Tree canopy was negatively related to the other greenspace measures, but the relationship between shrub/grass and bare earth was positive (Table 4). The percentage of tree canopy was positively associated with socioeconomic status, with higher levels of tree canopy corresponding to high family SES. Tree canopy showed an inverse relationship with minority race/ethnicity, indicating that youth from minority backgrounds had lower levels of tree canopy in their immediate census tract area. The other greenspace measures showed the reverse pattern: bare earth and grass/shrubs each had a negative relationship to socioeconomic status and a positive association with minority race/ethnicity. Only tree canopy was related to peer group deviance, with higher proportions of tree canopy associated with lower levels of peer deviance.

Tree canopy was inversely and significantly correlated with both outcomes. Higher levels of tree canopy were associated with lower levels of both antisocial behavior and depression. Percentage of bare earth had a smaller, positive relationships with both outcome variables, although the association between bare earth and antisocial behavior was not statistically significant. The percentage of grass/shrubs was not significantly associated with youth outcomes. Given these patterns of correlations, the remaining analyses will focus only on tree canopy.

Table 3. Correlation table for all variables

Variable	Tree Canopy	Grass/Shrub Cover	Bare Earth	SES	Race	Sex	Age	Age^2	Peer Group Deviance	Antisocial Behavior
Tree Canopy										
Grass/Shrub Cover	-0.464***									
Bare Earth	-0.208***	0.137**								
SES	0.358***	-0.219***	-0.219***							
Race	-0.381***	0.222***	0.226***	-0.398***						
Sex	0.026	-0.032	-0.029	-0.023	-0.013					
Age	-0.084	0.000	0.072	-0.057	0.044	0.006				
Age^2	-0.010	-0.051	-0.011	0.070	-0.003	0.057	0.163***			
Peer Group Deviance	-0.114*	-0.010	0.004	-0.109*	0.102*	-0.004	0.381***	-0.021		
Antisocial Behavior	-0.142**	0.059	0.093#	-0.227***	0.136**	0.081	0.244***	0.065	0.524***	
Depression	-0.138**	0.023	0.120*	-0.109*	0.151**	-0.138**	0.076	0.106*	0.336***	0.426***

Note. Correlation table between greenspace measures, covariates, and outcome variables, *=p<0.05, ***=p<0.00

Multiple Regression Models

Table 4 shows the results from the multiple regressions in the whole sample. Model 1 included tree canopy as the sole predictor. Model 2 added covariates of SES, minority race, male gender, age, and age^2. The effect of tree canopy was statistically significant for both antisocial behavior and depression, but these relationships become non-significant when the covariates were included.

Table 4. Outcome Models

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	3.476***	2.231***	1.777***	1.59***
	SE=0.3560, t=9.764	SE=0.2445, t=9.1252	SE=0.0613, t=29.00	SE=0.04323, t=36.931
Tree Canopy	-3.221**	-1.022	-0.539**	-0.286
	SE=1.1824, t= -2.7254	SE=1.26498, -t=0.8082	SE=0.2035, -t=2.6486	SE=0.224, -t=1.280
SES		-0.031**		-0.001
		SE=0.0093945, t=-3.2717		SE=0.002, t=-0.896
Race		0.175		0.081#
		SE=0.2699, t=0.6509		SE=0.048, t=1.696
Sex		0.342		-0.112**
		SE=0.2299, t=1.4873		SE=0.041, t= -2.758
Age		0.291***		0.010
		SE=0.0668, t=4.3520		SE=0.012, t=0.868
Age^2		0.019		0.010*
		SE=0.0261, t=0.7233		SE=0.005, t=2.094

Note. Models 1 and 2 are for the antisocial behavior outcome, 3 and 4 are for depression. #=p<0.1, *=p<0.05, **=p<0.01, ***=p<0.001

Subgroup Analyses

Correlations

The correlations between percentage of tree canopy and outcomes within each covariate group are shown in Table 5. Tree canopy was significantly related to lower antisocial behavior and depression for females, but not males. For age, tree canopy was associated with lower antisocial behavior and depression among youth aged 9 to 13 but was only significant for depression. For youth aged 14 and older, tree canopy was not significantly related to either outcome. There were significant associations between tree canopy and outcomes among White participants. Correlations among Hispanic participants were similar in magnitude and direction, but were not statistically significant, given the smaller sample size. In contrast, the associations between outcomes and tree canopy were markedly smaller, and positive, among Black participants. Finally, the associations between tree canopy and outcomes were small and non-significant for the low and medium SES groups but were significantly inversely related to outcomes among youth in the high SES group.

Table 5. Correlations between Tree Canopy and Antisocial Behaviors and Depression, by Subgroup

Variables	Frequency	Values	Antisocial Behavior	Depression
Sex	172	Male	-0.101	-0.039
	189	Female	-0.194**	-0.223**
Age	184	9-13	-0.127#	-0.182*
	177	14 and older	-0.142#	-0.086
Race[a]	132	White	-0.181*	-0.151#
	68	Hispanic	-0.153	-0.177
	128	Black	0.060	0.108
Family SES	92	Low	-0.030	-0.090
	182	Medium	-0.059	-0.006
	87	High	-0.198#	-0.283**

Note. [a] Only the three largest race and ethnicity groups are shown in the table below, the other/multiple option is not shown. # = p<0.10, * = p<0.05, **=p<0.01

Regressions by subgroup

Next, regression models were run within each subgroup shown in Table 5, controlling for other covariates. Figures 3a – 5b plot the regression lines for the gender, age, and race subgroups. For gender, the relationship between tree canopy and antisocial behavior (β = -1.18, SE = 1.71, t = -0.690, p=0.491) and depression (β=-0.641, SE= 0.343, t= -1.87, p= 0.0634) was not significant for females, nor males (antisocial behavior: β= -0.649, SE = 1.90, t = -0.342, p = 0.733; depression: β = 0.0754, SE=0.291, t = 0.259, p= 0.796).

For age, younger and older, tree canopy was non-significantly, negatively associated with antisocial behavior (younger: β= -0.678, SE= 1.49, t=-0.454, p=0.651; older: β=-2.07, SE=2.10, t= -0.988, p=0.324). Tree canopy was negatively associated with depression for both younger and older youths (younger: β= -0.510, SE=0.298, t=-1.71, p=0.0881; older: β= -0.0601, SE= 0.341, t=-0.176, p=0.860), neither relationship was significant.

Based on the correlations found in Table 5, the race/ethnicity variable was recoded to compare Black youths to all other participants. For Black participants, tree canopy was

positively related to antisocial behavior (β =2.36, SE=2.29, t=1.03, p=0.304) and to depression (β =0.572, SE=0.428, t=1.33, p=0.185). For the other youths, tree canopy was negatively related to antisocial behavior (β =-2.62, SE=1.51, t =-1.73, p=0.0842) and significantly related to depression (β =-0.740, SE=0.262, t=-2.82, p=0.00522).

For the low and high SES groups, tree canopy was negatively related to antisocial behavior (low: β =-1.26, SE=3.32, t=-0.379, p= 0.706; high: β =-5.29, SE=2.12, t=-2.49, p= 0.0147) and depression (low: β =-0.34, SE=0.498, t=-0.692, p=0.491; high: β =-1.18, SE=0.431, t=-2.73, p= 0.00785), but these relationships were only significant for the high group. In the medium SES group, tree canopy was non-significantly, positively related to the outcome variables (antisocial behavior: β =0.887, SE=1.72, t=0.516, p= 0.606; depression: β =0.285, SE=0.308, t=0.925, p= 0.356).

Figure 3a.

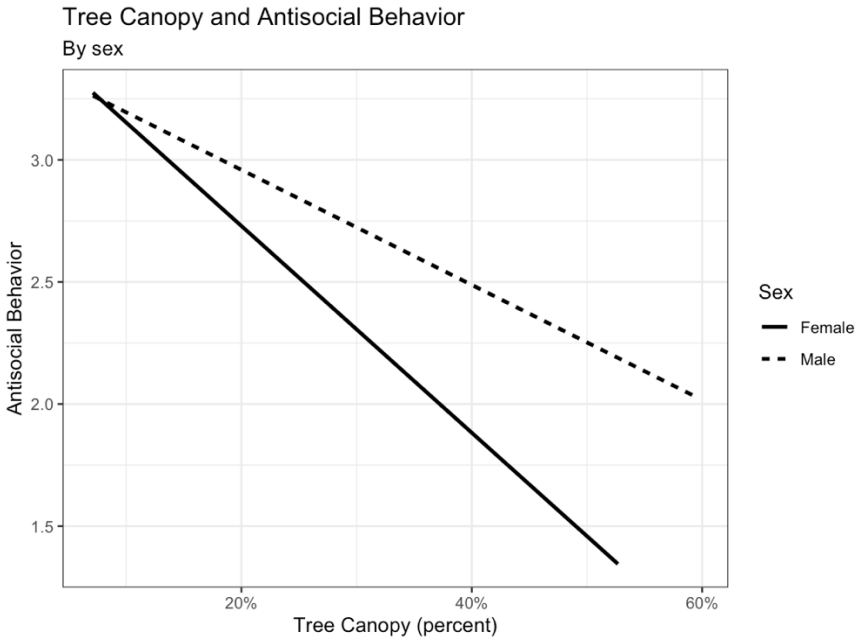


Figure 3b.

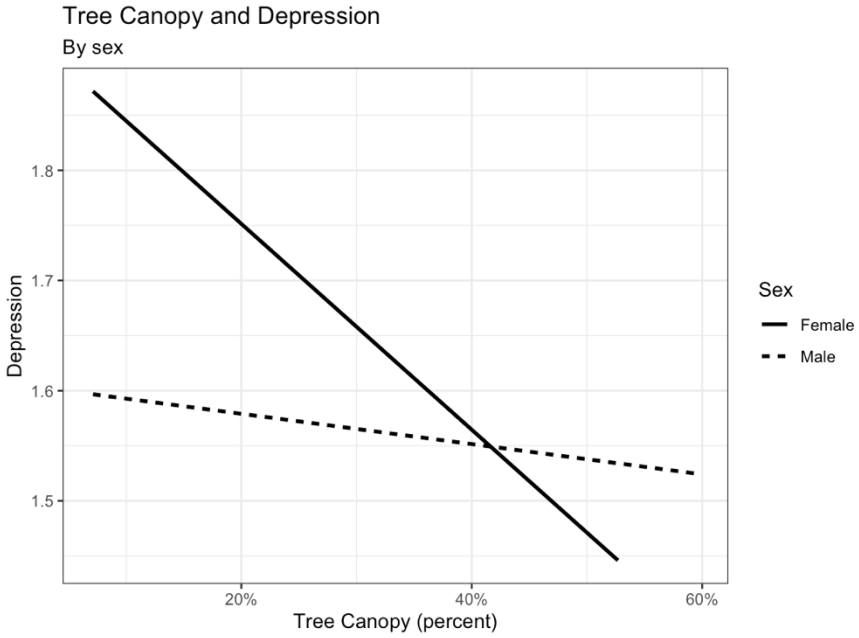


Figure 4a.

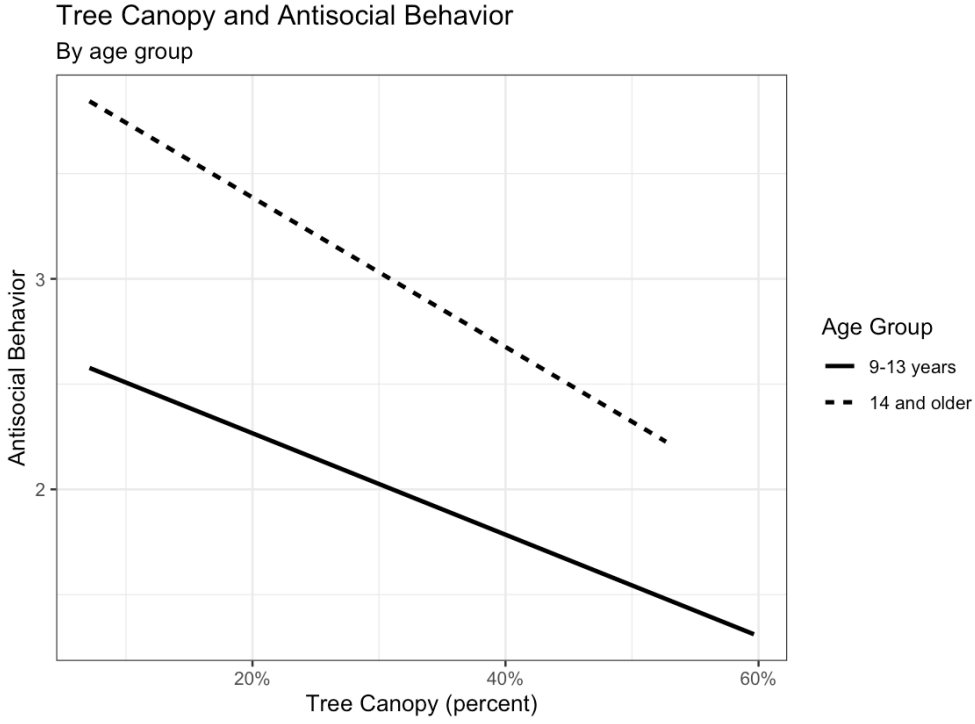


Figure 4b.

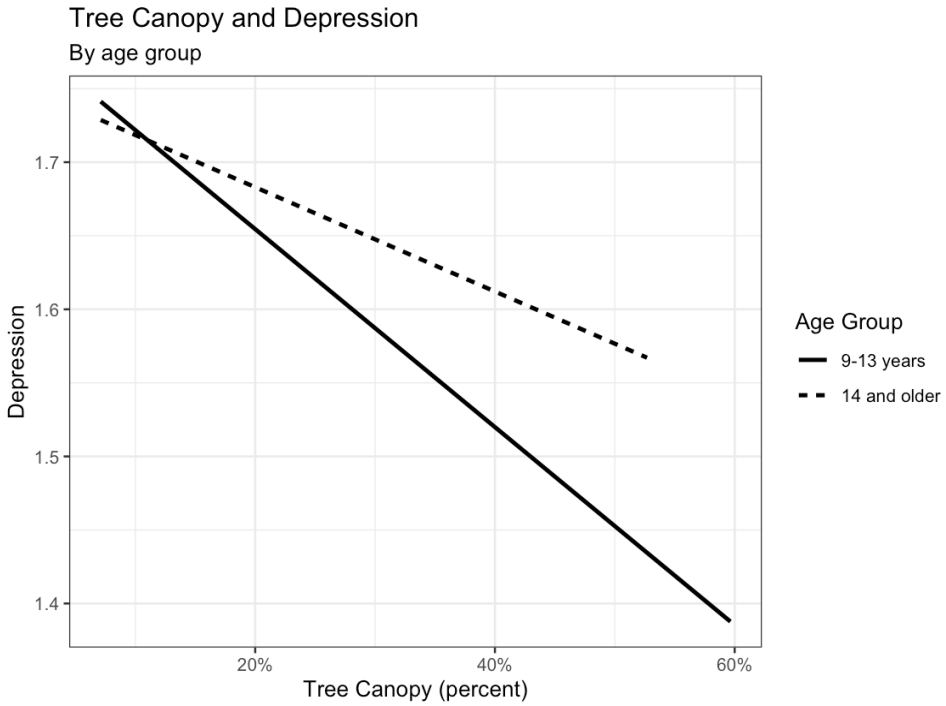


Figure 5a.

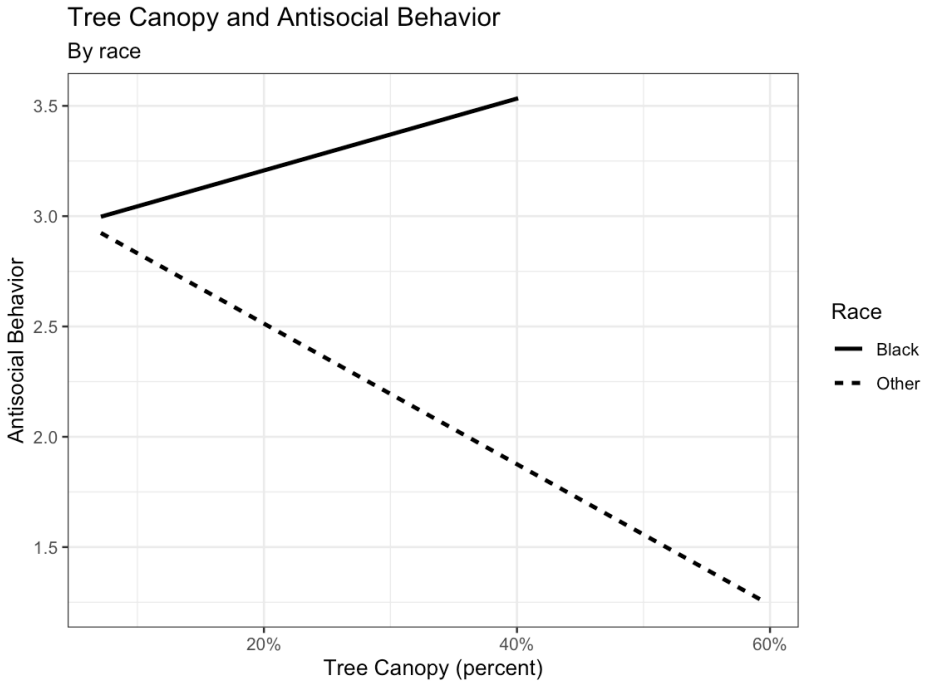
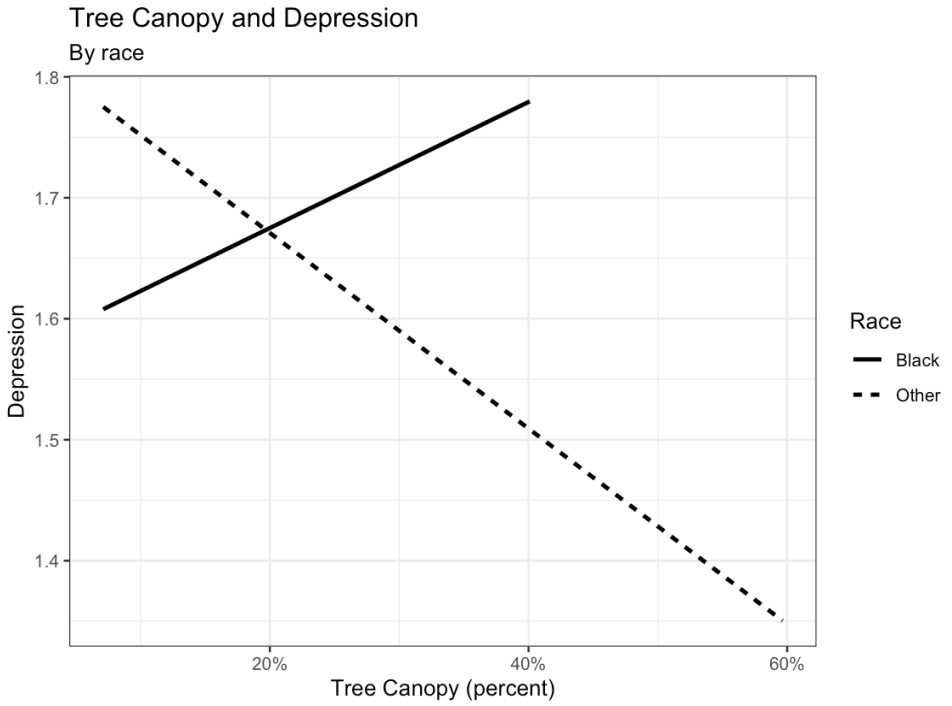


Figure 5b.



Peer Group Deviance as Moderator

The associations between tree canopy and outcomes for the three peer deviance levels are given below in Table 6. The associations are small and non-significant for all but tree canopy and depression for youth in the lowest peer deviance level; this negative relationship was statistically significant.

Table 6. Correlations by Peer Group Deviance Levels

Variable	Frequency	Value	Antisocial Behavior	Depression
Peer Deviance	136	Low	-0.097	-0.181*
	112	Medium	-0.083	-0.005
	113	High	0.012	-0.025

Note. R values for tree canopy and outcome variable within each peer group deviance level.
* = $p<0.05$

Next, we ran separate regression models within each of the three peer deviance groups, controlling for gender, age, age^2, minority race/ethnicity, and family SES. With the addition of these covariates, slightly different patterns emerged. For the low peer deviance group, tree canopy now had a positive relationship to antisocial behavior (β = 0.276, SE=1.47, t = 0.187, p= 0.852); this positive relationship was slightly stronger for the high group (β =1.11, SE=2.52, t=0.441, p= 0.660) but still non-significant. In the medium group, the association between tree canopy and antisocial behavior was negative and nonsignificant (β = -0.359, SE=2.08, t = -0.173, p= 0.863). For the low and medium peer deviance groups, tree canopy was negatively associated with depression (low: β =-0.202, SE=0.298, t=-0.679, p=0.498; medium: β =-0.184, SE=0.428, t=-0.430, p=0.668). However, the association was slightly positive for the high group (β =0.0215, SE=0.440, t =0.0490, p=0.961) and not significant. There was no significant interaction between tree canopy and peer deviance.

DISCUSSION

This researched explored the relationship between greenspace and youth outcomes on an individual level. This study used a racially, ethnically, and socioeconomically diverse sample of youth living near a large metropolitan area. This study expanded upon previous research by considering whether the effects of greenspace were confounded by demographic factors, by exploring whether the relationship between greenspace and youth outcomes varied across demographic groups, and by considering peer group deviance as a potential contextual factor that might moderate the association between greenspace and youth outcomes.

Our results indicate that the percentage of tree canopy was a better predictor of youth outcomes than bare earth or presence of grass and shrubs. Preliminary results indicated that greenspace had a small protective effect on youth outcomes; greater percentage of tree canopy was associated with lower rates of antisocial behavior and depression. This is consistent with other studies that found an increase in greenspace associated with a decrease in depression, anxiety, and other mood disorders (Nutsford et al., 2013; Bijnens et al., 2020; Madzia et al., 2018).

However, we also found that measures of greenspace were confounded by other sociodemographic factors. While there was no correlation between gender or age with greenspace, greenspace was positively associated with family SES, and inversely associated with minority racial/ethnic status. This is consistent with previous work indicating that there are disparities in access to greenspace across different populations. Studies have shown that higher-income and majority white areas have more greenspace and greater diversity of outdoor play spaces than lower-income and minority neighborhoods (Pérez-del-Pulgar et al., 2021; Reuben et al., 2020). Indeed, after we include measures of race/ethnicity and SES in our models, the effects of greenspace became non-significant. Race/ethnicity and SES are also strongly associated with access to other resources, which may impact youth outcomes rather than greenspace.

Other studies have also included measures of SES and found significant, independent effects of greenspace. The discrepancies may be accounted for by location; many studies were conducted in other countries, including Belgium (Bijnens et al., 2020) and Spain (Pérez-del-Pulgar et al., 2021). A second factor is the different measures of greenspace and SES across studies. Many studies used satellite imagery that did not

distinguish between types of greenness (tree canopy vs. shrub/grass). Furthermore, many studies only used parental education or whether students were a part of a free lunch program as an indicator of SES - or did not use an individual-level SES, and instead estimated SES for individuals based on the location they were from.

This area of research uses many different theoretical pathways. There is no single mechanism used to describe how greenspace and mental health may interact with each other; some studies have used greenspace as the independent variable, proposing that is the existence of greenspace itself that drives findings. However, other studies propose that greenspace is a moderating variable, for example, greenspace provides a place to run, linking fitness to improved physical health and increasing physical health if there is greenspace to run in. Finally, greenspace may also be a mediating variable, such as a higher socioeconomic status leading to an increase in greenspace, leading people to be healthier. This is pertinent to this paper, which demonstrated tree canopy and socioeconomic status was linked. The study of greenspace and youth outcomes is still an emerging area. More research is needed before clear patterns might emerge.

This study was one of the first to specifically examine whether the impact of greenspace on youth outcomes might vary across demographic subgroups. Our results suggest that the association between greenspace and outcomes may be stronger for females than males, although the interaction between greenspace and gender was not statistically significant. These results are supported by past research (Feng et al.,2021; Mennis et al., 2021).

There was some indication that the relationship between greenspace and outcomes is stronger among younger youth, although this was not significant. This speaks to

developmental changes as younger children are more likely to be under parental supervision of activities and young kids use greenspace in a more homogenous way. Older youth use greenspace in a wider variety of ways, which may include a place for deviant behavior, and travel further to natural areas than younger children (Mason & Korpela, 2009).

The relationship between greenspace and outcomes was stronger for the high SES group, indicating that greenspace may be more important among privileged youth. This is in opposition to the findings by Pérez-del-Pulgar et al. (2021), which found that more greenspace was a risk factor for youth in higher SES groups. Due to the small amount of greenspace found in the lower income areas included in this study, there may be a ceiling effect.

Related to this, we also found suggestive evidence that Black youth do not benefit from greenspace in the same way that White or Hispanic youth do. There are several potential explanations for this finding. One response is that very few Black youth in the sample lived in areas with a high percentage of tree canopy. This ceiling affect may have impacted the ability to detect an association. Second, the areas with less greenspace may have high levels of community violence. Due to this, the use of greenspace may differ than use in other areas. Finally, there may be other factors that were not measured in this study that are more strongly associated with outcomes, such as racial discrimination.

Taken together, our subgroup analyses suggest that the meaning of greenspace may vary among youth in different socioecological niches. Related to this, our study hypothesized that peer deviance may moderate the association between greenspace and youth outcomes. Specifically, we expected that there may be a protective effect of

greenspace among youth with low levels of peer deviance, while greenspace may actually be associated with poorer outcomes among youth with high levels of peer group deviance. This does not support the work by Mennis et al. (2021), where greenspace was found to be a moderator between peer group and deviant behavior. However, this study does support the findings of Mason & Korpela, (2009); youth who used more alcohol and marijuana more frequently often went to natural places to engage in deviant behavior. Our sample was relatively small, and levels of peer deviance were low; thus, more research with larger samples is needed to test these types of contextual moderation more thoroughly.

Strengths and Limitations

Strengths of this research include the integrated geocoded data into a data set from a modestly sized, diverse sample who were well-characterized; the use of two different outcomes representing internalizing and externalizing problems, and that it considered the impact of subgroups of demographic characteristics and peer group deviance.

There are a few limitations to this study, including that it does not have data for tracking the use of greenspace. Concerns arise over the quality of greenspace, with quality spaces meaning manicured, designated parks that are easy to access and may have playgrounds. It has been proposed that the use of greenspace and the perception of it being "of quality" that drive associations between greenspace and health (Lachowycz & Jones, 2012). Passive versus active use of greenspace mediating impacts is an important debate in greenspace research. It has been argued that the active use of greenspace is what matters for the benefits of greenspace, which this paper cannot attest to since it does not differentiate between the amount of greenspace and the quality of it. This leaves remaining the question of whether any type of greenspace will bring benefits to children in

communities, or if the greenspace must be parks and other areas that children can engage with in order for benefits to be enjoyed. Future research should distinguish between quantity and quality, and the actual use of the greenspace, to better address this question.

A final limitation is that this study was based on the data collection in 2010; thus, any results may not reflect the impact of greenspace in today's society. In particular, the COVID-19 Pandemic may have impacts on the role of greenspace in peoples' lives. Research is showing that people are interacting with greenspace less and for different reasons (Heo et al., 2021). This trend may continue beyond the pandemic, and may make the relationship between greenspace stronger, as people depend on it more for stress-relief.

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