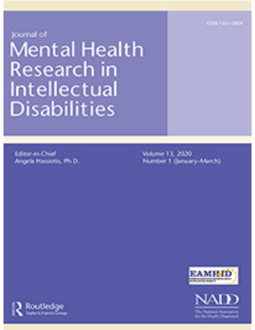

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Tree Canopy Coverage Predicts Lower Conduct Problem Severity in Children with ASD

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ABSTRACT

Introduction: Conduct problems are commonly reported among individuals with autism spectrum disorders (ASD) and children with other special health care needs (CSHCN). Environmental research indicates that exposure to natural environments can lead to decreased conduct problems; opposite effects (i.e., increased problems) are associated with built "gray" environments (e.g., roadways).

Methods: This exploratory study analyzed the association between Zip-code level tree canopy coverage and severity of conduct problems in typical children, children with ASD, and CSHCN. Tree canopy data came from National Land Cover Database and ASD data came from the cross-sectional National Survey of Children's Health (2011/2012).

Results: Percent tree canopy coverage predicted a decreased risk of severe conduct problems in youth with ASD, but not CSHCN; "gray" space was unassociated with conduct problems in any children.

Conclusions: Community tree canopy coverage is negatively associated with conduct problems in children with ASD. More research using individual assessments and street level metrics will help better determine the relationship between canopy coverage and conduct problems in ASD.

KEYWORDS
Children; autism; mental health; nature; tree canopy; conduct Problems; aggression

Introduction

Individuals with autism spectrum disorders (ASD) represent a heterogeneous group of people with atypical functioning in the areas of social communication and repetitive/circumscribed interests and behaviors (American Psychiatric

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Association, 2013). There is wide variability in the presentation of these atypicalities as some individuals with ASD may have intellectual deficits, but others present with high cognitive abilities (Crespi, 2016); some may have no, or low, communicative abilities, but others may be quite loquacious (Crespi, 2016; Tager-Flusberg, 2000); and some may present with co-morbid conditions, such as ADHD, but others may have no co-morbidities at all (Simonoff et al., 2008). Collectively, this wide-ranging heterogeneity makes ASD a difficult condition to classify and treat.

Social-emotional functioning is one area where the heterogeneity among individuals with ASD is particularly apparent (Downs & Smith, 2004). Research indicates that although many individuals with ASD present in the normal range of social-emotional functioning on scales measuring traits such as introversion/extraversion, agreeableness, neuroticism (i.e., tendency toward feeling/expressing negative affectivity), and positive affectivity, as a group individuals with ASD tends toward higher levels of negative emotions and lower levels of positive affectivity and sociability (Barger, Campbell, & Simmons, 2014, 2016). Clinically, multiple studies indicate that many individuals with ASD have higher levels of aggression and conduct/behavior problems than typical children, or children with conditions other than ASD (Ambler, Eidels, & Gregory, 2015; Kanne & Mazurek, 2011; Lecavalier, Leone, & Wiltz, 2006; Lidstone et al., 2014; Mayes, Calhoun, Murray, Ahuja, & Smith, 2011; Mazurek, Kanne, & Wodka, 2013). These increased negative affective states may directly relate to the core clinical areas of social and perseverative interests/behaviors in children with ASD (Ambler et al., 2015; Kanne & Mazurek, 2011; Mazurek et al., 2013).

Behavior and conduct problems are associated with conditions marked by higher levels of expressed anger and/or aggression, such as oppositional defiant disorder and conduct disorder, that are more prevalent in children with ASD compared to typically developing children (Kaat & Lecavalier, 2013; Lecavalier et al., 2006; Matson & Cervantes, 2014; Simonoff et al., 2008). Recent estimates indicate that 25 to 50% of children with ASD have co-morbid problems with anger and/or diagnosis of co-morbid behavioral or conduct disorder (Kaat & Lecavalier, 2013; Kanne & Mazurek, 2011; Mazurek et al., 2013; Simonoff et al., 2008). The effects of behavior and conduct problems in individuals with ASD are far-reaching, negatively influencing their ability to make friends, their academic performance, and the stress levels of their parents (Mazurek et al., 2013; Tomanik, Harris, & Hawkins, 2004). Indeed, research indicates that behavior and conduct problems are strongly related to caretaker stress (Davis & Carter, 2008; Hodgetts, Nicholas, & Zwaigenbaum, 2013; Tomanik et al., 2004). Collectively, data indicates that individuals with ASD, and their families, often suffer negative consequences due to increased anger, aggression, and behavior/conduct problems.

There are many traits associated with behavior and conduct problems found in typically developing populations, but many of these have not been replicated in populations with ASD. For example, cognitive ability, language ability, gender, socio-economic status, parent age at birth of child, and maternal education are commonly associated with behavior and conduct problems in typical populations, but not in individuals with ASD (Kanne & Mazurek, 2011; Mazurek et al., 2013). In children with ASD, however, some studies have found associations between behavior/conduct problems and sleep (Henderson, Barry, Bader, & Jordan, 2011; Kotagal & Broomall, 2012). Aggression, and associated behavioral/conduct problems, are also associated with higher levels of anxiety and stress in children with ASD (Ambler et al., 2015; Lidstone et al., 2014; Mayes et al., 2011). Altogether, studies indicate that conduct and behavior problems are more common in children with ASD and may be caused or exacerbated by other common co-morbid features such as anxiety and sleep problems.

Unsurprisingly, behavior and/or conduct problems in individuals with ASD are one of the primary foci of interventions seen in the literature; with some evidence indicating that these problems are of higher priority for many caretakers than addressing core ASD traits (Adler et al., 2015; Hodgetts et al., 2013; Horner, Carr, Strain, Todd, & Reed, 2002; Matson & Jang, 2014). Many studies display the effectiveness of applied behavioral, psycho-pharmacological interventions, and even cognitive behavioral interventions in populations with higher cognitive abilities. Behavior/conduct problems in individuals with ASD are manageable via different interventions; however, the cost of different interventions can be quite prohibitive, particularly for low income or un-insured families (Dorsett, 2015). Thus, there is a need to explore inexpensive options that might be used to augment treatment for individuals with ASD who have conduct/behavioral problems. Furthermore, many parents are concerned about the deleterious effects of psycho-pharmacological treatments and may prefer to consider natural therapeutic alternatives for their children.

The Effect of Natural Environments on Aggression

In recent years a growing evidence base indicates that natural environments confer health benefits to humans. In particular, data suggest that exposure to natural settings is associated with reduced stress, improved recovery from illness, and better attentional functioning (Berman, Jonides, & Kaplan, 2008; Hartig, Mitchell, De Vries, & Frumkin, 2014; Kaplan, 1995; Kaplan & Kaplan, 1989; Kuo, 2015). The bulk of research done on children has focused on the effect of natural environments on either stress reduction or improving attentional capacities (Berman et al., 2008; Berto, Pasini, & Barbiero, 2015; Bratman, Hamilton, & Daily, 2012). For example, a number of studies indicate that youth exposed to urban natural environments display improvements in mood, decreases in stress and anxiety, and improved attentional functioning (Berto et al., 2015; Kelz, Evans, & Röderer, 2015; Li & Sullivan, 2016; Taylor, Kuo, & Sullivan, 2002; Ulrich, 1983; Wells, 2000; Wells & Evans, 2003; Wells & Lekies, 2006).

Despite a robust literature in typical populations, there is relatively little research on children with disabilities, though several studies on children with ADHD indicate that greenspace exposure can improve attention skills and working memory in this population (Faber Taylor & Kuo, 2009, 2011; Kuo & Faber Taylor, 2004; Taylor, Kuo, & Sullivan, 2001). Recent research has also begun to indicate greenspace effects on children with ASD. For example, Larson et al. (2018) reported data indicating that zip-code level canopy coverage and gray space predicted increased anxiety problems in children with ASD compared to typical children. Furthermore, Wu and Jackson (2017) reported that school district greenspace had an inverse relationship with school level reported autism prevalence in California.

In addition to the aforementioned literature on the effects of natural environments on health and psychosocial outcomes, there is also evidence that natural environments might have positive effects on aggression and conduct problems. For example, research shows that urban areas with denser vegetation have lower crime rates, and inhabitants have lower self-reported rates of aggression (Kuo & Sullivan, 2001a, 2001b). In adults, studies have also shown that roadside vegetation is associated with greater tolerance for frustrating traffic situations (Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998). A recent meta-analysis indicated that natural environments are associated with decreases in negative emotions and increases in positive emotions in adults (McMahan & Estes, 2015) . The child literature has notably less research on this, but the available research indicates that natural environments relate to decreased aggression (Younan et al., 2016).

Natural environments and man-made "built" environments (i.e., "green" and "gray" spaces) appear to have contrasting effects on human health (Bratman et al., 2012; Frazer, 2005). While the bulk of available research shows that urban green spaces predict lower levels of aggression, this is typically contrasted with the amount of built gray space (e.g., Kuo & Sullivan, 2001a, 2001b). The increase in urbanization in the last 40 years has coincided with increases in numerous behavioral health concerns, some of which, like ADHD (Faber Taylor & Kuo, 2009, 2011; Kuo, 2015; Taylor et al., 2001) and anxiety disorders (Hartig et al., 2014), studies indicate may be affected by exposure to natural and built environments. While few would argue that natural or built environments necessarily play a causal role in the development of behavioral health conditions, growing evidence indicates that they may ameliorate or exacerbate behaviors.

Collectively, data from typically developing groups indicates that natural environments may have ameliorative effects on negative affective responses (i.e., anger) associated with aggression, behavior and conduct problems. Furthermore, the adult literature indicates that exposure to natural environments may result in decreased aggression and frustration. This literature, however, is limited in a number of different ways. First, while the literature on children has explored the relationship between natural and built environments on stress and attention, the relationship between natural environments and behavior or conduct problems is understudied generally. Second, while the effects of greenspace exposure on typical children and children with ADHD is relatively well advanced, only two studies have investigated the relationship between canopy coverage in ASD in relation to diagnostic status (Wu & Jackson, 2017) and anxiety severity (Larson et al., 2018). Thus, the purpose of this study is to extend the research base by conducting an exploratory investigation on the effects of green and gray space on conduct problems in children with ASD.

Methods

Autism & Conduct Problems Data Sources

The National Survey of Children's Health (NSCH, 2012; Bramlett et al., 2017), funded by the Maternal and Child Health Bureau of the Health Resources and Services Administration, was the source for data on children with ASD in this study. The National Center for Health Statistics and the National Immunization Survey administers the NSCH via State and Local Area Integrated Telephone Survey services. There are publicly available data on 95,677 NSCH (2012) caretaker provided surveys on U.S. children between the ages of 0 to 17 years, representative of all 50 states and the District of Columbia. NSCH data are broken out into populations greater or less than 50,000. The Center for Disease Control's Data Research Center housed in Atlanta, GA (CDC-RDC) makes available data at the Zip Code level. Due to identification concerns, the CDC-RDC does not make more spatially granular data available for analysis. Furthermore, the CDC-RDC maintains the right to mask outcomes when concerned about potential identification.

This study reports data on 53,650 children that were typically developing, 1,501 children with ASD, and 15,776 CSHCN 6 to 17-year-old children whose data is available in the NSCH (2012) dataset. Recent research indicates that the median age of six was selected as the lower threshold age because research indicates that 5 is the median age by which most identified cases of ASD were evaluated (Maenner et al., 2013). The NSCH is a valid scientific public health survey and is a major source of epidemiological data on ASD. Findings from the NSCH have been found to match data from CDC's Autism Developmental Disability Monitoring Network (CDC-ADDM), which is a 14-State ASD tracking network from which the CDC develops official autism epidemiological reports (Blumberg et al., 2013). NSCH reports on autism also match data from the National Health Interview Survey, another major source of epidemiological data on health in the U.S. population (Blumberg et al., 2013).

The NSCH (2012) identifies children with conduct problems via answering three questions. The first question is “Has a doctor or other health care provider ever told you that [CHILD’s NAME] had behavioral or conduct problems, such as Oppositional Defiant Disorder or Conduct Disorder?” Caretakers for whom this is not true go on with further survey questions; caretakers who answer affirmatively then receive the following two questions: (a) “Does [Child] currently have conduct problems?”; (b) “Would you describe [his/her] conduct problems as mild, moderate, or severe?” The current study analyzes, caretakers stating that their child either had no or mild conduct problems received a “No/Low” severity classification; caretakers indicating that their child’s conduct problems were in a moderate to severe range received a “Moderate/Severe” classification (see Table 1 for breakdown across groups).

Green Space Data Sources

We developed green space metrics from data available via the National Land Cover Database (NLCD) (http://www.mrlc.gov/nlcd2011.php). This 16-class land cover classification scheme is publicly available and provides details on various natural and built environments (e.g., canopy cover and impervious surface) from the 50 United States (Homer et al., 2015). NLCD environmental classifications for this study were derived from satellite images. Specifically, the third author developed measures from NLCD data of the average Zip Code level percentage tree canopy and impervious surface coverage across the United States. It should be noted that the spectral signature of different environmental types (e.g., tree canopy and low lying bushy areas) can be quite similar, which can lead to classification errors. Thus, NLCD metrics are considered best estimates of natural and built environments.

Specific NLCD environmental metrics considered here include “gray” and “green” space. Gray space refers to environments covered with constructed non-natural surfaces, like paved street surfaces and buildings. NLCD gray space metric was developed from a normalized spectral mixture analysis (NSMA) (Wu, 2004; Yuan & Bauer, 2007). Green space here refers to environments covered by tree canopy. Tree canopy data in the NLCD is derived from a three step process described by Huang, Yang, Wylie, and Homer (2001) that involves derivation of canopy density from high spatial resolution images, density prediction models calibrated using reference data and Landsat spectral bands, and spatial extrapolation to map per-pixel tree canopy density using a regression algorithm. Gray and green space were operationalized respectively as the percentage of a Zip code area covered by either impervious built surface or tree canopy (0-100%).

Table 1. Distribution of children with ASD across model covariates (Co-morbid conditions and socio-demographic attributes).

Variable	Typical	CSHCN	ASD
Total	53,650	15,776	1501
Conduct Problems			
None	53,481	14,078	1066
Mild	81	500	128
Moderate	78	831	193
Severe	9	364	112
ASD			
None	53,639	15,723	0
Mild	0	0	832
Moderate	0	0	491
Severe	0	0	178
Depression			
None	53,454	14,408	1303
Mild	135	695	87
Moderate	52	520	78
Severe	9	145	32
Anxiety			
None	53,216	13,601	929
Mild	312	1013	196
Moderate	112	906	258
Severe	9	251	115
Intellectual Disability			
None	53,613	15,185	1183
Mild	22	215	98
Moderate	^	^	^
Severe	^	^	^
Learning Problems			
None	52,200	12,159	458
Mild	1050	1749	336
Moderate	355	1418	456
Severe	37	434	244
ADD/ADHD			
None	52,741	10,693	851
Mild	674	2081	161
Moderate	217	2321	322
Severe	15	655	166
Age			
Early Childhood	21,260	6996	551
Middle Childhood	16,403	3851	413
Adolescence	15,987	4929	537
Race/Ethnicity			
White	34,723	10,578	1070
Black	4929	1671	110
Hispanic	7116	1623	131
Other-Unspecified	6882	1904	190
SES			
≤100 of poverty	7155	2652	246
100 to 199%	9234	2917	314
200 to 299%	8826	2473	282
300 to 399%	7984	2134	195
400%+	20,451	5600	464
Maternal Education	53,650	15,776	1501
High School	8973	2626	256
Less than High School	3734	923	77
More than High School	36,044	10,482	1022

Note: ASD = Autism Spectrum Disorder; CSHCN = Children with
Special Healthcare Needs; All data derived from National Survey for Children's Health (National Survey of Children's Health 2012)

The CDC-RDC merged the NLCD file, provided by the first author, with the NSCH (2012) using Zip code as the merging term. B.B. then analyzed data on-site at the CDC-RDC in Atlanta GA on June 13, 2018. In order to ensure no participants could be identified, the CDC-RDC reviewed the files before returning them to B.B. All files were reviewed and potentially identifying information was masked. The CDC-RDC returned the statistical files on June 18, 2018.

Model Covariates

In order to assess the impact of environmental factors on conduct problems in children with ASD we also need to control for variance from environmental factors, co-morbid conditions, and socio-demographic variables potentially associated with conduct problems. Continuous Zip code level percent canopy coverage and impervious space were first considered in relationship to conduct problems. Children were then included according to whether they were typically developing, had an ASD, or were a CSHCN. Co-morbid conditions associated with ASD or conduct disorder included depression (Strang et al., 2012), anxiety, intellectual disability (Baio, 2012), learning disability (O'Brien & Pearson, 2004), and ADHD (Simonoff et al., 2008). All co-morbid condition variables were stratified by severity by "none" (reference), "low," "moderate," and "high" classifications. ASD and conduct disorder are often associated with a variety of socio-demographic attributes (Crespi, 2016; Van Wijngaarden-Cremers et al., 2014). Thus, we included the following socio-demographic co-variates in our model: gender, and age grouped by early (6– 7 years), middle (8– 12 years), and adolescents (13–17 years). Race/Ethnicity included non-Hispanic White, non-Hispanic Black, non-Hispanic Other/Unspecified, and Hispanic. Socio-economic status included Less than 100% of the poverty line (reference), 100-199%, 200-299%, 300-399%, 400-499%, and 400+% above the poverty line. Maternal education included Less than, Greater than, or Equal to (reference) High School. Insurance status included none (reference), private, and public. Finally, English language status included English speaking (reference) and non-English.

Data Analysis

The R "survey" package (Lumley, 2004, 2010) was used to conduct weighted and stratified binary logistic regression models. Specifically, we were interested in the relationship between Zip code level nature (canopy coverage and impervious surface) exposure and conduct problem severity in children with ASD (controlling for the pre-specified covariates). NSCH weights data based on state level demographics and stratifies by State and whether interviews were conducted via cell or land line phones. All reported analyses use NSCH recommended weights and stratifications. Furthermore, Rao-Scott tests were used to answer our primary question: Do Zip code level measures of natural and built environment exposure predict caretaker reported conduct problem severity in children with ASD? Finally, odds ratios and 95% confidence intervals are reported to help assess the meaningfulness of statistical associations for key environmental and co-variates on conduct problems.

Results

Descriptive data of zip code percentage canopy coverage, percent non-impervious space, and square kilometers of zip code are seen in Table 2. Results of the binary regression model (Table 3) did not support a direct relationship between the predictors and conduct problems, and much of the variance in conduct problems severity was unaccounted for in the final model (Nagelkerke's R^2 = 0.47). Although there were no direct effects, there was a significant percentage canopy coverage X group interaction showing that caretakers of children with ASD residing in Zip codes with heavier tree canopy have lower odds of reporting severe conduct problems (OR = 0.97, 95%CI = 0.95 − 0.99, p < .05).

In addition to environmental relationships, being a CSHCN or having an ASD predicted increased odds of moderate to high levels of conduct

Table 2. Zip code level impervious "gray" and tree canopy "green" space for typical children, children with ASD, and CSHCN in the NSCH (2012).

	Conduct Problems			No Conduct Problems		
Variables	M	SD	Range	M	SD	Range
Impervious Space						
ASD	18.58	21.14	71.12	16.17	19.00	89.52
CSHCN	15.39	19.08	80.61	15.64	18.37	91.54
Typical	14.58	18.26	82.31	15.48	18.14	94.69
Canopy						
ASD	29.43	23.70	79.03	33.23	22.44	87.50
CSHCN	36.31	24.14	87.09	32.51	22.50	92.56
Typical	31.82	22.84	84.76	31.88	22.58	94.33
Square Km						
ASD	171.88	247.29	1175.69	209.21	400.10	8164.92
CSHCN	202.63	273.07	1632.64	201.06	370.66	8164.83
Typical	230.69	417.28	8164.37	208.83	381.23	8164.98

ASD = Autism Spectrum Disorder; CSHCN = Children with Special Healthcare Needs; NSCH = National Survey of Children's Health; Range = Difference between the minimum and maximum values.

Table 3. Parameter estimation from the binary logistic regression model predicting conduct problem severity (0 = No/Low vs. 1 = Moderate/High) in typical children, children with ASD, and CSHCN.

Variables	B	SE	Odds	2.5% CI	97.5% CI	*p*-value
(Intercept)	−6.43	0.47	0.00	0.00	0.00	
Canopy	0.01	0.01	1.01	1.00	1.03	
Impervious Space	0.01	0.01	1.00	0.98	1.03	
Area_SqKm	0.00	0.00	1.00	1.00	1.00	
Diagnostic Groups						
Typical (Ref)						
non-ASD CSHCN	2.81	0.45	16.50	6.38	39.83	***
ASD	4.13	0.60	61.90	19.13	200.28	***
Depression						
None (Ref)						
Mild	0.93	0.25	2.53	1.54	4.16	***
Moderate	1.33	0.30	3.77	2.10	6.79	***
Severe	1.47	0.38	4.33	2.06	9.11	***
Anxiety Problems						
None (Ref)						
Mild	0.74	0.21	2.10	1.39	3.18	***
Moderate	1.22	0.21	3.38	2.25	5.09	***
Severe	1.64	0.38	5.19	2.48	10.90	***
Intellectual Disability						
None (Ref)						
Mild	−0.02	0.59	0.98	0.31	3.13	
Moderate	0.19	0.35	1.21	0.61	2.40	
Severe	1.41	0.56	4.10	1.38	12.19	
Learning Problems						
None (Ref)						
Mild	0.36	0.21	0.98	0.31	3.13	
Moderate	0.44	0.19	1.21	0.61	2.40	*
Severe	0.54	0.32	4.10	1.38	12.19	
ADD/ADHD						
None (Ref)						
Mild	0.65	0.27	1.92	1.12	3.28	*
Moderate	1.94	0.17	6.97	5.00	9.71	***
Severe	2.32	0.22	10.19	6.65	15.61	***
Child Age						
Early Chilhood	0.19	0.18	1.21	0.84	1.73	
Middle Childhood	−0.03	0.16	1.17	0.71	1.34	
Adolescence (Ref)						
Sex						
Female (Ref)						
Male	0.38	0.19	1.46	1.10	1.93	*
Race/Ethnicity						
White(Ref)						
Black	0.11	0.19	1.12	0.77	1.63	
Hispanic	−0.05	0.05	0.95	0.61	1.47	
Other	−0.02	0.02	0.98	0.63	1.52	
SES						
≤100 of poverty (Ref)						
100 to 199%	−0.49	0.21	0.61	0.41	0.92	*
200 to 299%	−0.65	0.22	0.52	0.34	0.81	**
300 to 399%	−0.97	0.26	0.38	0.23	0.62	***
400%+	−1.36	0.23	0.26	0.16	0.40	***
Maternal Education						
High School						

(*Continued*)

Table 3. (Continued).

Variables	B	SE	Odds	2.5% CI	97.5% CI	*p*-value
Less than High School	−0.04	0.25	0.96	0.58	1.58	
More than High School	−0.17	0.17	0.84	0.61	1.16	
Canopy Mean * Group Interaction						
Canopy Mean Typical (Ref)						
Canopy Mean non-ASD CSHCN	−0.01	0.01	0.99	0.97	1.01	
Canopy Mean ASD	−0.03	0.01	0.97	0.95	0.99	*
non-Impervious Mean * Group Interaction						
non-Impervious Mean Typical (Ref)						
non-Impervious Mean CSHCN	0.00	0.01	1.00	0.97	1.02	
non-Impervious Mean ASD	−0.01	0.02	0.99	0.96	1.02	

Model Fit Statistics: Nagelkerke Pseudo R^2 = 0.48; * $p < .0.05$; ** $p < .0.01$; *** $p < .0.001$.

problems compared to typical children: CSHCN (*OR* = 16.50, 95% CI = 6.38–39.83, $p < .001$); ASD (*OR* = 61.90, 95%CI = 19.13–200.28, $p < .001$). Furthermore, severity of conditions comorbid with conduct problems predicted conduct problem severity including mild (OR = 2.53, 95%CI = 1.54–4.16, $p < .001$), moderate (*OR* = 3.77, 95%CI = 2.10–6.79, $p < .001$) and severe (*OR* = 4.33, 95%CI = 2.06–9.11, $p < .001$) depression; mild (*OR* = 2.10, 95%CI = 1.39–3.18, $p < .001$), moderate (*OR* = 3.38, 95% CI = 2.25–5.09, $p < .001$) and severe (*OR* = 5.19, 95%CI = 2.48–10.90, $p < .001$) anxiety; moderate learning problems (*OR* = 1.21, 95% CI = 0.61–2.40, $p < .01$); mild (*OR* = 1.92, 95%CI = 1.12–3.28, $p < .05$), moderate (*OR* = 6.97, 95%CI = 5.00–9.71, $p < .001$) and severe (*OR* = 10.19, 95%CI = 6.65–15.61, $p < .001$) ADHD. Intellectual disability severity was unrelated to conduct problems. For socio-demographic, sex and SES predicted moderate to severe conduct problems. Males had greater odds of conduct problems than females (*OR* = 1.46, 95%CI = 1.10–1.93). Compared to children in the lowest poverty range, children in 100-199% poverty (*OR* = 0.61, 95%CI = 0.41–0.92), 200-299% poverty (*OR* = 0.52, 95%CI = 0.34–0.81), 300-399% poverty (*OR* = 0.38, 95%CI = 0.23–0.62), and 400+ poverty (*OR* = 0.26, 95%CI = 0.16–0.40) ranges had fewer severe conduct problems.

Discussion

Analyses reported here indicate that community canopy (green) coverage, but not non-impervious (gray) space, is statistically associated with decreased conduct problems in children with ASD, but not typically developing children or CSHCN. This relationship was statistically significant even when controlling for a number of factors associated with conduct problems in ASD populations. However, although our exploratory models achieved statistical significance, the predicted odds of conduct problems were very small. Altogether, the data reported here suggests a *potentially* ameliorative effect of natural environments on behavior in children with ASD. Furthermore, data here suggests that built gray space is unlikely to affect the likelihood of severe conduct problems in children with ASD. Future research with more precise local measurements is needed to fully investigate this relationship.

There is now a solid body of evidence showing links between natural environments and behavioral health outcomes in typically developing children, and children with ADHD (for review see Hartig et al., 2014). Explorations of these relationships have only just begun in children with ASD. Stress reduction theory (SRT) and attention restoration theory are the primary frameworks the environmental health literature uses to interpret findings on natural environmental effects on behavioral health outcomes in children (Hartig et al., 2014; Kaplan & Kaplan, 1989; Kaplan, 1995). Most outcome variables include stress (e.g., self-reports, cortisol) or attention metrics (e.g., self-report or cognitive attention tasks); however, the relationship between natural environments and aggression in youth has not commonly been explored in youth with or without disabilities.

The findings for children with ASD resonate with research from the adult literature. For example, adult research indicates that urban vegetation correlates with reduced violent crime (Kuo & Sullivan, 2001a, 2001b; McMahan & Estes, 2015). Furthermore, a recent meta-analysis found that exposure to natural environments has a moderate impact on self-reported anger states across studies (Bowler, Buyung-Ali, Knight, & Pullin, 2010). Preliminary work indicates that this relationship is true for aggression in typical children too (Younan et al., 2016); however, our results conflict with these findings in that an association was found only for children with ASD and not for the general population of typically developing children or CSHCN. Collectively, these studies suggest that natural environments may have an ameliorative effect on expressions of negative affective states associated with conduct/behavior problems in typically developing adults, and children with ASD. However, more research and replication is needed to make more definite statements.

It is interesting to note that although the effects of canopy on conduct problems in ASD were in line with previously published work with typically developing populations (e.g., Bratman et al., 2012) the current study did not find expected relationships in typical or non-ASD CSHCN. Furthermore, no relationship was found for any group indicating that built space was associated with increased conduct problems. That children with ASD only showed expected relationships could be related to greater sensory sensitivity found in this population (Lidstone et al., 2014), which is also associated with anxiety, and could result in greater degrees of relief in response to canopy covered areas. However, sensory sensitivity is not unique to ASD as typical populations and CSHCN show varying degrees of sensory responsiveness and negative affectivity that may be responsive to canopy coverage. That said, one interesting future line of research might be to investigate the degree to which sub-clinical ASD traits, sensory sensitivity, and negative affectivity in non-ASD populations relate to perceived effects of greenspace. The null findings in relationship to built space are less readily apparent, but may have to with the relatively unrefined measures used in the current study.

The current study is not directly comparable to others due to the scope of measurement. Our primary outcome metric measured caretaker's perceptions of whether children with ASD's conduct problems were low or non-existent, versus moderate to severe. Other studies have used multi-item metrics to capture *in vivo* affective states related to anger or behaviors associated with frustration. Conduct problems, such as those found in oppositional defiant disorder and conduct disorder, are often associated with anger, but conduct problems may present in the absence of anger, such as impulsive acts associated with ADHD. Furthermore, the construct of behavior and conduct problems, often referred to within this context as "externalizing" behaviors, is multi-faceted (Hinshaw, 1992), and there is a great deal of variance across parents ratings influenced by multiple individual differences. For example, authoritarian parents may perceive eye-rolling and mild disrespect as moderate in severity, but less-authoritarian parents might perceive these behaviors as benign (Darling & Steinberg, 1993). Furthermore, caretakers of children with ASD frequently report high stress and burnout, which could affect the perceived severity of their child's behaviors (Shepherd, Landon, & Goedeke, 2018). Thus, in addition to more refined metrics operationalizing "problem behaviors," there is also a need for research to better understand potential interactive effects between parenting attitudes, parent stress, and parent's ratings of conduct problems in children. For example, it might be that for children who express similar levels of problem behaviors are rated as less problematic by parents with, for example, an authoritarian parenting style who live in areas with higher levels of greenspace compared to parents with a similar parenting style, but who live in areas with less greenspace and thus do not encounter the stress-ameliorating benefits of natural environments.

Limitations regarding the scope of measurement extend to our operationalization of green and gray space as well. Due to the limitations of using the NSCH our operational definition is essentially the proportion of green and gray space in Zip-codes wherein participants reside. This is problematic as there is much variation across a given zip-code in terms of the proportion of built environment to natural environment. For example, an apartment complex across the street from, or next door to, a strip mall area may have a far lower percentage of green space than a relatively heavily canopied residential area a mile away. Additionally, the NSCH does not provide metrics of the amount of time children spend outside in their particular Zip-code, we cannot be certain that children are actually engaging their natural environment. It may be that measurements of the lower level micro-environment wherein individuals directly experience nature may have greater predictive value compared to broader level metrics such as those used there. In the greenspace and health literature, more fine grained metrics of the environment are common, particularly in relationship to the home (Audrey & Batista-Ferrer, 2015; Ulmer et al., 2016; Villanueva et al., 2012); however, others argue for metrics broader than zip-code including entire metropolitan areas (Larson, Jennings, & Cloutier, 2016; Richardson et al., 2012). Furthermore, we operationalized greenspace as areas with canopy coverage, but could have allowed for a broader scope (e.g., open green fields, low lying shrubbery). Finally, the NSCH are collected throughout the year and the amount of green canopy varies greatly during the fall and winter months across the country. This is potentially problematic as some children's ratings may be collected during a time of minimal canopy coverage, thereby introducing an uncontrolled source of variance; however, recent research indicates that winter forest walks, even with diminished canopy, relates to improved mood and decreased stress in adults (Bielinis, Takayama, Boiko, Omelan, & Bielinis, 2018; Song et al., 2013), but this has not been actively studied in relationship to conduct problems or aggression in children. Thus, while the zip-code level analysis in the current manuscript is certainly within the scope of acceptable metrics, as is canopy coverage, future research should seek to augment these findings with fine grained analyses at micro-environment levels, more expansive greenspaces included in analyses, and possibly controlling for seasonal effects.

Conclusion

This is the first study to investigate the relationship between natural and built environments on conduct problems in children with ASD and CSHCN. Generally, these data suggest a role for canopy covered green space having small effects on conduct problems in children with ASD, but do not support a role for built environment having a negative effect. As such, these data add to a growing body of research showing that natural environments have positive mental health benefits for children with developmental disabilities. This study should be considered a very coarse "first cut" into the relationship between environmental variables and conduct problems. Future research should seek to replicate these results on a more precise scale in order to gain a more fine-tuned measurement of aggression, conduct problems, and natural and built environments.

Disclosure statement

No potential conflict of interest was reported by the authors.

Data availability statement

The data described in this article are openly available in the Open Science Framework at DOI:10.17605/OSF.IO/TPA6U.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

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