



## Gray space *and* green space proximity associated with higher anxiety in youth with autism



Lincoln R. Larson<sup>a,\*</sup>, Brian Barger<sup>b</sup>, Scott Ogletree<sup>c</sup>, Julia Torquati<sup>d</sup>, Steven Rosenberg<sup>e</sup>, Cassandra Johnson Gaither<sup>f</sup>, Jody Marie Bartz<sup>g</sup>, Andrew Gardner<sup>h</sup>, Eric Moody<sup>i</sup>, Anne Schutte<sup>j</sup>

<sup>a</sup> Dept. of Parks, Recreation & Tourism Management, College of Natural Resources, North Carolina State University, Raleigh, NC 27695, USA

<sup>b</sup> School of Public Health, Center for Leadership in Disability, Georgia State University, Atlanta, GA 30303, USA

<sup>c</sup> Dept. of Parks, Recreation & Tourism Management, College of Behavioral, Social, and Health Sciences, Clemson University, Clemson, SC, USA

<sup>d</sup> Dept. of Child, Youth and Family Studies, College of Education and Human Sciences, University of Nebraska, Lincoln, NE 68588, USA

<sup>e</sup> Dept. of Psychiatry, School of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>f</sup> U.S.D.A. Forest Service, Southern Research Station, Athens, GA 30602, USA

<sup>g</sup> Dept. of Health and Human Development, College of Education, Health and Human Development, Montana State University, Bozeman, MT 59717, USA

<sup>h</sup> Dept. of Psychology, College of Social and Behavioral Sciences, Northern Arizona University, Flagstaff, AZ 86011, USA

<sup>i</sup> JFK Partners, School of Medicine, University of Colorado Anschutz Medical Campus, Aurora, CO 80045, USA

<sup>j</sup> Dept. of Psychology, College of Arts and Sciences, University of Nebraska, Lincoln, NE 68588, USA

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### ABSTRACT

This study used ZIP code level data on children's health (National Survey of Children's Health, 2012) and land cover (National Land Cover Database, 2011) from across the United States to investigate connections between proximity to green space (tree canopy), gray space (impervious surfaces), and expression of a critical co-morbid condition, anxiety, in three groups of youth: children diagnosed with autism spectrum disorder (ASD,  $n = 1501$ ), non-ASD children with special healthcare needs (CSHCN,  $n = 15,776$ ), and typically developing children ( $n = 53,650$ ). Both impervious surface coverage and tree canopy coverage increased the risk of severe anxiety in youth with autism, but not CSHCN or typical children. Children with ASD might experience the stress-reducing benefits of nature differently than their typically developing peers. More research using objective diagnostic metrics at finer spatial scales would help to illuminate complex relationships between green space, anxiety, and other co-morbid conditions in youth with ASD.

### 1. Introduction

Exposure to nature and green space confers a wide array of physical, mental, and social health benefits (Hartig et al., 2014; Jennings et al., 2016; Shanahan et al., 2015b). Furthermore, exposure to natural environments is associated with improved mental health outcomes, lower stress and anxiety, and improved attentional states. However, most studies examining relationships between green space, health, and well-being focus on adults (Berman et al., 2008; Bratman et al., 2015; Kuo, 2015) or typically developing children (Bagot et al., 2015; Berto et al., 2015; Schutte et al., 2017; Taylor et al., 2002). Although some studies have focused on children with ADHD (Taylor and Kuo, 2009, 2011; Taylor et al., 2001; Wells, 2000), there remains a growing need to expand understanding of the impacts of nature and green space on the

mental health of youth, who have much to gain from the restorative potential of nature (Dzhambov et al., 2018; Kaplan, 1995; Taylor and Kuo, 2006; Williams, 2017). This study investigates connections between proximity to green space (environments with high vegetation density), gray space (human-constructed environments), and expression of a critical co-morbid condition, anxiety, in youth with and without autism spectrum disorder (ASD).

#### 1.1. Connections between Green Space & Children's Mental Health

The effects of nature exposure on children's mental health are often interpreted with respect to Attention Restoration Theory (ART), which posits that natural environments enhance attentional functioning (Berman et al., 2008; Bratman et al., 2012). Attention is a foundational

\* Corresponding author.

E-mail addresses: [LR.Larson@ncsu.edu](mailto:LR.Larson@ncsu.edu) (L.R. Larson), [bbarger1@gsu.edu](mailto:bbarger1@gsu.edu) (B. Barger), [sogletr@clemson.edu](mailto:sogletr@clemson.edu) (S. Ogletree), [jtorquati@unl.edu](mailto:jtorquati@unl.edu) (J. Torquati), [steven.rosenberg@ucdenver.edu](mailto:steven.rosenberg@ucdenver.edu) (S. Rosenberg), [cjohnson09@fs.fed.us](mailto:cjohnson09@fs.fed.us) (C.J. Gaither), [jody.bartz@montana.edu](mailto:jody.bartz@montana.edu) (J.M. Bartz), [andrew.gardner@nau.edu](mailto:andrew.gardner@nau.edu) (A. Gardner), [eric.moody@uwyo.edu](mailto:eric.moody@uwyo.edu) (E. Moody), [aschutte2@unl.edu](mailto:aschutte2@unl.edu) (A. Schutte).

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executive function (EF), with strong associations with inhibitory control (i.e., the capacity to stop a naturally occurring response) and working memory (i.e., the capacity to maintain information within one's scope of attention in the face of distractions) (Miyake et al., 2000; Schutte et al., 2017). ART builds on William James's theory of attention and maintains that natural environments encourage the restoration of attentional capacity by capturing involuntary attention and relieving the burden of directed attention focused on omnipresent stimuli in non-natural settings (Kaplan, 1995). In urban areas, these non-natural settings are often defined by gray infrastructure, or "gray space," comprised of roads, buildings, and other constructed features (Benedict and McMahon, 2006). To test the concepts of ART, researchers have relied on ratings scales designed to measure attention and/or attentional functioning, such as the Attention Deficit Disorders Evaluation Scale (Bagot, 2004; Wells, 2000), the Perceived Restorativeness Scale (Bagot et al., 2015; Ulrich, 1983), and a variety of in vivo executive and attentional functioning tasks (Berto et al., 2015; Schutte et al., 2017; Tennessen and Cimprich, 1995). Collectively, research indicates that exposure to more natural environments is associated with positive effects on typically developing children's attention and working memory (Bagot, 2004; Bagot et al., 2015; Dadvand et al., 2015; Kelz et al., 2013; Taylor et al., 2002; Tennessen and Cimprich, 1995; Wells, 2000).

Despite a historical focus on cognitive functioning, the influence of nature on affective dimensions of children's mental health might be equally important (Bratman et al., 2012). A complementary explanation of nature's effects on humans is stress reduction theory (SRT). SRT maintains that contact with nature or natural environments reduces stress through ameliorative physiological and psychological responses (Hartig et al., 2014; Ulrich, 1983). Assessment of these responses, often tracked through mood reports or physiological data (e.g., blood pressure, skin conductance, cortisol levels, neural activity), suggest that viewing natural scenes and vegetation (Kahn et al., 2009; Li and Sullivan, 2016; Ulrich, 1981, 1986) or experiencing nature directly (Bratman et al., 2015; Cole and Hall, 2010; Park et al., 2010) minimizes stress and stress-inducing processes such as cognitive rumination. Because stress and anxiety are strongly related, particularly in children (Mash and Barkley, 2003), these nature-based stress reduction strategies might help alleviate certain symptoms of anxiety-related disorders. However, there are few studies exploring the role of SRT in children's mental health, and most of these data focus on blood pressure and mood reports (Berto et al., 2015; Taylor et al., 2002; Ulrich, 1983). Some evidence suggests that nature exposure in typically developing youth positively impacts stress responses (Kelz et al., 2013; Li and Sullivan, 2016; Taylor et al., 2002; Wells and Evans, 2003), including mitigation of aggressive behaviors (Roe and Aspinall, 2011; Younan et al., 2016), but the stress inducing capacity of gray space and the stress recovery functions of green space (nature) in younger children, particularly children with disabilities, remains largely unexplored.

Currently, the literature examining connections between nature and the health and wellbeing of youth has primarily focused on one disability group: children with attention deficit hyperactivity disorder (ADHD). Research suggests that exposure to natural environments improves ADHD symptom expression (Kuo and Taylor, 2004; Taylor and Kuo, 2009, 2011; Taylor et al., 2001). For example, one experimental study reported that when children with ADHD took a 20 min walk in a city park, they had higher scores on a working memory task than after walking in downtown or residential areas (Taylor et al., 2009). This body of research highlights the value of natural environments for augmenting therapeutic interventions. However, much work is needed to detail how natural settings can be incorporated into interventions and what the appropriate "doses of nature" might be (Dzhambov et al., 2018; Shanahan et al., 2015a; Taylor and Kuo, 2011). Furthermore, there is a need to consider whether nature exposure might be beneficial for populations with developmental disabilities such as autism spectrum disorder (ASD) and stress-related co-morbidities like anxiety.

## 1.2. Autism, anxiety and potential benefits of stress reduction

The primary behavioral markers of ASD are atypical social-communication and restrictive and repetitive behaviors or interests (American Psychiatric Association, 2013; Bodfish et al., 2000; Lord et al., 2000; South et al., 2005). ASD affects 1 in 59 children and is associated with a number of cognitive and affective co-morbidities (Baio, 2018); a large body of evidence indicates that children with ASD have difficulties on a number of tasks related to problem solving and intellectual abilities (Hill, 2004; Pellicano, 2012). For example, many children with ASD have cognitive deficits and/or atypical information processing styles that may hamper their academic abilities, potentially affecting co-morbid learning disorders (Hill, 2004; Pellicano, 2012; Russell et al., 1996).

Children with ASD are also at greater risk for developing significant co-morbid anxiety conditions (e.g., generalized anxiety disorder) than typical peers and other clinical groups (Wood and Gadow, 2010); up to 39% of children with ASD have a co-morbid anxiety disorder and many others display sub-clinical anxiety traits (Van Steensel et al., 2012; White et al., 2009). Anxiety in ASD is associated with increased aggression, conduct problems, depression, self-injury, insistence on sameness, and irritability (Ambler et al., 2015; Lidstone et al., 2014; Mayes et al., 2011). Interestingly, some data supports the idea that anxiety in children with ASD is associated with *greater* cognitive, verbal, and/or developmental functioning (Hallett et al., 2013). Researchers theorize that children with ASD and greater social and cognitive capacity functioning may lead to increased awareness of their social differences, which could lead to increased levels of anxiety (Hallett et al., 2013, p. 2350; Wood and Gadow, 2010). However, other data indicates that anxiety disorders are more common in individuals with lower abilities (Van Steensel et al., 2012).

The heterogeneity in this literature likely relates to the variety of instruments used to assess anxiety symptoms (Wigham and McConachie, 2014), the particular sub-type of anxiety considered (e.g., separation, social, specific phobia) (Van Steensel et al., 2011), and difficulties related to accurately measuring anxiety in non-verbal children with ASD (Hallett et al., 2013). A recent meta-analysis supports the general view that increased anxiety is indeed positively correlated with cognitive abilities (Van Steensel and Heeman, 2017); however, previous work indicates that the relationship between anxiety and cognitive ability may vary according to anxiety subtypes (Van Steensel et al., 2011).

Overall, research indicates that anxiety symptoms are elevated in populations with ASD, and co-morbidities are high. Additionally, a study analyzing cross-sectional data from students in California suggests the prevalence of ASD in youth may be negatively linked to vegetation and tree canopy coverage and positively linked to road density (Wu and Jackson, 2017). Thus, individuals with ASD are an intuitive group in which to explore the relationship between nature exposure and anxiety, testing the general framework of SRT. According to SRT, the propensity for anxiety in youth with ASD might be exacerbated by exposure to urban development and positively impacted by time in nature.

## 1.3. Operationalizing "Nature"

Before the impacts of nature on anxiety can be assessed, "nature" must be defined. Natural environments are perceived and experienced by humans in a variety of ways (Hartig et al., 2014; Kaplan and Kaplan, 1989). Collectively, these social conceptualizations and objective realities often result in a definition of nature that encompasses easily perceived natural features (e.g., trees and forests, animals, water bodies) and process (e.g., wind, clouds and rain, sunlight) (Bratman et al., 2012; Hartig et al., 2011). Therefore, the task of converting the complex concept of nature into measurable variables impacting human health is inherently difficult. Some studies have focused on

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