The complex relationship between greenspace and well-being in children with and without autism

Title

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Authors

Abstract

Greenspace (defined here as canopy coverage) positively correlates with improved wellbeing in typically developing individuals, but this relationship has not been established in children with autism spectrum disorder (ASD). To investigate this relationship, the current study merged data from the National Survey of Children's Health (2012) with the National Land Cover Database (NLCD). Across typically developing children, children with ASD, and non-autistic children with special healthcare needs, greenspace unexpectedly negatively correlated with wellbeing. Further, compared to typically developing children, children with ASD or CSHCN status had lower wellbeing. Interestingly, typically developing children with conduct problems displayed an unexpected negative relationship (i.e., as greenspace increased while wellbeing decreased), though those without conduct problems showed no relationship. Children with ASD displayed no relationship between greenspace independent of conduct problems. CSHCN displayed non-significant trends sugesting mild positive relationships between greenspace and wellbeing. These data indicate the relationship between greenspace and wellbeing is more complex than expected, and may depend on the diagnostic traits of the population studied.

Keywords: Autism, CSHCN, Wellbeing, Greenspace, Environmental Science

Introduction

A substantive body of research supports the notion that the natural environment exposure positively impacts human health and wellbeing (Chawla, 2015; Dadvand & Nieuwenhuijsen, 2019; Hartig et al., 2014; Twohig-Bennett & Jones, 2018). Research suggests that exposure to nature results in greater working memory capacity, executive functioning, attentional functioning, and positive affective states, and decreases in stress, aggression, negative mood states and depression (Capaldi et al., 2015; Gascon et al., 2015; Hartig et al., 2014; McMahon & Estes, 2015). Additionally, a growing literature indicates that exposure to natural environments has non-psychological positive health benefits in areas such as weight management, diabetes and blood pressure (Lachowycz & Jones, 2011). Collectively, this body of evidence suggests that exposure to natural environments has a net positive impact on individuals subjective wellbeing (Twohig-Bennett & Jones, 2018).

Research on natural environments and wellbeing

One of the largest bodies of research has examined the effects of natural environments on emotional aspects of wellbeing (McKormick, 2017). For example, Stress Reduction Theory (SRT) proposes that natural environments impact human health primarily via reducing stress reactivity (Hartig et all., 2014; Ulrich, 1993). Numerous studies show that natural environments are associated with decreased anxiety, depressive and psychiatric symptoms, and affective psychiatric disorders (e.g., depression) (Gascon et al., 2015). Furthermore, a meta-analysis of 32 experimental studies in adult populations reported that exposure to natural environments resulted in moderate increases in positive affective states and smaller decreases in negative affective states (McMahon & Estes, 2015). Notably, there is much variability across studies in terms of the operational definition and measurement of natural environments and wellbeing that may impact results. However, collectively, a sizeable body of research supports the proposition that natural environments impact human wellbeing in terms of increasing positive affective states and decreasing negative ones (McKormick, 2017).

While most research focuses on affective aspects of wellbeing, there is reason to believe that exposure to natural environments also positively impacts well-being via cognitive and social routes. For example, Attention Restoration Theory (ART) is another major theory in the literature, suggesting that natural environments increase individuals' capacity to maintain focus (Kaplan & Kaplan, 1989; Kaplan, 1995; Kaplan & Berman, 2010). Recent meta-analyses investigating ART showed small effects across studies on measures of working memory (e.g., digit span) (Ohly et al., 2016). A core function of

working memory is to maintain focus on a task at hand in the presence of distractors, and it is a known factor aiding in the accomplishment of personal goals (e.g., not snacking when on a diet) and academic achievement (Cowan, 2001; Hofman et al., 2008; Swanson & Alloway, 2012). Further, studies identifying associations between natural environments and increases in prosocial behaviors (Bell & Dyment, 2008) and decreased aggression and conduct problems suggest that exposure to natural environments affect behaviors associated with wellbeing (Putra et al., 2020; Zelenski et al., 2015). Considering the deleterious effects of conduct problems on social relationships, and the importance of relationships to wellbeing (Ehrensaft, 2005; Ettekal & Shi, 2020), exposure to natural environments may improve wellbeing via increased capacity to manage ones' affective states thereby maintaining good social standing with peers and community members.

Nature effects on the wellbeing of children

There is longstanding interest in the impact of natural environments on children (Kellert, 2002; Louv, 2008) and the literature on child outcomes largely mirrors that of adults (McCormick, 2017). For example, numerous studies support that exposure to natural environments is associated with increased attention and reduced stress and anxiety in children (McCormick, 2017). Collectively, findings from this research are often framed along the lines of natural environments having a positive effect on "mental wellbeing" (McCormick, 2017); combining these disparate metrics gives credence to the notion that cognitive (e.g., working memory) and affective (e.g., stress) wellbeing outcomes, though different, are related in terms of being generally beneficial to human functioning. Additionally, cognitive and affective dimensions of wellbeing are interdependent. For example, the ability to direct attention away from unpleasant and toward pleasant stimuli or thoughts is essential to regulating emotions.

Research on the effects of the natural environment on wellbeing is mostly conducted on typical children and children with attention deficit hyperactivity disorder (ADHD), and a growing body of evidence suggests that natural environments have positive effects on children with other disabilities like autism spectrum disorder (ASD). For example, a number of studies suggest that exposure to natural environments improves the attentional functioning of children with ADHD, as well as typical children (Kuo & Taylor, 2004; Kuo, 2015; Kuo et al., 2017; Taylor et al., 2002; Taylor & Kuo, 2009; Taylor & Kuo, 2011). Furthermore, recent research shows that natural environments are associated with decreased conduct problems and increased anxiety in children with and without an autism spectrum disorder (ASD) (Barger et al., 2020; Larson et al., 2018). Notably, ASD research suggests that there may be differential effects of nature for children with ASD compared to typically developing children or children with special healthcare needs (CSHCN). For children with ASD, but not CSHCN, greenspace exposure was associated with greater level of reported anxiety and lower levels of reported conduct problems than typical children. The authors hypothesize that these counter-intuitive relationships are possibly moderated by increased sensory sensitivity in children with ASD and require further investigation (Barger et al., 2020). Children with ASD and CSHCN are frequently reported to have lower levels of reported wellbeing than typically developing children (Hilton et al., 2019a; Hilton et al., 2019b). Collectively, these findings suggest that investigations into the relationship between greenspace and subjective wellbeing in children with ASD is warranted.

The primary purpose of this manuscript is to investigate the relationship between greenspace environments and a measure of wellbeing related to engagement. In particular, the National Survey of Children's Health (NSCH) includes items conceptualized as a wellbeing metric related to children's capacity to effectively function in their communities (Child and

Adolescent Health Measurement Initiative, 2017). This metric of wellbeing is measured with a series of items related to skills and capacities aimed at initiating and maintaining engagement, and following through on tasks (for items, see Primary Outcome in Methods). To date, there have been two published studies using data from the NSCH to investigate the effects of greenspace on child outcomes (Larson et al., 2018; Barger et al., 2020). Both studies examined affective outcomes, one the relationship between a zip-code level metric of greenspace (i.e., % covered by tree canopy) and presence of anxiety in children with and without autism (Larson et al., 2018), and the other the presence of conduct problems (Barger et al.,2020). This study will extend the research base on natural environments and children's development using the NSCH to explore non-affective outcomes that impact mental health. Considering the proposition that natural environments have a positive impact on wellbeing (McCormick, 2017), the current study tests the hypothesis that ZIP-Code level greenspace will positively predict wellbeing measured in the NSCH (2012).

Method

Child Outcomes Data Source

Data for this study came from The National Survey of Children's Health (NSCH, 2012). The NSCH (2012) was funded by the Maternal and Child Health Bureau of the Health Resources and Services Administration and administered by the National Center for Health Statistics via State and Local Area Integrated Telephone Survey services (Child and Adolescent Health Measurement Initiative, 2017). NSCH (2012) provides data on 95,677 caretakers reporting on one child from their household across the 50 United States and the District of Columbia who responded to surveys and renders data representative of U.S. children from birth to 17 years (Child and Adolescent Health Measurement Initiative, 2017). The NSCH (2012) reports wellbeing items for children age 6 and older. Furthermore, following from previous research using the NSCH (2012) to investigate greenspace effects on conduct problems and anxiety in children with and without an autism spectrum disorder (ASD), we conducted our analyses on typical children, children with ASD, and Children with Special Healthcare Needs (CSHCN) without an ASD (Larson et al., 2018; Barger et al., 2020).

Primary Outcome

The NSCH (2012) measures engagement wellbeing (called "flourishing" in NSCH manual) for children 6 and older using the following 5 items:

1. [He/She] finishes the tasks [he/she] starts and follows through with what [he/she] says [he'll/she'll] do.
2. [He/She] stays calm and in control when faced with a challenge.
3. [He/She] shows interest and curiosity in learning new things.
4. [He/She] cares about doing well in school.
5. [He/She] does all required homework.

Caregivers rated each item on a 5-point Likert scale (1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Usually, 5 = Always) which were summed to create an overall score. Cronbach alpha for this sample indicates adequate reliability (α = .73).

Green Space Data

Environmental data for this study came from the National Land Cover Database (NLCD) (http://www.mrlc.gov/nlcd2011.php), a publicly available16-class land cover classification scheme from the United States (Homer et al., 2015). Green space here refers to environments covered by tree canopy with metrics reflecting derivations using Huang et al.'s (2001) process. Grey space here refers to constructed non-natural surfaces (e.g., paved streets; houses) with NLCD metrics developed via normalized spectral mixture analysis (NSMA) (Wu, 2004; Yuan & Bauer, 2007). For this study, L.L. and S.O. developed satellite-based NLCD measures at the Zip Code level as the percentage of tree canopy (hereafter "green") and impervious ("grey") spaces measured from 0-100%.

Co-variates

In addition to environmental predictors, a number of co-variates were also considered. First, the literature supports that wellbeing is lower in populations with autism and children with special healthcare needs (Hilton et al., 2019a; Hilton et al., 2019b). Following recent research on green and grey environments with the NSCH, a measure delineating typical children, children with autism, and non-autistic CSHCN was developed by merging these groups into a single categorical variable (see Barger et al., 2020; Larson et al., 2018). The presence of anxiety, conduct problems, and depression were also coded as present/not-present, as the literature indicates that anxiety, depression and conduct problems relate to both greenspace and wellbeing. A dichotomous metric of learning disabilities (present/not-present) was included as the wellbeing measure has two items related to school performance (Fletcher et al., 2018). Further, a number of categorical socio-demographic co-variates were included in the model: gender (female [reference]), race/ethnicity (non-Hispanic White [reference], non-Hispanic Black, non-Hispanic Other/Unspecified, and Hispanic), Socio-economic status (< 100% of the poverty line [reference], 100-199%, 200-299%, 300-399%, 400-499%, and > 400% of the poverty line), maternal education (high school or less, more than high school [reference]), insurance status (none, private, and public [reference]), and whether the child lives in an urban area of 50,000+ [reference] or fewer. Children's age (6-17 years) was included as a continuous variable.

Data Analysis

All data were analyzed in base R (descriptives), the 'psych' package (Cronbach alpha) or the R 'survey' package (Lumley, 2004; 2010). Using 'survey,' weighted and stratified linear regression models were conducted regressing the 6 item well-eing metric available from the NSCH on predictors. Univariate and multi-variate analyses all included appropriate weighting and stratifications as recommended by the NSCH (Child and Adolescent Health Measurement Initiative, 2017).

Results

Table 1 provides sample descriptive statistics for each group: typically developing children (N = 65,593) children with autism (N = 1,393), and non-autistic CSHCN (14,947). Children in all three groups were exposed to similar percentages of Zip-Code level greenspace: typically developing children (55.31%), CSHCN (56.19%) and children with ASD (55.62%). Typically developing children had significantly higher greenspace than CSHCN ($t(64{,}285) = 5.75$, $p < .001$, $d = 19$). Zip code level greyspace was also similar for typically developing children (15.56%) as CSHCN (15.40%) and children with ASD (16.50%), though children with ASD were higher than CSHCN ($t(16{,}355) = 2.22$, $p = .03$, $d = 03$). Wellbeing metrics were significantly higher in typical children ($M = 21.43$, $SD = 2.64$) than in CSHCN (M = 19.78, SD = 3.53) ($t(64{,}205) = 23.97$, $p < .001$, $d = .19$) and children with ASD (M = 17.61, $SD = 3.82$) ($t(50{,}639) = 14.46$, $p < .001$, $d = .13$), who also differed from one

another ($t(16,300) = 8.16$, $p < .001$, $d = .13$). CSHCN children were older ($M = 12.00$, $SD = 3.41$) than typical children ($M = 11.66$, $SD = 3.51$) ($t(64,235) = 4.89$, $p < .001$, $d = .04$) and children with ASD (M = 11.52, SD = 3.29) ($t(16,305) = 2.10$, $p = 0.03$, $d = .03$). Typical children had fewer males than CSHCN ($_{wald}\chi^2(1, N = 64,236) = 39.42$, $p < .001$) and children with ASD ($_{wald}\chi^2(1, N = 50,665) = 117.53$, $p < .001$) who had greater proportions of males than CSHCN ($_{wald}\chi^2(1, N = 16,306) = 89.90$, $p < .001$). Furthermore, typical children had greater proportions of individuals from non-White race/ethnicity groups compared to CSHCN ($_{wald}\chi^2(3, N = 64,234) = 24.62$, $p < .001$) and children with ASD ($_{wald}\chi^2(1, N = 50,663) = 5.64$, $p = .001$); children with ASD were also less likely to be non-White compared to CSHCN ($_{wald}\chi^2(1, N = 16,304) = 2.77$, $p = .04$). Finally, children with ASD had a greater percentage of individuals living in areas with population densities of 50,000+ compared to CSHCN ($_{wald}^2(1, N = 16,306) = 24.62$, $p = .009$) and typical children ($_{wald}\chi^2(1, N = 50,665) = 4.68$, $p = .03$).

Table 1. Descriptive statistics, outcome variables, predictor variables and co-variates for children 6 to 17 years old in the National Survey of Children's Health (2012) broken out by Children with Special Healthcare Need and autism spectrum disorder (ASD) status

		Non-ASD		
		Typical	CSHCN	ASD
Total		49,323	14,964	1,393
% Greenspace^	M (SD)	55.31% (16.49)	56.19% (16.04)	55.62% (16.13)
% Greyspace^	M (SD)	15.56% (18.16)	15.40% (17.69)	16.50% (18.12)
Wellbing	M (SD)	21.43 (2.64)	19.78 (3.53)	17.61 (3.82)
Age	M (SD)	11.66 (3.51)	12.00 (3.41)	11.52 (3.29)
Sex	N (%)			
Female		24,792 (50.34%)	6,562 (43.90%)	253 (18.16%)
Male		24,461 (49.66%)	8,385 (56.10%)	1140 (81.84%)
Race/Ethnicity	N (%)			
Black		4,543 (9.21%)	1,557 (10.40%)	104 (7.47%)
Hispanic		6,430 (13.04%)	1,527 (10.20%)	116 (8.33%)
Other		6,253 (12.68%)	1,781 (11.90%)	163 (11.70%)
White		32,097 (65.07%)	10,099 (67.50%)	1010 (72.50%)
Learning Disability	N (%)			
No Learning Disability		47,868 (97.13%)	11,426(26.66%)	421 (30.35%)
Learning Disability		1,415 (2.87%)	3,499 (23.44%)	966 (69.65%)
Depression	N (%)			
No Depression		49,119 (99.60%)	13,570 (90.02%)	1,193 (86.01%)
Depression		195 (0.40%)	1,355 (9.08%)	194 (13.99%)
Anxiety	N (%)			
No Anxiety		48,892 (99.14%)	12,828 (85.82%)	838 (60.33%)
Anxiety		424 (0.86%)	2,120 (14.18%)	551 (39.67%)
Conduct Problems	N (%)			
No Conduct Problems		49,163 (99.68%)	13,303 (89.01%)	979 (70.33%)
Conduct Problems		158 (0.32%)	1,644 (10.99%)	413 (29.67%)
Maternal Education	N (%)			
More than H.S.		11,705 (26.12%)	3,348 (25.14%)	303 (24.09%)
H.S. or Less		33,101 (73.88%)	9,970 (74.86%)	955 (75.91%)
Population	N (%)			
< 50,000		7,288 (15.46%)	2,282 (16.48%)	185 (11.88%)
50,000+		25,688 (84.54%)	8,056 (83.52%)	749 (88.12%)
Poverty Level	N (%)			
<=100% of poverty		6,426 (13.09%)	2,466 (16.48%)	218 (15.65%)

100 to 199% of poverty	8,435 (17.09%)	2,746 (18.35%)	300 (21.54%)
200 to 299% of poverty	8,219 (16.65%)	2344 (15.66%)	263 (18.88%)
300 to 399% of poverty	7,347 (14.88%)	2035 (13.60%)	184 (13.21%)
400%+ of poverty	18,896 (38.29%)	5373 (35.91%)	428 (30.72%)
Insurance Status N (%)			
Public Insurance	2,571 (5.02%)	407 (2.72%)	27 (1.94%)
No Insurance	35,641 (72.54%)	9,422 (63.02%)	757 (53.38%)
Public Insurance	11,022 (22.44%)	5,122 (34.26%)	608 (43.68%)

Note.

^ = measured at Zip Code level

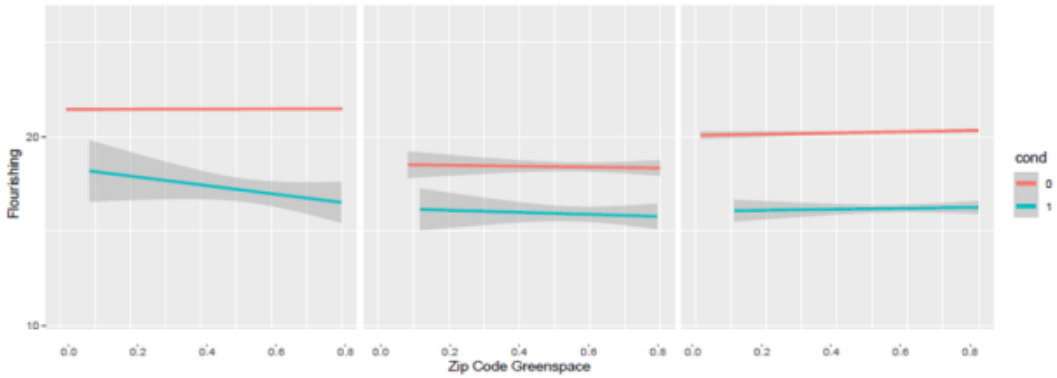
NSCH (2012) = National Survey of Children's Health (2012)

Compared to typical children, CSHCN and ASD had greater rates of learning disabilities (CSHCN: ${}_{wald}\chi^2(1, N = 64,236) = 842.26, p < .001$; (ASD: ${}_{wald}\chi^2(1, N = 50,665) = 185.17, p < .001$)), anxiety (CSHCN: ${}_{wald}\chi^2(1, N = 64,236) = 472.32, p < .001$; (ASD: ${}_{wald}\chi^2(1, N = 50,665) = 137.09, p < .001$)), depression (CSHCN: ${}_{wald}\chi^2(1, N = 64,236) = 305.14, p < .001$; (ASD: ${}_{wald}\chi^2(1, N = 16,306) = 22.35, p < .001$)) and conduct problems (CSHCN: ${}_{wald}\chi^2(1, N = 64,236) = 372.21, p < .001$; (ASD: ${}_{wald}\chi^2(1, N = 50,665) = 61.41, p < .001$)); compared to CSHCN, children with ASD had more learning disabilities (${}_{wald}\chi^2(1, N = 16,306) = 9.48, p < .001$), anxiety (${}_{wald}\chi^2(1, N = 16,306) = 24.64, p < .001$), and conduct problems (${}_{wald}\chi^2(1, N = 16,306) = 9.02, p = .002$). Typical children had lower proportions of mothers reporting a High School education or less compared to CSHCN (${}_{wald}\chi^2(1, N = 64,236) = 5.78, p = .02$) or children with ASD (${}_{wald}\chi^2(1, N = 50,665) = 17.23, p = .002$), who also differed from one another (${}_{wald}\chi^2(1, N = 16,306) = 9.66, p = .002$). Typical children were proportionally more likely to come from higher income levels compared to CSHCN (${}_{wald}\chi^2(1, N = 64,233) = 3.59, p = .006$) and children with ASD (${}_{wald}\chi^2(1, N = 50,662) = 3.72, p = .005$), who also differed from one another (${}_{wald}\chi^2(1, N = 16,303) = 6.33, p < .001$). Typical children were proportionally more likely to be uninsured compared to CSHCN (${}_{wald}\chi^2(1, N = 64,235) = 57.71, p < .001$) and children with ASD (${}_{wald}\chi^2(1, N = 50,664) = 22.20, p < .001$), who did not differ from one another.

The final multi-variate model is presented in Table 2. Model 1 shows that greenspace and greyspace accounted for a trivial amount of variance in children's wellbeing ($R^2 = 0.0006$); greenspace did have a significant negative relationship with children's wellbeing ($\beta = -0.69, p < 0.001$) and greyspace was unrelated to children's wellbeing ($\beta = 0.00, p = 0.18$). Model 2 indicates a complex relationship between wellbeing, greenspace, and child disability status ($R^2 = 0.09$). Specifically, when co-variates are included neither greenspace ($\beta = -0.15, p = 0.59$) nor greyspace ($\beta = -0.00, p = 0.21$) were associated with the wellbeing outcome, but ASD status ($\beta = -1.61, p = 0.06$), CSHCN status ($\beta = -0.98, p = 0.006$), having a learning disorder ($\beta = -1.78, p < 0.001$), having depression ($\beta = -1.46, p < 0.001$), and having anxiety ($\beta = -0.57, p = 0.007$) negatively predicted wellbeing; males had lower wellbeing than females ($\beta = -0.76, p < 0.001$) and Hispanic ($\beta = 0.54, p < 0.001$) and other race groups ($\beta = 0.41, p = 0.001$) were higher in wellbeing than Black children. Significant interaction effects were identified for Greenspace X Conduct Problems, Greenspace X Diagnostic Groups and Greenspace X Conduct Problems X Diagnostic Groups. Figure 1 illustrates these interactions. Across groups there is a clear distinction between greenspace and wellbeing in

that children without conduct problems have higher wellbeing scores as evidenced by trend lines with non-overlapping 95% confidence intervals. Further, diagnostic groups differed from one another in terms of the associations between greenspace and conduct problems: there was a minimal association between greenspace and wellbeing for typically developing children without conduct problems, but there was an inverse association between greenspace and wellbeing for those with conduct problems wherein as zip-code level greenspace increased wellbeing decreased; there was minimal association between zip code level greenspace and wellbeing for children with ASD with and without conduct problems; and a mild positive correlation between greenspace and wellbeing for CSHCN with and without conduct problems.

Figure 1. Greenspace X Clinical Group X Conduct Problems Impact on Wellbeing



Notes. Y Axis Truncated at 10 and 25 to display relationships.

0 = No Conduct Problems

1 = Conduct Problems

GREENSPACE AND WELLBEING

Table 2. Regression models displaying the relationship between greenspace, greyspace and wellbeing for U.S. children 6-17 from the NSCH (2012)

	Model 1				Model 2			
Variables	β	s.e.	t-value	p-value	β	s.e.	t-value	p-value
% Zip Greenspace	-0.69	0.23	-3.00	<0.001	-0.15	0.28	-0.54	0.587
% Zip Greyspace	0.00	0.00	-1.36	0.18	0.00	0.00	-1.24	0.213
Diagnostic Group								
Typical (ref)								
CSHCN - ASD					-1.61	0.85	-1.89	0.058
CSHCN – non-ASD					-0.98	0.36	-2.77	0.006
Sex								
Female (ref)								
Male					-0.76	0.06	-12.67	<0.001
Race/Ethnicity								
Black (ref)								
Other					0.54	0.12	4.36	<0.001
Hispanic					0.41	0.12	3.40	0.001
White					0.15	0.10	1.53	0.127
Age of Child (Years)					-0.08	0.01	-9.11	<0.001
Learning Disability								
No Learning Disability								
Learning Disability					-1.78	0.13	-13.56	<0.001
Depression								
No Depression								
Depression					-1.46	0.29	-5.10	<0.001
Anxiety								

No Anxiety					
Anxiety		-0.57	0.21	-2.68	0.007
Conduct Problems					
No Conduct Problems					
Conduct Problems		1.25	1.87	0.67	0.501
Maternal Education					
More than H.S.					
H.S. or Less		0.12	0.07	1.62	0.104
Poverty Level					
<=100% of poverty (Ref)					
100 to 199% of poverty		0.04	0.12	0.36	0.719
200 to 299% of poverty		-0.15	0.13	-1.17	0.242
300 to 399% of poverty		-0.01	0.13	-0.05	0.962
400%+ of poverty		0.19	0.12	1.60	0.109
Insurance Status					
No Insurance					
Private Insurance		0.11	0.16	0.70	0.484
Public Insurance		0.01	0.17	0.07	0.940
Population					
50,000+					
<50,000		-0.08	0.08	-0.92	0.356
Greenspace X Conduct Problems		-8.08	3.25	-2.49	0.013
Greenspace X Diagnostic Groups					
ASD X Greenspace		0.27	1.55	0.18	0.860
CSHCN X Greenspace		0.46	0.59	0.79	0.430
Conduct Problems X Diagnostic Group					
Conduct Problems X ASD		-6.13	2.93	-2.09	0.036
Conduct Problems X CSHCN		-3.45	2.15	-1.60	0.109
Greenspace X Conduct Problems X Diagnostic Group					
Greenspace X Conduct Problems X ASD		12.40	5.11	2.42	0.015
Greenspace X Conduct Problems X CSHCN		6.84	3.69	1.85	0.064
R^2	0.0006				0.09

Note. Wellbeing was measured with 5 caretaker report items from the NSCH (2012): He/She] finishes the tasks [he/she] starts and follows through with what [he/she] says [he'll/she'll] do; [He/She] stays calm and in control when faced with a challenge; [He/She] shows interest and curiosity in learning new things; [He/She] cares about doing well in school; [He/She] does all required homework (α = .73).

Discussion

This study contributes to a growing research base investigating the association between natural and built environments on the health and well-being of children with and without autism. In simple models the current study found, unexpectedly, that caretaker reports of wellbeing were negatively predicted by Zip Code level greenspace, indicating that as the percentage of greenspace in a child's Zip Code increased, wellbeing decreased; however, the greenspace accounted for a trivial amount of the variance in the NSCH wellbeing metric. Variance in wellbeing was better accounted for by the inclusion of a number of co-variates, including a complex interaction between greenspace, diagnostic group and the presence of conduct problems. Collectively, these data provide preliminary evidence indicating that the relationship between greenspace and wellbeing is more nuanced than the current literature suggests.

This study is unique in the use of a wellbeing measure available from the NSCH (2012). Wellbeing is a complex multi-faceted construct consisting of affective, cognitive and relational aspects (Forgeard et al., 2011). The greenspace and wellbeing literature currently has a primary research focus on affective components of wellbeing, particularly in relation to

greenspace increasing positive affective states and decreasing negative, as well as framing attention research in terms of a wellbeing outcome (McKormick, 2017). Additionally, there is a growing research base indicating that greenspace positively correlates with prosocial behavior in adults (Putra et al., 2020) and increased wellbeing is frequently inferred from research on attention and working memory (Ohly et al., 2016; McKormick, 2017). However, the wellbeing metric from the NSCH is somewhat different from affective, relational and cognitive dimensions of wellbeing discussed in the literature. This metric is akin to what has been termed as "engagement wellbeing," conceptualized as "a psychological state in which individuals report being absorbed by and focused on what they are doing" (Foregeard et al., 2011, p. 84). The NSCH (2012) wellbeing measure fits conceptually within this definition in that it measures children's (a) capacity to focus on tasks, (b) ability to face challenges calmly, (c) interest/curiosity about new things, (d) interest/care in doing well at school, and (e) completing homework. Thus, although the literature generally indicates that greenspace is associated with increases in positive affect, decreases in negative affect, and improved attentional capacity. The findings reported here extend this literature by suggesting that that engagement wellbeing has a more complicated relationship depending on which clinical group is considered and if children have conduct problems.

The results reported here are an important extension to the literature in a number of ways. First, the vast majority of results bearing on the wellbeing literature include data from small study samples that are not nationally representative (McKormick, 2017). By using NSCH data and analyzing with appropriate weights and stratifications this is the first study to date reporting on the relationship between greenspace and wellbeing using a nationally representative sample. While there are some fairly large school-based attention research studies that have been framed as wellbeing (e.g., Dadvand et al., 2015) most of these use in vivo cognitive attention measures or questionnaires designed to measure ADHD symptoms (for review, see McKormick, 2017). Additionally, while some studies include vital socio-demographics such as SES, race, and insurance status, and behavioral co-variates known to correlate with both greenspace and wellbeing (e.g., conduct problems, anxiety), many do not (Barger et al., 2021). Thus, by employing a large nationally representative sample this study had the power to control for a variety of important co-variates that smaller clinical studies often are not able to include their models. Furthermore, the vast majority of greenspace-wellbeing research studies using scales or cognitive measures are from samples of typically developing samples or populations of children with ADHD (Barger et al., 2021; McKormick, 2017). In recent years, studies investigating associations between greenspace and developmental outcomes in children with ASD and CSHCN have begun to emerge, but have only reported results on binary outcomes such as the presence of anxiety, conduct problems, or an ASD diagnosis (Barger et al., 2019; Barger et al., 2020; Wu & Jackson, 2017). Thus, this study is the first to compare the effects of greenspace effects on a wellbeing scale in children with disabilities other than ADHD.

The findings from this study build on the literature examining relations between greenspace and conduct problems. The literature on greenspace, aggression and conduct problems is generally uniform in finding that greenspace is associated with positive impacts on aggression and conduct problems, but is limited in that it primarily focuses on adult samples (Kuo & Sullivan, 2001a; Kuo & Sullivan, 2001b), and occasionally children (Barger et al., 2020). The few studies investigating relationships in children differ in terms of design; one focused solely on adolescents with a caretaker-rated clinical instrument (Yuan et al., 2016); the other used a single binary conduct problems outcome (Barger et al., 2020). To the authors' knowledge, this is the first study linking wellbeing with both greenspace and conduct problems. These results suggest that the

presence of conduct problems is a clear source of variance distinguishing children, independent of diagnostic group. However, the direction of the relationship is most seen in Figure 1 between children rated as having conduct problems across the three diagnostic groups: For typical children with conduct problems, there was a negative association between greenspace and wellbeing, for children with ASD a minimal association, and for CSHCN without ASD there was a small positive association between greenspace and wellbeing. Notably, for CSHCN with or without conduct problems there was a trend toward the anticipated positive relationship between greenspace and wellbeing. While suggestive, this complex interaction should be considered preliminary and requires replication with more refined and local measures of greenspace; a clear takeaway is that more research is needed considering disability status and the presence of conduct problems as co-variates in research measuring the effects of greenspace on wellbeing.

Limitations

A consideration of the study limitations is critical for identifying future directions. The first thing to note is that this study is a cross-sectional public health survey designed to gain a big-picture understanding of numerous health outcomes in U.S. children. As such, all items reported here are embedded in an intensive phone interview with caretakers randomly phoned to take the survey. Thus, standard limitations such as interview fatigue may have affected the quality of data collected (Bethlehem & Kersten, 1985). Further, the engagement wellbeing measure is also caretaker report. As such, this study does not directly measure child engagement, but instead measures a caretaker's perceptions of their child's engagement. Although the current study controlled for important variables, such as the presence of a learning disability, that could impact a child's level of perceived engagement, the NSCH do not provide granular data from the child's perspective that could be important for considering engagement as an outcome (Child and Adolescent Health Measurement Initiative, 2017). Furthermore, there are a number of factors that could impact children's perceived engagement by their caretakers that could be considered. For example, the match between what a child finds intrinsically motivating and a caretaker's preferences for their child's activities could impact caretaker's ratings (Cantley, 2005). If a caretaker primarily frames "successful" engagement in relation to academic tasks, but their child is primarily intrinsically motivated by sports and becomes bored or irritable when engaging with homework or school tasks, this could impact a caretaker's ratings. On the other hand, caretakers whose frame for successful engagement more broadly includes sports might be more likely to take that context into account compared to caretakers who primarily focus on academics. Relatedly, caretakers differ in the degree of autonomy they provide children, which can impact actual engagement on school-related tasks (e.g., homework; Doctoroff & Arnold, 2017). Thus, caretaker parenting styles and match with children's interests are a source of variance unaccounted for in the current study. A critical goal for future research in this area will be controlling for important variables related to caretaker parenting styles and expectations, and children's personal goals and subjective interest in measured engagement outcome.

One particular limitation not addressed in the current study is that a number of studies show that greater greenspace in schoolyards and other environments can elicit greater levels of physical activity (McCrorie et al., 2014). Physical activity and affective measures of wellness are correlated in that physical activity increases positive affective states and decreases negative states (Pretty et al., 2007). However, the relationship between physical activity and engagement wellness is not currently known, though research suggests that physical activity increases attentional capacity (Sattelmaier & Ratey, 2009). Some research suggests that physical activity interventions can have positive impacts on children's scholastic engagement in that

taking part in physically vigorous activities can increase positive engagement post-exercise (Nicholson et al., 2011). Although the cross-sectional study here does not allow for greater understanding of this relationship, one hypothesis for future research to consider is that a positive relationship between greenspace and engagement wellbeing may be contingent on one's ability to physically interact with ones' environment (Soga et al., 2015). That is, while some research suggests that engagement in physical activity or greenspaces may enhance attention and cognitive engagement, it may be that having access to greenspace without opportunity to be active in it could decrease engagement and actually increase distractions (Dzhamabov et al., 2018). Considering the notable decreases in children's opportunities to engage in outside activities, both during school (Ridgers et al., 2012) and free play (Mainella et al., 2011), and evidence suggesting outdoor education positively predicts outcomes for students with learning problems (Szcytko et al., 2018), makes this a particularly interesting line of research to further investigate.

A major limitation not addressed in this analysis is that ADHD was not explicitly analyzed. Since ADHD is comorbid with ASD, future research might seek to determine if inclusion of ADHD relevant covariates impacts findings (Harkins, Handen, & Mazurek, 2022). Notably, however, ADHD symptom presentation in children with ASD is quite complex, sharing both overlapping and unique executive functioning and wellbeing profiles compared to children with ADHD (Benallie, McClain, Bakner, Roanhorse, & Ha, 2021; Dieckhaus, Hardy, Anthony, Verbalis, Kenworthy, & Pugliese, 2021; Lee, Ward, Lane, Aman, Loveland, Mansour, & Pearson, 2021). Considering the body of work on greenspace and ADHD symptomology a clearly fruitful line of in *vivo work* would be to compare the overlapping and unique effects of greenspace environments on executive functioning in relation to wellbeing in children with ASD.

It is important to note that the scale of measurement used for environmental predictors in this study are objective physical measures at the Zip Code level. While research supports the measurement and predictive utility of greenspace and greyspace metrics at numerous levels including experimentally manipulated exposure to green environments (Schutte et al., 2017), greenspace around one's personal address (Taylor et al., 2002; Wells, 2000; Wells et al., 2003), neighborhood (Dadvand et al., 2015), Zip Code (Larson et al., 2018) and city levels (Larson et al., 2016), more localized measures could produce different results. For example, Taylor et al. (2002) reported that greenspace measures from around children's residential areas correlated with measures of self-discipline in girls (e.g., delay of gratification), but not boys. This study measured greenspace via an ordinal scale querying caretakers perceived views of nature from apartment windows, which is a comparatively much more subjective measure of greenspace provided in reference to a living context than the satellite-based method used in the current study. Notably, recent research suggests that perceptions of greenspace or engagement with greenspace may be more sensitive predictors of wellbeing outcomes than just the amount available (Putra et al., 2020; Putra, Astell-Burt, Cliff, Vella, & Feng, 2021). Thus, future research might blend these approaches via measuring greenspace with more refined satellite based measures, such as those used in the current study, and perceptions greenspace in caretakers' lived environments.

A major confound in the current study concerns the relationship between physical location and identified ASD. Current data, and past research, indicates higher rates of urban dwelling for identified cases of ASD (Lauritsen et al., 2014). Relationships identified in our sample may be a byproduct of the fact that families of children with ASD are more likely to live in urban areas where there are more clinical services, but less greenspace compared to rural areas. This could result in,

for example, more “mild” behavioral ASD cases found in urban areas, and more severe cases in rural areas, confounding the correlations between conduct problems and greenspace in this population. This could be complicated by rural families migrating to urban areas for better supports (i.e., healthcare migration; Flear, 2007). Future research should seek to more adequately control for population density with more refined metrics, perhaps augmented by measures of proximity to clinical services, or whether families engaged in healthcare migration to urban areas based on the severity of their child’s symptoms.

Conclusion and Future Research

The data reported here underscore the need for considering the relationship between greenspace and wellbeing beyond primarily affective and mental health-oriented constructions, especially for youth with disabilities. Future research should seek to build on this study via replication and extension. In particular, child self-reported engagement wellness measures and more local greenspace measures would help determine if the current findings are unique to the caretaker measures and Zip Code level greenspace measures in this study. Additionally, research statistically controlling (in correlational studies) or manipulating (in experimental studies) children’s capacity to engage in nature-based physical activity (or green exercise) would help determine if the negative relationship identified currently is partially due to fewer opportunities to engage in natural environments when they are present.

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