THE BENEFITS OF NATURE-BASED SOLUTIONS TO PSYCHOLOGICAL HEALTH

EDITED BY: Giovanni Sanesi, Giuseppina Spano and Payam Dadvand
PUBLISHED IN: Frontiers in Psychology

frontiers Research Topics

frontiers

ISSN 1664-8714
ISBN 978-2-88966-584-6
DOI 10.3389/978-2-88966-584-6

About Frontiers

Frontiers is more than just an open-access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers Journal Series

The Frontiers Journal Series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the Frontiers Journal Series operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to Quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews.
Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the Frontiers Journals Series: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area! Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers Editorial Office: frontiersin.org/about/contact

THE BENEFITS OF NATURE-BASED SOLUTIONS TO PSYCHOLOGICAL HEALTH

Topic Editors:
Giovanni Sanesi, University of Bari Aldo Moro, Italy
Giuseppina Spano, University of Bari Aldo Moro, Italy
Payam Dadvand, Instituto Salud Global Barcelona (ISGlobal), Spain

Citation: Sanesi, G., Spano, G., Dadvand, P., eds. (2021). The Benefits of Nature-Based Solutions to Psychological Health. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-88966-584-6

Table of Contents

frontiers in Psychology

EDITORIAL
published: 04 February 2021
doi: 10.3389/fpsyg.2021.646627

Editorial: The Benefits of Nature-Based Solutions to Psychological Health

Giuseppina Spano[1]*, *Payam Dadvand*[2,3] *and Giovanni Sanesi*[1]

[1] Department of Agricultural and Environmental Sciences, University of Bari Aldo Moro, Bari, Italy, [2] ISGlobal, Barcelona, Spain, [3] Centro de Investigación Biomédica en Red Epidemiología y Salud Pública (CIBERESP), Madrid, Spain

Keywords: psychological health, mental health, well-being, human-environment interaction, urban green space, natural environment

Editorial on the Research Topic

The Benefits of Nature-Based Solutions to Psychological Health

INTRODUCTION

Nature-based solutions (NBS) have been defined by the European Commission as actions aiming to provide environmental, social, and economic benefits through the inclusion of natural features in the urban environment. The exposure to natural environments, including NBS in urban contexts, has been associated with a large number of health benefits (Ulrich et al., 1991; Berman et al., 2008; Spano et al., 2020), particularly mental health and well-being among those most studied. Earlier studies on such benefits have been mainly experimental, investigating the short-term effects of brief exposure to natural environments on stress reduction and cognitive restoration (Kaplan and Kaplan, 1989; Berto, 2005; Nilsson et al., 2010; Carrus et al., 2017). More recently, large-scale epidemiological studies have provided further evidence of the long-term effects of sustained exposure to green spaces on mental health and well-being throughout the life course (Hartig et al., 2014; Gascon et al., 2015; McCormick, 2017; de Keijzer et al., 2020).

Several dimensions characterize the human–nature interaction. In this sense, the present Research Topic was intended to provide an overview of studies focusing on the association of exposure to natural environments in urban, peri-urban, and rural settings with psychological well-being and mental health from different perspectives.

EFFECTS DURING CHILDHOOD, ADOLESCENCE AND YOUNG ADULTHOOD

Touloumakos and Barrable offered an interesting perspective on the potential protective effect of nature engagement in children with adverse childhood experiences such as family abuse and dysfunctional experiences related to poor parenting skills. These childhood experiences have been shown to produce physiological and psychological symptoms, including chronic stress, cognitive dysfunctions, psychopathologies, and cardiovascular and metabolic disorders. From an overview of published studies, a significant gap emerged in the potential therapeutic and protective effect of nature engagement (NE) in individuals with adverse childhood experiences. In this perspective,

OPEN ACCESS

Edited and reviewed by:
Giuseppe Carrus,
Roma Tre University, Italy

***Correspondence:**
Giuseppina Spano
giuseppina.spano@uniba.it

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *27 December 2020*
Accepted: *14 January 2021*
Published: *04 February 2021*

Citation:
Spano G, Dadvand P and Sanesi G (2021) Editorial: The Benefits of Nature-Based Solutions to Psychological Health. Front. Psychol. 12:646627. doi: 10.3389/fpsyg.2021.646627

the authors suggested that NE can positively impact the physiological and psychological health of children who have experienced trauma, opening the door to the potential beneficial effects of nature inducing a retroactive effect.

Inconsistent evidence has been found on the association between green space and pro-social behavior in children and adolescents. Putra et al. presented a systematic review on 15 available studies highlighting mixed findings and methodological heterogeneity. In particular, green space indicators and pro-social behavior measures varied among studies and a lack of mediators and potential confounding variables was detected. This review provides preliminary evidence on the association between green space and pro-social behavior. Nevertheless, the authors underlined the need to further develop rigorous studies in order to identify underlying pathways in this promising association and suggested considering the role of perceived quality of green space as an important variable in relation to pro-social behavior.

Another neglected topic was found to be the relationship between NE and pro-social behavior among undergraduate students, a sub-population that is well-known for being at high risk of stress, anxiety and depression. Sachs et al. showed that NE during childhood appeared to be positively associated with NE during college. Similarly, a pro-environmental attitude was positively associated with NE both in childhood and during college. This work enhanced the long-term effect of green space exposure during childhood also in light of the considerable decrease of time spent in nature during college. However, their study did not reveal any association between NE and stress levels, probably because, as reported by some participants, contact with nature could have been perceived as a waste of time given the many school commitments.

EFFECTS DURING ADULTHOOD

Pro-environmental behavior was also investigated in a study by Panno et al. in a sample of urban park visitors. The authors tested a novel modeling framework in which pro-environmental behavior was directly predicted by an emotion-regulating strategy (namely, cognitive reappraisal) and indirectly through the experience of "being away" when embedded in a natural environment. This study offered relevant insights on the role of cognition and perceived restorative experience of the natural environment, which together prove to significantly trigger pro-environmental choices.

Although its multiple benefits are well-known, direct contact with the natural environment is not always possible. For this reason, Browning et al. compared the impacts of simulated (i.e., virtual) and actual nature experiences on mood based on data from six published studies. Simulated experiences varied from looking at pictures to walking on the treadmill while watching a video of the natural environment. Results suggest a greater positive effect on mood due to the real experience of green exposure. This work also highlighted the possibility of considering valid alternatives, especially when green exposure is not possible, as in the case of recent confinement due to the COVID-19 pandemic.

Surprising findings emerged in the study results by Trammell and Aguilar. They found that natural environments could positively affect performance improvement when the required task involves a moderate attention level, while no effect was found on tasks requiring minimal or greater amounts of attention. However, this positive effect was greater in the indoor environment than in the natural environment. Physical activity, on the other hand, seemed to have beneficial effects on affect and cognition regardless of whether it was carried out in indoor or natural environments. This study suggests that a complex relationship exists between the natural environment and the benefits that cannot be reduced to the concepts of exposure and restorativeness. Other mechanisms may play a role in diversifying outcomes, including adaptation mechanisms.

With regard to complexity, new theoretical insights on green space exposure and the reduction of psychosis risk have been advanced by Ebisch. This perspective paper provides an overview of the unexplored role of the self and brain network interactions in the connection between green space and psychosis. This topic is of particular relevance, since psychotic disorders (e.g., schizophrenia) have been a priority for the public health agenda due to the pervasiveness and chronicity of the disorder, high rate of hospitalizations and comorbidities, and premature mortality.

CONCLUSIONS

This Research Topic provides a multidisciplinary perspective of the human–nature interaction throughout the life-course in association with mental health and well-being. The studies included in this topic have generally demonstrated potential beneficial associations; however, they have also highlighted inconsistencies in the evidence available in terms of their applied methodologies and reported findings.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

ACKNOWLEDGMENTS

We thank all the authors who have contributed to this Research Topic with their highly valuable research. We also thank the reviewers for their effort in maintaining the quality of the contributions very high and the editorial team of Frontiers in Psychology—Environmental Psychology section for their support throughout the production of this Research Topic.

REFERENCES

Berman, M. G., Jonides, J., and Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychol. Sci.* 19, 1207–1212. doi: 10.1111/j.1467-9280.2008.02225.x

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *J. Environ. Psychol.* 25, 249–259. doi: 10.1016/j.jenvp.2005.07.001

Carrus, G., Scopelliti, M., Panno, A., Lafortezza, R., Colangelo, G., Pirchio, S., et al. (2017). A different way to stay in touch with 'urban nature': the perceived restorative qualities of botanical gardens. *Front. Psychol.* 8:914. doi: 10.3389/fpsyg.2017.00914

de Keijzer, C., Bauwelinck, M., and Dadvand, P. (2020). Long-term exposure to residential greenspace and healthy ageing: a systematic review. *Curr. Environ. Health Rep.* 7, 65–88. doi: 10.1007/s40572-020-00264-7

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., et al. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. *Int. J. Environ. Res. Public Health* 12, 4354–4379. doi: 10.3390/ijerph120404354

Hartig, T., Mitchell, R., De Vries, S., and Frumkin, H. (2014). Nature and health. *Annu. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Kaplan, R., and Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective*. Cambridge: Cambridge University Press, 340.

McCormick, R. (2017). Does access to green space impact the mental well-being of children: a systematic review. *J. Pediatr. Nurs.* 37, 3–7. doi: 10.1016/j.pedn.2017.08.027

Nilsson, K., Sangster, M., Gallis, C.,Hartig, T., De Vries, S., Seeland, K., et al. (eds.). (2010). *Forests, Trees and Human Health*. Dordrecht: Springer Science, Business Media B.V.

Spano, G., Giannico, V., Elia, M., Bosco, A., Lafortezza, R., and Sanesi, G. (2020). Human health–environment interaction science: an emerging research paradigm. *Sci. Total Environ.* 704:135358. doi: 10.1016/j.scitotenv.2019.135358

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

SYSTEMATIC REVIEW
published: 30 April 2020
doi: 10.3389/fpsyg.2020.00859

The Relationship Between Green Space and Prosocial Behaviour Among Children and Adolescents: A Systematic Review

I Gusti Ngurah Edi Putra[1], *Thomas Astell-Burt*[1,2,3,4*], *Dylan P. Cliff*[5,6], *Stewart A. Vella*[6,7], *Eme Eseme John*[1] *and Xiaoqi Feng*[1,2,3,8]

[1] *Population Wellbeing and Environment Research Lab (PowerLab), School of Health and Society, Faculty of Social Sciences, University of Wollongong, Wollongong, NSW, Australia,* [2] *Menzies Centre for Health Policy, University of Sydney, Sydney, NSW, Australia,* [3] *National Institute for Environmental Health, Chinese Center for Disease Control and Prevention, Beijing, China,* [4] *School of Public Health, Peking Union Medical College, The Chinese Academy for Medical Sciences and Tsinghua University, Beijing, China,* [5] *School of Education, Early Start, Faculty of Social Sciences, University of Wollongong, Wollongong, NSW, Australia,* [6] *Illawarra Health and Medical Research Institute, University of Wollongong, Wollongong, NSW, Australia,* [7] *School of Psychology, Faculty of Social Sciences, University of Wollongong, Wollongong, NSW, Australia,* [8] *School of Public Health and Community Medicine, University of New South Wales, Sydney, NSW, Australia*

OPEN ACCESS

Edited by:
Payam Dadvand,
Instituto Salud Global Barcelona (ISGlobal), Spain

Reviewed by:
Simon Bell,
University of Edinburgh, United Kingdom
Mi Jeong Kim,
Hanyang University, South Korea

****Correspondence:***
Thomas Astell-Burt
thomasab@uow.edu.au

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *04 February 2020*
Accepted: *07 April 2020*
Published: *30 April 2020*

Citation:
Putra IGNE, Astell-Burt T, Cliff DP, Vella SA, John EE and Feng X (2020) The Relationship Between Green Space and Prosocial Behaviour Among Children and Adolescents: A Systematic Review. Front. Psychol. 11:859. doi: 10.3389/fpsyg.2020.00859

The plausible role of nearby green space in influencing prosocial behaviour among children and adolescents has been studied recently. However, no review has been conducted of the evidence testing the association between green space and prosocial behaviour. This systematic review addresses this gap among children and adolescents. Within this review, we propose a conceptual framework describing potential pathways linking green space to prosocial behaviour, discuss the direction, magnitude, moderators, and mediators of the association, and develop a narrative synthesis of future study directions. Out of 63 extracted associations from 15 studies, 44 were in the positive or expected direction, of which 18 were reported to be statistically significant ($p < 0.05$). Overall, the current evidence shows that exposure to green space may potentially increase prosocial behaviour among children and adolescents, with some contingencies (e.g., child's sex and ethnic background). However, the volume and quality of this evidence is not yet sufficient to draw conclusions on causality. Further, heterogeneity in the indicators of green space exposure could lead to mixed findings. In addition, none of the included studies investigated potential mediators. Nevertheless, this review provides preliminary evidence and a basis for further investigation with rigorous study methodology capable of drawing causal inferences and testing potential effect modifiers, linking pathways, and relevant green space measures.

Keywords: prosociality, altruism, nature, environment, green space quantity, green space quality, children, adolescents

INTRODUCTION

Prosocial behaviour is increasingly recognised as an important part of child development (Dunfield, 2014). It includes a range of behaviours that "benefit others or at very least promote harmonious relations with others" (Hay, 1994, p. 33). Prosociality among children is characterised by the presence of positive interactions, such as sharing, helping, cooperating, and comforting (Hay, 1994; Dunfield, 2014; Hammond et al., 2015; Piotrowski et al., 2015; Wittek and Bekkers, 2015). Prosocial behaviour emerges in early childhood and can progressively increase in variety, frequency, and complexity as children get older (Hay et al., 2004; Knafo et al., 2008; Brownell, 2013). In addition, newly established social networks (e.g., friendship) and the growth of socio-cognitive capabilities potentially lead to more opportunities for older children to behave prosocially (Hay and Cook, 2007; Abrams et al., 2015; Eisenberg et al., 2015). However, the evidence suggests that prosocial behaviour might decline in early- and middle-adolescence, but may start to rebound in late adolescence or early adulthood (Eisenberg et al., 2015).

A current body of literature highlights the importance of prosocial behaviour in positively contributing to aspects of youth development. Positive outcomes include greater academic success (Collie et al., 2018; Gerbino et al., 2018), social competence (Bar-Tal, 1982), and problem-solving skills (Carlo et al., 2012; Eisenberg et al., 2015). Prosocial behaviour is considered a psychosocial asset (Leventhal et al., 2015), that contributes to better quality peer relationships (Caputi et al., 2012), lower reported aggression (Swit, 2012; Obsuth et al., 2015), and favourable subjective well-being (Aknin et al., 2012, 2015; Proctor and Linley, 2014; Yang et al., 2019). Previous work also suggests that prosocial behaviour was associated with child health-related outcomes and behaviours including fewer externalising and internalising behavioural problems (Flynn et al., 2015; Flouri and Sarmadi, 2016), lower screen time (Healy and Garcia, 2019), and optimal cardiometabolic health (Qureshi et al., 2019). Given these potential benefits for positive health, psychological, and social aspects, promoting prosocial behaviour development beginning in early childhood is important.

The development of prosocial behaviours is jointly determined by factors that can be broadly described as personal and environmental characteristics (Piliavin, 2001). Genetic factors (Fortuna and Knafo, 2014; Israel et al., 2015; Knafo-Noam et al., 2015), gender (Abdi, 2010; Kok et al., 2018), personality traits or self-concepts (Cauley and Tyler, 1989; Gallitto and Leth-Steensen, 2019), and empathy (Garaigordobil, 2009; Williams et al., 2014) are the factors that contribute to prosocial behaviour differences between individuals. In addition, published literature has also suggested that cultural background and values are correlates of prosocial behaviour (Richman et al., 1988; Smith et al., 2019). Socio-environmental factors such as parental influences (parental nurturing, parent-child relationship, parental warmth, parental socialisation; Carlo et al., 2010; Pettygrove et al., 2013; Ferreira et al., 2016; Pastorelli et al., 2016) and peer influences (Fujisawa et al., 2008; Fabes et al., 2012; Lai et al., 2015; Lee et al., 2016; Oldfield et al., 2016; Silke et al., 2018) are important predictors for the development of prosocial skills among children and adolescents. Moreover, the exposures to prosocial content from media positively influence prosocial acts, whereas the use of violent media exhibits negative associations (Bar-on, 2000; Greitemeyer, 2011; Prot et al., 2014; de Leeuw et al., 2015). Aspects of the physical environment such as schools are also important to promote prosocial behaviour since schools enable social interactions among children and adolescents through organised cooperative learning activities in class, and through opportunities for play (Wentzel, 2015). The presence of other physical environments that facilitate social contacts and interactions such as green space in urban environments potentially serves as an additional space for children to develop and practice prosocial acts.

Green spaces are public areas that include natural vegetation components, such as grass, trees, and/or shrubs that people commonly utilise as gathering places for recreation, sport, relaxation, and other social activities (Dinnie et al., 2013; Dennis and James, 2016; Jennings and Bamkole, 2019). Those areas can be naturally created, such as forests, other landscapes with natural entities or human-made or built environments that contain natural vegetation, such as gardens and parks (Hartig et al., 2014; Taylor and Hochuli, 2017). While children in urban areas tend to spend less time in outdoor activities and have less social contact with other children (Singer et al., 2009), the presence of nearby green space might promote positive social interactions that lead to prosocial behaviour development. The plausible influence of urban green space on child prosocial acts is increasingly being studied in recent years (Amoly et al., 2014; Balseviciene et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019). However, no systematic review of these studies is available so far.

This systematic review aimed to evaluate the available literature on the association between urban green space and prosocial behaviour among children (0–12 years) and adolescents (13–18 years). These age ranges were selected based on a previous systematic review on prosocial behaviour among adolescents (Silke et al., 2018). Further, we propose a conceptual framework and provide discussion of the potential mechanisms linking green space and prosociality. In addition, a narrative synthesis of the existing published literature on green space and prosocial behaviour nexus is presented, followed by the discussion of our findings and future study directions.

POTENTIAL MECHANISMS LINKING GREEN SPACE AND PROSOCIAL BEHAVIOUR

Health benefits due to neighbourhood green space exposures in urban environments have been well-documented among children that include better mental health and well-being (Flouri et al., 2014; Feng and Astell-Burt, 2017c,d; McCormick, 2017; Vanaken and Danckaerts, 2018), more physically active and/or less screen time (Roemmich et al., 2006; Sanders et al., 2015; Akpinar, 2017), and reduced odds of respiratory health problems (Feng and Astell-Burt, 2017b; Tischer et al., 2017; Eldeirawi et al., 2019). Moreover, favourable health outcomes due to green space

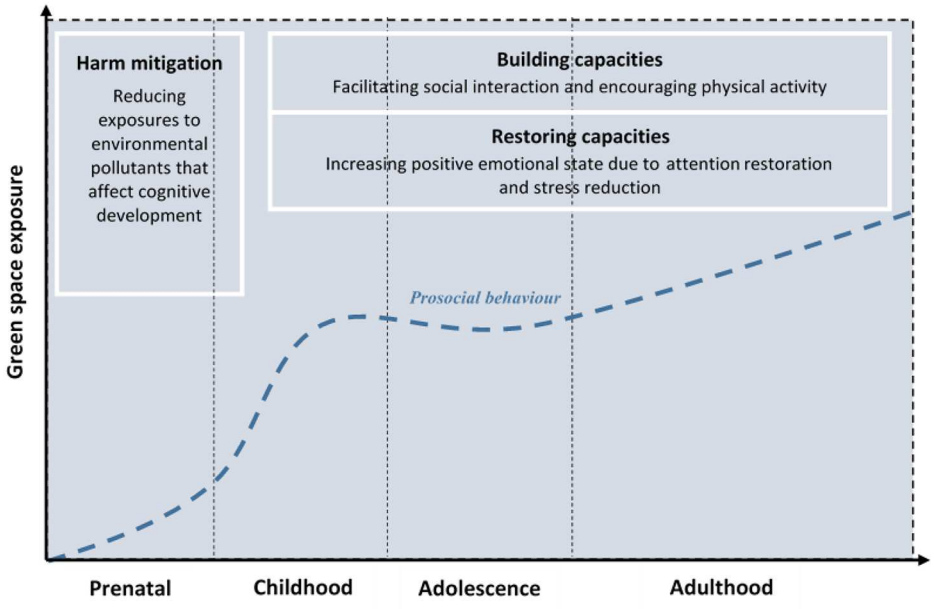


FIGURE 1 | Potential pathways linking green space to prosocial behaviour. Adapted from Markevych et al. (2017) and Ben-Shlomo et al. (2014).

exposure across the lifespan have been reported in some recent systematic reviews (Lee and Maheswaran, 2011; van den Berg et al., 2015; Kondo et al., 2018; Twohig-Bennett and Jones, 2018). However, the potential association between greenness and prosocial behaviour and its underlying mechanisms have not been widely reported.

Scholars in multidisciplinary fields suggested a conceptual model to help understand the mechanisms linking urban green space to health outcomes. Three domain pathways are proposed and these include (i) harm mitigation (e.g., reducing harmful environmental exposures—air pollution, noise, heat), (ii) restoring capacities (e.g., restorative effects, stress recovery), and (iii) building capacities (e.g., promoting physical activity, facilitating social cohesion; Markevych et al., 2017). Under the frame of this theoretical model, we elaborated potential mechanisms linking urban green space to prosocial behaviour. In addition, we also adopted the concept of life course epidemiology which suggests that exposures to physical or social factors during the life course might have long term effects on later disease risk or health outcomes (Kuh et al., 2003; Ben-Shlomo et al., 2014). Based on this concept, we identified potential critical and sensitive periods for the influence of green space on the development of prosocial behaviour. Our combined model is shown in **Figure 1** and discussed below.

Harm mitigation may be the first pathway linking green space to child prosocial behaviour. Exposures to environmental pollutants during vulnerable windows, such as prenatal or early postnatal periods might have adverse impacts on child cognitive development (Dadvand et al., 2015), which in turn, influences prosocial behaviour. Ren et al. (2019) conducted a cross-sectional study to examine the associations of prenatal exposure to outdoor air pollution on prosocial behaviour among China's preschoolers. Exposures to PM_{10} (particulate matter $<10\,\mu m$ in diameter) and $PM_{2.5}$ (particulate matter $<2.5\,\mu m$ in diameter) during the full gestation period were reported to be associated with increased odds of abnormal range of prosocial behaviour after controlling for child-related factors, maternal factors, and socio-economic status. Meanwhile, past work suggested that air-related pollution can be reduced by the presence of green space (Su et al., 2011; Dadvand et al., 2012a,b). Previous studies also found the association between urban greenness and cognitive development among children was partly explained by reduction in air-related pollution (Dadvand et al., 2015; Liao et al., 2019). Therefore, early and frequent exposures to nearby greenness can positively affect later prosocial behaviour by mitigating harmful environmental stressors during windows of susceptibility such as during the prenatal period. Furthermore, negative effects of prenatal exposure to air pollution on prosociality can be attenuated by factors driving cognitive development, such as learning activities and social interactions that can occur in other settings (e.g., schools; Weinstein and Bearison, 1985; Gustin et al., 2018).

Childhood could be one of the critical periods for the green space-prosociality association. Critical period refers to a specific time window in which exposure has effects on the development and subsequent outcome (Kuh et al., 2003). While prosocial behaviour can progressively increase with age during childhood, exposures to green space might help to elevate prosocial behaviour development through mechanisms of building and restoring capacities. Moreover, late childhood can be considered as the sensitive period for the association between green space and prosociality due to exposures to green space

might have a greater effect than it would be at other childhood periods. Older children widen their friendships and develop socio-cognitive skills (Hay and Cook, 2007; Abrams et al., 2015; Eisenberg et al., 2015). They tend to have more social interactions and behave more prosocially than their younger counterparts and the presence of nearby green space might multiply these opportunities. According to the building capacities pathway, green space provides attractive places for children to foster social interactions and then facilitate prosocial behaviour development. This is supported by the social network theory which posits that repeated and frequent interaction among individuals brings opportunities for cooperation and helps to build trustworthiness, which in turn, stimulates individuals to perform prosocial behaviour toward others (Wittek and Bekkers, 2015). In addition, the intergroup contact hypothesis contends that time spent interacting with people from different backgrounds can promote positive intergroup attitudes and decrease prejudice (Allport et al., 1954; Davies et al., 2011). A study conducted by Meleady and Seger (2016) showed that imagining social interactions with outgroup members can encourage prosocial behaviour and the association is mediated by increased trust. Furthermore, some previous studies suggested that green space potentially facilitates social interactions among adults (Kazmierczak, 2013; Hong et al., 2018; Aram et al., 2019; Jennings and Bamkole, 2019). These studies indicate that green space can possibly influence prosocial behaviour through increased social interactions that align with the nature of prosociality which is developed and practised through frequent interaction (Oerlemans et al., 2018). Neighbourhood green space also can attract children to engage in outdoor physical activity with peers (Sanders et al., 2015; Ward et al., 2016), which in turn brings opportunities to foster prosocial behaviour (Di Bartolomeo and Papa, 2017).

Other theoretical perspectives help explain the possible roles of green space for restoring capacities in relation to prosocial behaviour. According to Ulrich's psycho-evolutionary theory (PET), natural environments are best suited for humans as places where we initially evolved and humankind's survival was reliant on nature before the agricultural revolution. Emotional responses upon natural environments are viewed as part of feeling connected to nature and as being "central to the psychological components of stress and restoration" (Ulrich et al., 1991, p. 207). PET is more commonly known as stress reduction theory (SRT) which suggests that contact with natural environments can reduce the levels of stress (Ulrich, 1983). Another complementary theory, attention restoration theory (ART) contends that taking time in natural environments reduces attention-demanding tasks and allows to restore attention thereby building more positive emotional and psychological responses (Kaplan, 1995; Ohly et al., 2016). Zhang et al. (2014) reported that positive emotions mediate the association between exposures to greenery perceived as beautiful and prosocial behaviour among adults. Positive emotional states due to exposures to nature can lead to greater prosocial tendencies by changing from an individual to collective mental frame (Schwartz et al., 2019). In addition, Goldy and Piff (2020) argued that contact with natural environment can increase attention to others and enhance prosocial behaviour through psychological processes of positive feelings that include feelings of awe and perception of beauty.

Building and restoring capacities might interact to link green space and prosocial behaviour among children and adolescents. For example, children who spend time in green space for having friendly talks and plays with friends may also experience attention restoration due to viewing natural vegetation. Frequent exposure to green space may be required to enable repeated and increased social interactions, as well as to build positive emotionality, that in turn facilitate prosocial behaviour development. Early and longer accumulation of exposure to green space may generate greater levels of benefit for prosocial behaviour, particularly in childhood as critical periods and late childhood as the sensitive period. However, the increase of prosocial behaviour associated with accumulated green space exposures in adolescence might not be as high as in childhood since the natural decline of prosociality is reported in this period (Eisenberg et al., 2015). Another possible scenario is that accumulated exposures are insufficient to lessen or moderate the intrinsically-caused decline in prosocial behaviour. Later, prosocial behaviour may start to rebound in early adulthood (Eisenberg et al., 2015) and the accumulation of exposure to green space may help to increase the levels of prosocial behaviour.

Having outlined a model by which green space may influence the development of prosocial behaviour across childhood and adolescence, the remainder of this paper is dedicated to a systematic review of existing literature to examine how the published evidence addresses the hypothesised direction and magnitude of association, potential mediators, moderators, and temporal nature.

METHODS

Search Strategy and Selection Criteria

This review was conducted following the guidelines from the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA; Moher et al., 2009). The literature search was carried out in 5–6 October 2019 using nine frequently used databases, including PubMED (US National Library of Medicine, Maryland, U.S.), Scopus, ScienceDirect (Elsevier, Amsterdam, Netherlands), Web of Science (Clarivate Analytics, Philadelphia, U.S.), PsycINFO, PsyschARTICLES (American Psychologist Association, Washington D.C., U.S.), CINAHL (EBSCO Publishing, Massachusetts, U.S.), Cochrane Library (John Wiley & Sons, New Jersey, U.S.), and ProQuest (ProQuest LLC, Michigan, U.S.). Guidance on the search terms selected was obtained from recently published systematic reviews on green space (Houlden et al., 2018; Vanaken and Danckaerts, 2018) and prosocial behaviour (Oviedo, 2016; Silke et al., 2018; Vilar et al., 2019). The terms as presented in **Table 1** were searched in the titles, abstracts, and/or keywords of the articles. In addition, references from eligible articles were also searched.

Eligibility Criteria

The inclusion criteria consisted of studies that; (1) were peer-reviewed research articles, (2) had quantitative observational or experimental design; (3) investigated association between green

TABLE 1 | Search terms and strategy used to search relevant literature.

Main keywords	Search terms
Green space	"green space" OR greenspace OR greenness OR greenery OR green OR "green area" OR landscape OR wilderness OR wild OR natur* OR park OR garden OR playground OR playspace OR "play space" OR "open space" OR recreation OR vegetation OR wood OR woodland OR tree OR plant OR grass OR forest OR shinrin-yoku
Prosocial behaviour	prosocial* OR pro-social* OR altruis*

**Truncation symbol used to enable search all possible variations of the word.*

space as an exposure that includes objective and/or subjective measures (quantity, quality, or both) and prosocial behaviour as either an outcome or as a mediator of a health outcome; (4) were published in English; and (5) included participants ≤18 years of age. No restriction on publication date was applied. Published articles that only contained an abstract (e.g., conference proceedings) were excluded.

Prosocial behaviour among children and adolescents was the outcome of interest. In this review, prosociality was defined as a range of positive behaviours that include offering help, sharing, cooperating, and comforting. The outcome focuses on the behavioural aspect rather than cognitive or affective responses (e.g., kindness, love, etc.). Meanwhile, green space refers to naturally-created areas or built environments that bear natural vegetation. Green space exposure in this review considered all characteristics of green space in accordance with the keywords provided (presented in **Table 1**). Green space characteristics measured using land cover maps, remote sensing data, physical observation, and audits were categorised as objective measures, whilst green space exposure data collected through interviews and questionnaires were assigned as subjective measures (Houlden et al., 2018; Vanaken and Danckaerts, 2018). Green space measures can also be classified as assessing quantity which refers to amount of green space available locally within a particular administrative area (e.g., average greenness, percentage of green space), while quality of green space is evaluated by some aspects that influence the usability (e.g., cosiness, safety, amenities, facilities, attractiveness, etc.; McCormack et al., 2010; Marselle et al., 2014; Feng and Astell-Burt, 2017d, 2018). In addition, studies examining subjective connectedness to nature were also taken into account following a previous systematic review on green space (Houlden et al., 2018).

Selection Strategy and Data Collection

All articles retrieved using the search terms in the selected databases were downloaded into EndNote. Duplicate articles were removed either using the EndNote function or manually. Two reviewers (IP and EJ) independently assessed the title and abstract of the published articles using the same inclusion criteria, followed by the full-text assessment. Further, any discrepancies between the two reviewers were discussed and consulted with a third reviewer (TA). Information about publication details, study design, sample size, participant characteristics, exposure concept and measurement, measure instrument of prosocial behaviour, and the results were extracted into **Table 2**.

Data Analysis

Quality and risk of bias of the articles were assessed using the quality assessment tools developed by the National Institutes of Health (2019) for observational and experimental studies. Similar to the process of article screening and data extraction, two reviewers independently performed the quality assessment and any discrepancies were discussed with the third reviewer. The extracted data from all eligible articles were summarised along with study quality assessment outcomes, followed by the narrative synthesis of the evidence on direction, magnitude, effect modifiers, and mediators of the association. The findings were then discussed and future study directions were proposed.

RESULTS

Literature Search Results

Figure 2 presents the search results based on the PRISMA guidelines. Out of 15,267 articles retrieved from nine databases, 5,686 duplicates were removed. Screening based on title and abstract resulted in the selection of 35 articles for the full review. After the full-text assessment, 14 studies met the eligibility criteria. During this process, one paper (Carrus et al., 2015) was identified through references, resulting in a total of 15 papers for review.

Study Characteristics and Methods

Table 2 presents a summary for studies included in this review. All studies were from high-income countries. The majority were carried out in European countries (9; 60%), and followed by the US (3; 20%). Even though there was no restriction for publication date applied, all eligible studies were published between 2012–2019 and more than half (66.7%) were published in the last 3 years (2017–2019). There was an equal number (six studies) of cross-sectional (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) and experimental studies (Carrus et al., 2015; Park et al., 2016; Mayfield et al., 2017; Bates et al., 2018; van Dijk-Wesselius et al., 2018; Dopko et al., 2019). The remaining studies were of a longitudinal design (Richardson et al., 2017; McEachan et al., 2018; Van Aart et al., 2018). The design of experimental studies varied with regards to the inclusion of a control group and measurement of the outcome before the intervention (pre-test). Out of two single group experimental studies, one study was a single group post-test only experiment (Bates et al., 2018), whereas another used a single group pre-post design (Park et al., 2016). The other four experimental studies reported using a control group, including two studies with—(Mayfield et al., 2017; van Dijk-Wesselius et al., 2018) and two without pre-test (Carrus et al., 2015; Dopko et al., 2019), respectively. Moreover, two (Richardson et al., 2017; McEachan et al., 2018), eight (Amoly et al., 2014; Balseviciene et al., 2014; Park et al., 2016; Mayfield et al., 2017; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019), and five (Odgers et al., 2012; Carrus et al., 2015; Bates et al., 2018; Sobko et al., 2018;

TABLE 2 | Summary of study characteristics and results.

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Amoly et al. (2014), Spain	Cross-sectional study	2,111 (7–10 years)	a. Time spent playing in green spaces *(a total number of hours during the last school period and summer holidays)*; b. Residential surrounding greenness in buffers of 100, 250, and 500 m; c. School greenness in a buffer of 100 m; d. Home-school greenness *(average residential and school surrounding greenness in a buffer of 100 m, weighted by daily time spent at home and school)*; e. Residential proximity to a major green space *(a binary variable indicating whether the child's home within 300 m of a major green space).*	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable).*	Child's sex, school level, ethnicity, preterm birth, breastfeeding, exposure to environmental tobacco smoke, maternal smoking during pregnancy, responding person, parental educational achievement, parental employment status, and neighbourhood socioeconomic.	Quasi-Poisson mixed-effects models	No statistically significant association was found between all green space indicators and prosocial behaviour (*non-significant in expected direction*).	Fair
Andrusaityte et al. (2019), Lithuania	Cross-sectional study.	1,489 (4–6 years)	a. Time spent in a city park (*hours per week*); b. Residential surrounding greenness in buffers of 100 m.	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a binary outcome: borderline/abnormal* vs. *normal).*	Child's sex, birth weight, wheeze, asthma, allergy, BMI, breastfeeding, siblings, paracetamol and antibiotic usage during the first year of life, maternal education, tobacco smoke, age at childbirth.	Logistic regression	Increased time spent in city parks per 1 h per week was associated with decreased odds of borderline/abnormal prosocial behaviour: aOR = 0.98 (0.96, 0.99) (*significant in expected direction*). Non-significant association was found for residential surrounding greenness (*non-significant in expected direction*).	Fair
Balseviciene et al. (2014), Lithuania	Cross-sectional study.	1,468 (4–6 years)	a. Residential surrounding greenness in a buffer of 300 m; b. Proximity to the nearest city parks *(transformed using the square root function in meters).*	NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable).*	Child's age, sex, and parenting stress.	Linear regression	Analysis was stratified by mother's educational level. Increased distance to city parks was negatively associated with prosocial behaviour among lower education group: $\beta = -0.029$ ($p < 0.05$) *(significant in expected direction).* Residential greenness was negatively associated with prosocial behaviour among higher education group: $\beta = -1.104$ ($p < 0.05$) *(significant in unexpected direction)*.	Fair

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Bates et al. (2018), USA	Experimental study (one-group post-test-only design)	3,345 and 3,710 observations at the first (T1) and second (T2) time, respectively (age ranges from pre-kindergarten to 8th grade)	Schoolyard renovation by increasing the presence of natural components (e.g., grass, trees) and also the quality (e.g., aesthetics; facilities).	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship during Play (SOCARP). It was measured two times (T1, T2) after schoolyard renovation.	No confounders adjusted in the analysis	Chi-square test	The percentage of observed positive social interaction or prosocial behaviour increased from T1 (27.10%) to T2 (35.20%) ($p < 0.001$) *(significant in expected direction)*.	Poor (no pretest, no randomisation)
Carrus et al. (2015), Italy	Experimental study (two-group post-test-only design)	39 (1.5–3 years)	Children's spending time in school green space vs. in internal space of school	In-person observation	Positive social interaction, measured by a behavioural checklist to record frequency of positive relational behaviours	No confounders adjusted in the analysis	ANOVA	After children were exposed to green space, more frequent positive relational behaviours were observed on days when children spent time in school green space compared to days when they did not ($p = 0.038$) *(significant in expected direction)*.	Poor (no pretest, no randomisation)
Dopko et al. (2019), Canada	Experimental study (two-group post-test-only design)	80 (mean age = 10.49 years)	Children' spending time outdoors at the nature school vs. indoors at the museum	In-person observation	Using two tasks: a. A windfall task by asking children to imagine that they received money and what they decided on four available options (buy things they want, give to charity, spend on gifts for other people, and save for the future). Children who decided for charity and spending on gifts for other people represent higher prosociality. b. A tangram task by asking children to imagine that they assigned 11 tangrams from three categories: easy, medium, and hard to someone else in their class. Children who assigned more tangrams in easy and medium categories, and few in hard category represent higher prosociality.	No confounders adjusted in the analysis	Paired sample *t*-test	Windfall task: Mean score for spending money on charity was statistically higher among children visiting nature school than museum: $\beta = 3.66$ (0.06, 7.26) *(significant in expected direction)*. Mean score for spending money on gift was lower among children visiting nature school than museum: $\beta = -4.15$ (−8.32, 0.03) *(non-significant in unexpected direction)*. Tangram task: Mean score for assigning easy tangram was statistically higher among children visiting nature school than museum: $\beta = 0.74$ (0.01, 1.46) *(significant in expected direction)*. Mean score for assigning hard tangram was statistically lower among children visiting nature school than museum: $\beta = -1.29$ (−2.15, −0.42) *(significant in expected direction)*.	Poor (no pretest, no randomisation)

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Mayfield et al. (2017), USA	Experimental study (two-group pretest-post-test design)	Two elementary schools for each intervention and control groups. This study included 3,588 SOCARP scans representing 1,196 child recess days with 3 rotation conducted.	The intervention was carried out by improving the quality of playground through adding playground marking with colourful interactive games. In addition, intervention schools received equipment to use with the game and training sessions for teachers.	In-person observation	Positive social interaction, measured by behavioural mapping using System for Observing Children's Activity and Relationship during Play (SOCARP).	Scans nested within days nested with schools	Mixed-effects regression analysis	There was a non-significant decrease in prosocial behaviour in the verbal or physical manner before and after the intervention (*non-significant in unexpected direction*).	Fair
McEachan et al. (2018), UK	Longitudinal study	2,594 (aged 0 at baseline, 4 years at follow up)	a. Satisfaction with green space *(asked among a sub-sample of 832 (32%) only)* b. Time spent playing outside *(minutes per week calculated for winter and summer months - asked among a sub-sample of 832 (32%) only)* c. Residential surrounding greenness in buffers of 100 m, 300 m, and 500 m	Questionnaires; NDVI	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, maternal age, cohabitation status, maternal education, subjective poverty, household size, neighbourhood deprivation index, mother's smoking behaviour, and mother's treatment record of mental disorder	Linear regression	Analysis was stratified by ethnicity (white British vs. south Asian). Satisfaction with green space was significantly associated prosocial behaviour among south Asian children only: $\beta = 0.20$ (0.02, 0.38) *(significant in expected direction).* Time spent playing outside was not associated with prosocial behaviour among both ethnicities *(non-significant in expected direction for south Asian children and non-significant in non-reported direction for white British children)*. Residential greenness in all buffer distances were not associated with prosocial behaviour among both ethnicities *(non-significant in expected direction)*.	Good
Odgers et al. (2012), UK	Cross-sectional study	2,024 (12 years)	Percentage of green space in a buffer of 0.5 mile (*measured only among a sub-sample of 200 neighbourhoods*)	A systematic social observation using Google Street view	A combined parent and teacher's reports of Revised Rutter Parent Scale for School-Age Children (*a continuous variable)*	No confounders adjusted in the analysis	Linear regression	No association was observed between percentage of green space and prosocial behaviour (*non-significant in unexpected direction*).	Poor (no control for confounders)

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
Park et al. (2016), South Korea	Experimental study (one-group pretest-post-test design)	336 (5–7 years)	Participation in 24-session horticultural activity program that included indoor and outdoor activities, such as transplanting, planting seeds, making and applying eco-friendly fertilizer, observing vegetable plants, harvesting, etc.	In-person observation	Teacher-reported of prosocial behaviour using the revised questionnaire with four subscales (helping, sharing, cooperation, kindness) (*a continuous variable)*	No confounders adjusted in the analysis	Paired sample *t*-test	All prosocial behaviour scales (helping, sharing, cooperation, kindness) increased from pretest to post-test *(significant in expected direction).*	Fair
Richardson et al. (2017), UK	Longitudinal study	2,909 (aged 4 years at baseline, 6 years at follow-up)	a. Percentage of park space in a buffer of 500 m b. Percentage of total natural space in a buffer of 500 m c. Garden access (*indicating whether the child had access to a private garden*)	Land cover map; Questionnaire	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, screen time, household income, educational attainment, carer's mental health, and neighbourhood socio-economic status	Linear regression	Analysis was stratified by the child's sex and household educational level. Percentage of total natural space was significantly associated with prosocial behaviour among girls: $\beta = 0.14$ ($p < 0.01$) and among high education households: $\beta = 0.12$ ($p < 0.05$) *(significant in expected direction)*. Percentage of parks was not significantly associated with prosocial behaviour among all sub-sample groups *(non-significant in expected direction)*. Access to private garden was not significantly associated with prosocial behaviour among all sub-sample groups *(non-significant in unexpected direction)*.	Good
Sobko et al. (2018), Hong Kong	Cross-sectional study	299 (2–5 years)	Connectedness to nature (enjoyment of, empathy for, responsibility toward, and awareness of nature)	Questionnaire	Parent-reported prosocial scale from SDQ (*a continuous variable)*	No confounders adjusted in the analysis	Structural equation modelling	Greater responsibility toward nature was significantly associated with improved prosocial behaviour: $\beta = 0.77$ *(significant in expected direction).*	Poor (no control for confounders)
Van Aart et al. (2018), Belgium	Longitudinal study	172 (6–12 years at baseline, 9–15 years at follow-up)	a. Percentage of semi-natural and forested area in a buffer of 2,000 m b. Percentage of agricultural area in a buffer of 300 m	Land cover map	Parent-reported prosocial scale from SDQ (*a continuous variable)*	Child's age, sex, and parental socio-economic status	Linear regression	Percentage semi-natural and forested area was not associated with prosocial behaviour *(non-significant in unexpected direction)*. Percentage of agricultural area was not associated with prosocial behaviour *(non-significant in expected direction)*.	Fair

(Continued)

TABLE 2 | Continued

References, country	Study design	Sample size (age)	Green space exposure concept	Green space data source	Prosocial behaviour measure	Confounders adjusted in the model	Methods	Results in adjusted model	Quality
van Dijk-Wesselius et al. (2018), Netherlands	Experimental study (two-group pretest-post-test design)	About 700 (7–11 years)	The intervention was carried out by increasing the presence of natural components (e.g., grass, trees) and also the quality of schoolyards (e.g., aesthetics; facilities).	In-person observation	a. Prosocial orientation assessed by self-administrated Social Orientation Choice Card (SOCC) (*a binary variable)* b. Self-reported prosocial scale from SDQ (*a continuous variable)*	Child's sex, grade level	Multi-level analysis	Analysis was stratified by grade levels (4, 5, and 6). Proportion of prosocial orientation in grades 4 and 5 in intervention compared to control group increased from baseline to the follow-up, but there was a significant decrease in grade 6 *(significant in expected and unexpected directions)*. There was no significant increase of self-reported prosocial behaviour *(non-significant in non-reported direction)*.	Fair
Whitten et al. (2018), Australia	Cross-sectional study	26,848 (mean age = 11.92 years)	Connectedness to nature	Questionnaire (self-report)	Self-reported prosocial scale from SDQ (*a continuous variable)*	Child's sex, social supports, empathy, attention, and neighbourhood socio-economic status	Linear regression	Increased connection to the nature was associated with higher prosocial behaviour: $\beta = 0.12$ ($p < 0.001$) *(significant in expected direction)*.	Fair

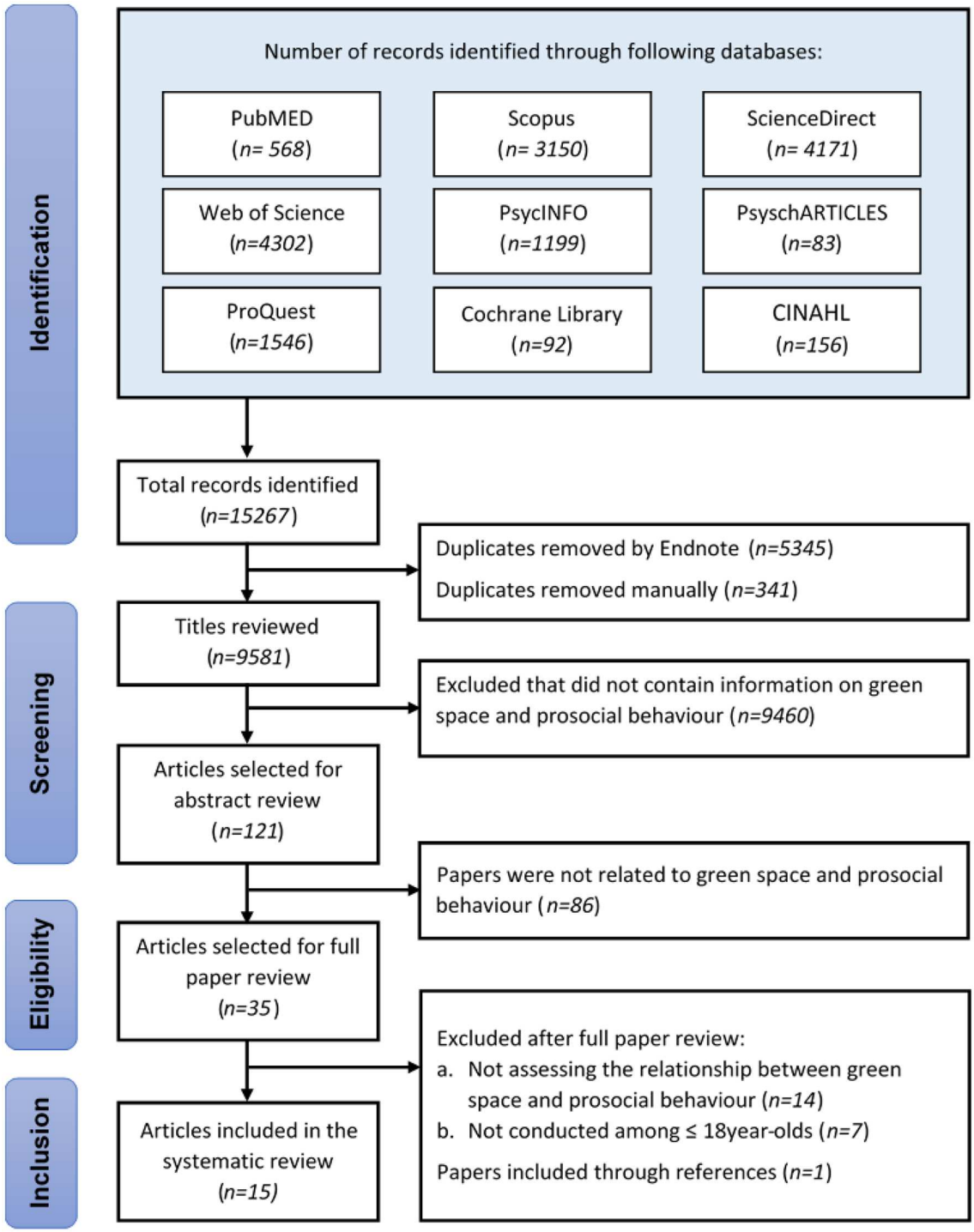


FIGURE 2 | Study selection process based on PRISMA guidelines.

Dopko et al., 2019) studies included in this review were judged to be of good, fair, and poor quality, respectively.

Sample size and age of participants differed by included study. Small sample sizes (<100) were reported in two experimental studies (Carrus et al., 2015; Dopko et al., 2019), whilst the largest sample size was observed in a cross-sectional study of 26,848 Australian children aged 11.9 years on average (Whitten et al., 2018). Two experimental studies recorded the number of person-observations as the unit of analysis instead of number of participants (Mayfield et al., 2017; Bates et al.,

2018). Furthermore, age of participants differed across studies. One of the longitudinal studies collected the baseline data of exposure during pregnancy and then did the follow-up measurement of prosocial behaviour when children were aged 4 years old (McEachan et al., 2018). In cross-sectional studies, the age of participants ranged from 2 to 12 years-old (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019). Two experimental studies did not explicitly mention the age of participants (Mayfield et al., 2017; Bates et al., 2018). The youngest participants in experimental studies were aged 1.5 years, while 8th-grade students (aged 13–14 years depending on the country) were the oldest participant.

Green Space Measures

Green space measurements varied by study. Secondary data linked with objective measurements of area-level green space were used in seven observational studies mostly reported from European countries (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Van Aart et al., 2018; Andrusaityte et al., 2019). Green space quantity, such as residential nearby greenness, as well as the percentage of green space or other related characteristics (e.g., park space, semi-natural and forested, agricultural area) within specified distances from participants' homes were commonly used objective measurements of green space exposure. Only one study reported measuring school and combined home-school greenness in relation to prosocial behaviour (Amoly et al., 2014). In addition, residential proximity (e.g., distance to major or nearby green space) was assessed by two studies (Amoly et al., 2014; Balseviciene et al., 2014). Normalised Difference Vegetation Index (NDVI) was predominantly utilised (Amoly et al., 2014; Balseviciene et al., 2014; McEachan et al., 2018; Andrusaityte et al., 2019), followed by land cover map (Richardson et al., 2017; Van Aart et al., 2018), and Google Street View (Odgers et al., 2012).

Some studies (Amoly et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) also introduced subjective measures of green space and mostly relied on questionnaire-based parental-led approach. The indicator of children's time spent in green space was reported by three studies in Europe (Amoly et al., 2014; McEachan et al., 2018; Andrusaityte et al., 2019). Other studies from the UK also measured access to private gardens (Richardson et al., 2017) and satisfaction with green space (McEachan et al., 2018). Only two studies measured the contacts of green space as a perception of connectedness to nature, of which one measured connection to nature in general (Whitten et al., 2018) and the other (Sobko et al., 2018) employed multiple indicators (enjoyment of, empathy for, responsibility of, and awareness of nature).

For six experimental studies, exposure to green space was observed directly among participants. There were two main concepts of intervention model for green space exposures exhibited that included: (1) improving the appearance of frequently accessed green space by children and adolescents (e.g., schoolyards; playground markings) and (2) spending time in green space or participating in activities involving contacts with natural vegetation (e.g., horticultural programs). Improvements in the quality of schoolyards by increasing the presence of natural components and other facilities was evaluated in studies in the US (Bates et al., 2018) and the Netherlands (van Dijk-Wesselius et al., 2018), while another study in the US measured the change of prosocial behaviour due to improved playgrounds in schools (Mayfield et al., 2017). Moreover, studies in Italy (Carrus et al., 2015) and Canada (Dopko et al., 2019) compared differences in prosocial behaviour between children spending time outdoors in school green space compared to indoors within or outside a school setting. A study in South Korea observed change in prosocial behaviour after children participated in a horticultural program that facilitated contact with natural vegetation (Park et al., 2016).

Prosocial Behaviour Measures

Even though tools for assessing prosocial behaviour varied by study, the data were mostly documented based on parental report (7; 47%). However, measurements based on teacher-reports (1; 7%), combined parent- and teacher-report (1; 7%), and self-report (2; 13%) were also observed. In addition, prosociality was assessed through in-person observations in four experimental studies (27%). The Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997), which is a common tool for assessing prosocial behaviour, was employed in the majority of studies (9; 60%). This prosocial scale consists of five Likert-scale questions with a higher total score indicating more favourable prosocial behaviour. Only one study categorised a prosocial behaviour score into a binary variable using a validated cut-off point (normal with score >5; abnormal/borderline with score ≤ 5) (Andrusaityte et al., 2019). Meanwhile, experimental studies used different measures, such as the System for Observing Children's Activity and Relationship during Play (SOCARP; Mayfield et al., 2017; Bates et al., 2018), a behavioural checklist (Crust et al., 2014), assigned tasks (Dopko et al., 2019), the Social Orientation Choice Card (SOCC; van Dijk-Wesselius et al., 2018), and a questionnaire developed by previous researchers (Park et al., 2016). Three experimental studies used multiple measures of prosociality to disentangle which measure or component of prosocial behaviour is more relevant for green space exposure (Park et al., 2016; van Dijk-Wesselius et al., 2018; Dopko et al., 2019).

Association Between Green Space and Prosocial Behaviour Among Children and Adolescents

A total of 63 associations between green space and prosocial behaviour were observed from 15 articles, including all indicators of green space and prosocial behaviour analysed within individual studies, as well as multiple analyses disaggregated by moderators (see **Table 3**). Exposure to green space was objectively (Odgers et al., 2012; Amoly et al., 2014; Balseviciene et al., 2014; Carrus et al., 2015; Park et al., 2016; Mayfield et al., 2017; Richardson et al., 2017; Bates et al., 2018; McEachan et al., 2018; Van Aart et al., 2018; van Dijk-Wesselius et al., 2018;

TABLE 3 | Summary of associations extracted from 15 articles.

Green space measurements	*n*[a]	Association				
		Significant		Non-significant		
		E[b]	UE[c]	E[b]	UE[c]	NR[d]
OBJECTIVE						
Residential surrounding greenness in buffers of:						
- 100 m	4			4		
- 250 m	1			1		
- 300 m	4		1	2	1	
- 500 m	3			3		
School greenness in a buffer of 100 m	1			1		
Home-school greenness in a buffer of 100 m	1			1		
Percentage of green or natural space in a buffer of:						
- 500 m	4	2		2	1	
- 0.5 mile (≈804.672 m)	1					
Percentage of park space in a buffer of 500 m	4			3	1	
Percentage of semi-natural and forested area in a buffer 2,000 m	1				1	
Percentage of agricultural area in a buffer 300 m	1			1		
Residential proximity to green space	3	1		2		
Schoolyard renovation[e]	7	3	1			3
Spending time in school green space[e]	5	4			1	
Playground marking[e]	4			1	3	
Participation in horticultural program[e]	4	4				
Sub-total	48	14	2	21	8	3
SUBJECTIVE						
Time spent in green space	4	1		2		1
Access to private garden	4				4	
Satisfaction with green space	2	1				1
Connectedness to nature	1	1				
- [-] Enjoyment of nature	1			1		
- Empathy for nature	1			1		
- Awareness of nature	1			1		
- Responsibility of nature	1	1				
Sub-total	15	4	0	5	4	2
Total: *n* (%)	63	18 (28.6)	2 (3.2)	26 (41.3)	12 (19.0)	5 (7.9)

[a]*Number of associations examined between green space and prosocial behaviour that count multiple indicators of green space or prosocial behaviour, as well as, multiple analyses (e.g., analysis stratified by moderators).*
[b]*Association in expected direction.*
[c]*Association in unexpected direction.*
[d]*Association in non-reported direction.*
[e]*Green space exposures assessed by in-person observation in experimental studies.*

Andrusaityte et al., 2019; Dopko et al., 2019) or subjectively (Amoly et al., 2014; Richardson et al., 2017; McEachan et al., 2018; Sobko et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019) measured. Overall, 44 (69.9%) out of 63 associations were in the expected direction. However, only 18 associations were reported to be statistically significant in the expected direction (Balseviciene et al., 2014; Carrus et al., 2015; Park et al., 2016; Richardson et al., 2017; Bates et al., 2018; McEachan et al., 2018; Sobko et al., 2018; van Dijk-Wesselius et al., 2018; Whitten et al., 2018; Andrusaityte et al., 2019; Dopko et al., 2019).

Two studies reported statistically significant associations between objective area-level measures of green space and prosocial behaviour after socio-demographic characteristics were counted as moderating factors (Balseviciene et al., 2014; Richardson et al., 2017). A longitudinal study in the UK reported statistically significant confounder-adjusted associations between percentage of green space in a buffer of 500 m and prosocial behaviour among 2,909 children (Richardson et al., 2017). Analyses stratified by the child' sex (males vs. females = 51 vs. 49%) and household educational level (high vs. low = 38 vs. 62%) showed that positive associations was only found among samples of girls and participants in highly educated households (Richardson et al., 2017). By contrast, a cross-sectional study in Lithuania found that increased residential greenness within

a distance of 300 m from home was associated with lower levels of prosocial behaviour among children from high-educated mothers (Balseviciene et al., 2014). This study also reported an expected direction association that lower distance to city parks increased prosocial behaviour among children from low-educated mothers.

In-person observations used to measure green space exposure in experimental studies tended to report statistically significant findings. Children and adolescents who had used the quality-improved schoolyards (Bates et al., 2018; van Dijk-Wesselius et al., 2018) or participated in activities involving contact with nature (Carrus et al., 2015; Park et al., 2016; Dopko et al., 2019) had higher prosociality. One study in the Netherlands suggested that grade levels as a proxy of children's age modified the effects of intervention (van Dijk-Wesselius et al., 2018). The effects of a schoolyard renovation on child prosocial orientation varied by grade level. Among younger students (grade 4 and 5), the proportion of prosocial orientation increased from baseline to the follow-up, but a negative association was observed among older students (grade 6).

Nine out of 15 associations between subjective measures of green space and prosociality were reported in positive direction, of which only four were statistically significant. One study reported that increased time spent in city parks by 1 h per week was associated with decreased odds of borderline or abnormal prosocial behaviour after controlling for covariates (Andrusaityte et al., 2019). By contrast, studies that measured either spending time in green space as annual total hours during the last school period and holidays (Amoly et al., 2014), or time spent playing outside (minutes per week during summer and winter months; McEachan et al., 2018) did not report statistically significant associations. Only one study from Bradford, UK assessed the green space quality by asking parents about their satisfaction with frequently visited green space (McEachan et al., 2018). Analysis was disaggregated by the child's ethnicity (white British vs. south Asian), which was defined by parental report of which ethnicity they belonged to. This study found a statistically significant positive association for south Asian children, but the direction of the non-significant association was not reported among white British children. In addition, analyses of the access to private green space stratified by child's sex (male vs. female) and household educational level (low vs. high) consistently found non-significant negative associations for all sub-group analyses (Richardson et al., 2017). Furthermore, studies in Australia (Whitten et al., 2018) and Hong Kong (Sobko et al., 2018) reported that increased feelings of connection to nature and responsibility for nature were statistically significant associated with greater prosocial behaviour, respectively.

DISCUSSION

This review aimed to provide an overview of existing evidence assessing potential links between green space and prosocial behaviour among children and adolescents. The balance of evidence suggests that the development of prosocial behaviour may be associated with exposure to higher levels of nearby green space. However, the quality of this evidence is not yet sufficient to draw firm conclusions around causality or to offer specific guidance around well-defined interventions. Moreover, potential effect modifiers of the relationship between green space and prosocial behaviour were evident in some study contexts. Plausible mechanisms linking green space to prosociality have not been explored so far that need further investigation.

Inconsistent Findings

Differences in methodological approaches, such as the measurement of green space, could have led to inconsistent findings. Measures of exposure to green space from included studies consisted of land cover-based metrics, distance to green space, and in-person observations, as well as subjective measurements of green space-related satisfaction, the amount of time spent outdoors, access to private gardens, and perceived connectedness to nature. There were 20 associations between green space quantity and prosocial behaviour in the expected direction, but only two associations were statistically significant. Meanwhile, five associations were reported in unexpected direction, of which one association was statistically significant. The small number of statistically significant associations in expected direction might be due to limitations in measurements. Specifically, NDVI as the common measure for area-level green space has some limitations, such as its inability to distinguish different types of green space (park, garden, etc.) and does not take into account the quality of green space including abandoned or unsafe areas (Villeneuve et al., 2018). Previous studies reported that parental concern on children's safety for playing outdoors might discourage green space use (Strife and Downey, 2009; Sefcik et al., 2019). Therefore, adequate quantity of neighbourhood green space available might not fully lead to its utilisation due to other characteristics are paid attention for children's use, such as green space quality.

Parental report on green space-related satisfaction measured in a study in Bradford, UK (McEachan et al., 2018) could be considered as a proxy of green space quality. While the higher parental satisfaction with green space was associated with greater prosocial behaviour among south Asian children, none of the green space quantity indicators was identified as a predictor of prosociality. Since children are reliant on their parents to chaperon them to green spaces, parental perceptions whether the aspects of green space quality (e.g., safety, physically attractive, etc.) meet their acceptable level might be a more reliable measurement for children's access to and use of green space. It can be an important factor for children's contact with green space than the amount of neighbourhood green space (Feng and Astell-Burt, 2017d). Three studies on child health in Australia confirmed that favourable green space quality—defined subjectively by asking parents to what extent they agreed that good parks, playgrounds, and play spaces were available in the neighbourhood—was associated with higher child well-being (Feng and Astell-Burt, 2017c,d) and general health (Feng and Astell-Burt, 2017a) independently of the green space quantity. One of those studies also reported that green space quality was a stronger determinant of children's externalising behaviours (conduct and hyperactive problems), as measured by the SDQ,

than green space quantity (Feng and Astell-Burt, 2017c). It might suggest that parental report on green space quality matters in evaluating the relationship between green space and child health-related outcomes.

Out of three studies from Spain, Lithuania, UK assessing children's time spent in green space, studies that expressed time as annual total hours during the last school period and holidays in Spain (Amoly et al., 2014) and total minutes per week in summer and winter months in the UK (McEachan et al., 2018) might be prone to recall bias, leading to non-significant associations with prosocial behaviour. Meanwhile, having access to a private garden was negatively associated with prosociality in Scotland, UK, which may be because private gardens might promote less social interaction compared to public green space (Richardson et al., 2017). In addition, the use of different measurements (Connectedness to Nature Index for Parents of Preschool Children vs. combined Connection to Nature Index and Connectedness to Nature Scale) and to whom perceived connection to nature (parental report vs. self-report) was asked might generate different findings between studies in Hong Kong (Sobko et al., 2018) and Australia (Whitten et al., 2018).

The statistically significant associations between green space and prosocial behaviour were more apparent in experimental studies, which might be due to assessments of green space exposure. The more consistent association in experimental studies could be possibly due to the use of in-person observation. While cross-sectional and longitudinal studies commonly used area-level of, proximity to green space, or other subjective measurements as proxies of green space exposure, in-person observation in experimental was potentially a more accurate assessment of use and direct contact with green space among children. Indeed, having direct contact with green space may enable children to gain necessary benefits for prosocial development.

Moderators and Mediators of the Association

Findings from the studies in this review indicating that socio-demographic background moderates associations between green space and prosocial behaviour might suggest that green space inequalities exist in some settings. For example, ethnic background was found to moderate the association between green space-related satisfaction and prosociality among chidren in Bradford, UK (McEachan et al., 2018). Within the study context in Bradford, south Asian families were found with less green space quantity and they reported less time spent in green space by their children and lower green space-related satisfaction compared to those from white British communities. A study in Kaunas, Lithuania reported an association in the non-hypothesised direction among children whose mothers had high education (Balseviciene et al., 2014). High socio-economic families in Kaunas live in suburban areas (more expensive than residing in cities) with an adequate amount of residential greenness available, but it does not promote outdoor activities due to parental concern of children's safety. Inversely, in Scotland, UK, a positive association was observed among children from high-education households (Richardson et al., 2017). These families had more green space available in their neighbourhoods, where a lack of safety might be less of an issue. In addition, this study also found a statistically significant association between green space measured as total natural space and prosocial behaviour among girls only. The characteristics of natural spaces (e.g., amenity areas, playing fields) might be more important for mentally-stimulating play and prosocial development among girls (Richardson et al., 2017). Furthermore, a moderation effect of grade level (as proxy for children's age) may indicate short-term increase in prosocial behaviour among younger, but negative impact on older children (van Dijk-Wesselius et al., 2018). To conclude, depending on the study settings, moderating variables may work in different ways.

The conceptual model described earlier suggests different pathways linking green space to child prosocial behaviour. Unfortunately, none of the included studies analysed potential mediators to test plausible linking pathways. Current literature indicates that mediators may influence this association. A study conducted among adult samples by Zhang et al. (2014) confirmed that mental health and well-being aspects (e.g., positive emotions) mediated the association between green space exposure and prosocial behaviour. In addition, Chen et al. (2019) reported bidirectional relationships between subjective well-being and prosocial behaviour among elementary school-aged children, of which, well-being leads to greater prosociality. Given the well-established relationships between green space and child mental well-being (Flouri et al., 2014; Feng and Astell-Burt, 2017c,d; McCormick, 2017; Vanaken and Danckaerts, 2018), it is plausible that mental health may mediate the association between green space and prosocial behaviour. Moreover, physical activity may also influence the green space-prosociality relationship. Recent growing literature suggest that exposure to local greenness improved physical activity among children (Roemmich et al., 2006; Sanders et al., 2015; Akpinar, 2017). Physical activity performed with other children can encourage social interactions and promote prosocial behaviour. Studies among Peruvian (Pawlowski et al., 2016) and Dutch children (Moeijes et al., 2018) confirmed that participation in a sport group fostered prosocial behaviour. A systematic review among the general population also showed that outdoor sports, in particular, can help increase prosocial behaviour (Eigenschenk et al., 2019). Therefore, child mental health and physical activity may potentially explain the relationship between green space and prosocial behaviour that needs further investigation.

In general, this review summarises preliminary evidence on the positive association between green space exposure and prosocial behaviour with some reported potential effect modifiers. However, the current available evidence available is not sufficient to infer causal associations. The longitudinal studies had short periods of observation (2–4 years) and did not account for time-variant measures of green space and prosocial behaviour. This prevents the examination of possible variations in prosocial behaviour as a response to changes in green space exposure over time. According to the conceptual framework, the accumulation of exposure to green space might elevate the benefits for prosocial behaviour development and greater impact

may be observed during the late childhood as the sensitive period. Therefore, testing this hypothesis in longitudinal studies will provide new insights that will be beneficial for policy recommendations. In addition, mediation analyses are needed to test mechanistic pathways that may underlie the documented associations between green space and prosocial behaviour.

Strengths and Limitations

To our knowledge, this is the first systematic review evaluating the relationship between green space and prosocial behaviour. The findings are presented and discussed by different measures of green space exposure with additional explanations on potential moderators. The use of nine databases with keywords adopted from current published systematic reviews, no restriction on publication date, and screening of references of included studies allowed a comprehensive search. The process of developing and reporting this review following the PRISMA guidelines lends credibility to the findings.

There are some limitations of the evidence reviewed and review method. Firstly, there was only a limited number of longitudinal studies which preclude drawing causal inferences. The findings from experimental studies without control groups are also prone to low internal validity. Secondly, area-level measures of green space varied by study and resulted in mixed-findings, making it difficult to define absolute amount of green space needed in the neighbourhood for positive development of prosocial behaviour. Thirdly, all studies were from high-income countries. Thus, findings can be applicable to these countries, including high-income countries with hot climates and rapidly growing populations where the presence of green space is substantial for mitigating harmful environmental stressors (e.g., heat) and bridging people to the community (e.g., social interactions). However, findings may not be widely applicable to middle- and low-income countries. A limitation of the review method is that some articles that were not published in English may not have been retrieved.

Future Research Directions

This review provides preliminary evidence of positive associations between green space exposure and prosociality. However, experimental studies are just as limited as observational studies, the exposure to green space can be randomly assigned, but individual compliance in reality is agentic. Therefore, it might lead to the question of what aspects or characteristics of green space might further influence the use of green space. It is conceivable that individuals might not use green space if it is not well-maintained, physically attractive, or generally of poor quality. Therefore, the quality of green space might be an important aspect that should be considered in understanding the potential benefits of green space on human health.

Green space quality has been associated with health outcomes independently of the green space quantity (van Dillen et al., 2012). In addition, green space quality was identified to be more strongly associated with mental health outcomes than green space quantity (Francis et al., 2012; de Vries et al., 2013; Feng and Astell-Burt, 2018). Comparing between objective and subjective measurements of quality, expert-determined quality of green space involving audit tools or checklist, physical observation, GIS analyses often do not take into account the appraisal of laypeople (e.g., residents) of their environment. Laypeople are more likely to know about their environment and more qualified to assess the green space quality (Hur et al., 2010). Since they have day-to-day experiences and live in the neighbourhood, their perceptions of nearby green space are likely to be consequential for successful policymaking. The importance of subjective quality compared to objective quality of green space was noted by a study in the Netherlands (Zhang et al., 2017). This study found that subjective quality mediated the association between objective quality of green space and neighbourhood satisfaction. It strongly indicates that the perceived quality of green space was a proximate determinant for neighbourhood satisfaction and might apply to other outcomes, such as prosocial behaviour. Green space quality might be an important determinant for further study in relation to prosocial behaviour since low evidence was found on green space quantity and green space quality is less studied in relation to prosociality.

New studies with greater methodological rigor (e.g., longitudinal studies that examine time-variant measures of green space quality and prosocial behaviour for change-on-change analyses) are required to edge closer to causal inferences and evidence-based policy recommendations. Based on a conceptual model described above, using a longitudinal approach may also help to understand to what extent the accumulation of green space exposure affects the levels of prosocial behaviour in different stages of development, particularly during critical and sensitive periods of the green space-prosociality association. Assessment of potential mediators could help to test plausible pathways linking green space with prosocial behaviour. Moreover, measuring green space exposure as perceived quality is needed due to a sensitive measurement in relation to child health and behaviour outcomes. Lastly, given reported effect modifiers from previous studies, analysis of green space and prosocial behaviour should be tested across strata of other variables (e.g., socio-economic status).

CONCLUSIONS

The current evidence shows that exposure to higher levels of green space may be associated with greater prosocial behaviour. Different measurements of green space exposure led to mixed findings. Area-level green space measures were less consistent in demonstrating statistically significant associations between green space and prosocial behaviour, whereas associations were more consistent when green space was measured using in-person observation. The number of studies was too few to draw conclusions on subjective green space measurements. Further investigation on the association between green space and prosociality is warranted, especially with studies employing longitudinal designs to confirm

temporality and sensitive period, as well as, capable of testing potential effect modifiers, mediators, and measures of green space quality.

AUTHOR CONTRIBUTIONS

IP, TA-B, and XF conceptualised the review. IP conducted the systematic search, study quality assessment, summarised the findings, wrote, and revised the manuscript. EJ peer-reviewed the systematic search, performed full-paper assessment of the eligible articles, and reviewed the manuscript draft. TA-B, DC, SV, and XF provided critical inputs throughout the process and edited the manuscript. All authors approved the final version of the manuscript.

FUNDING

This work was supported by the Hort Frontiers Green Cities Fund, part of the Hort Frontiers strategic partnership initiative developed by Hort Innovation, with co-investment from the University of Wollongong (UOW) Faculty of Social Sciences, the UOW Global Challenges initiative and contributions from the Australian Government (project number #GC15005). TA-B was supported by a National Health and Medical Research Council Boosting Dementia Research Leader Fellowship (#1140317). XF was supported by a National Health and Medical Research Council Career Development Fellowship (#1148792). All aspects related to the conduct of this study including the views stated and the decision to publish the findings are that of the authors only.

REFERENCES

Abdi, B. (2010). Gender differences in social skills, problem behaviours and academic competence of Iranian kindergarten children based on their parent and teacher ratings. *Proc. Soc. Behav. Sci.* 5, 1175–1179. doi: 10.1016/j.sbspro.2010.07.256

Abrams, D., Van de Vyver, J., Pelletier, J., and Cameron, L. (2015). Children's prosocial behavioural intentions towards outgroup members. *Br. J. Dev. Psychol.* 33, 277–294. doi: 10.1111/bjdp.12085

Aknin, L. B., Broesch, T., Hamlin, J. K., and Van de Vondervoort, J. W. (2015). Prosocial behavior leads to happiness in a small-scale rural society. *J. Exp. Psychol.* 144, 788–795. doi: 10.1037/xge0000082

Aknin, L. B., Hamlin, J. K., and Dunn, E. W. (2012). Giving leads to happiness in young children. *PloS ONE* 7:e39211. doi: 10.1371/journal.pone.0039211

Akpinar, A. (2017). Urban green spaces for children: a cross-sectional study of associations with distance, physical activity, screen time, general health, and overweight. *Urban Forest. Urban Green.* 25, 66–73. doi: 10.1016/j.ufug.2017.05.006

Allport, G. W., Clark, K., and Pettigrew, T. (1954). *The Nature of Prejudice.* Cambridge, MA: Addison-Wesley.

Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., et al. (2014). Green and blue spaces and behavioral development in barcelona schoolchildren: the BREATHE Project. *Environ. Health Perspect.* 122, 1351–1358. doi: 10.1289/ehp.1408215

Andrusaityte, S., Grazuleviciene, R., Dedele, A., and Balseviciene, B. (2019). The effect of residential greenness and city park visiting habits on preschool children's mental and general health in lithuania: a cross-sectional study. *Int. J. Hyg. Environ. Health*. 223, 142–150. doi: 10.1016/j.ijheh.2019.09.009

Aram, F., Solgi, E., and Holden, G. (2019). The role of green spaces in increasing social interactions in neighborhoods with periodic markets. *Habit. Int.* 84, 24–32. doi: 10.1016/j.habitatint.2018.12.004

Balseviciene, B., Sinkariova, L., Grazuleviciene, R., Andrusaityte, S., Uzdanaviciute, I., Dedele, A., et al. (2014). Impact of residential greenness on preschool children's emotional and behavioral problems. *Int. J. Environ. Res. Public Health* 11, 6757–6770. doi: 10.3390/ijerph110706757

Bar-on, M. E. (2000). The effects of television on child health: implications and recommendations. *Arch. Dis. Child.* 83, 289–292. doi: 10.1136/adc.83.4.289

Bar-Tal, D. (1982). Sequential development of helping behavior: a cognitive-learning approach. *Dev. Rev.* 2, 101–124. doi: 10.1016/0273-2297(82)90006-5

Bates, C. R., Bohnert, A. M., and Gerstein, D. E. (2018). Green schoolyards in low-income urban neighborhoods: natural spaces for positive youth development outcomes. *Front. Psychol.* 9:805. doi: 10.3389/fpsyg.2018.00805

Ben-Shlomo, Y., Mishra, G., and Kuh, D. (2014). "*Life* course epidemiology," in *Handbook of Epidemiology,* eds W. Ahrens and I. Pigeot (New York, NY: Springer), 1521–1549.

Brownell, C. A. (2013). Early development of prosocial behavior: current perspectives. *Infancy* 18, 1–9. doi: 10.1111/infa.12004

Caputi, M., Lecce, S., Pagnin, A., and Banerjee, R. (2012). Longitudinal effects of theory of mind on later peer relations: the role of prosocial behavior. *Dev. Psychol.* 48, 257–270. doi: 10.1037/a0025402

Carlo, G., Mestre, M. V., McGinley, M. M., Samper, P., Tur, A., and Sandman, D. (2012). The interplay of emotional instability, empathy, and coping on prosocial and aggressive behaviors. *Pers. Individ. Differ.* 53, 675–680. doi: 10.1016/j.paid.2012.05.022

Carlo, G., Mestre, M. V., Samper, P., Tur, A., and Armenta, B. E. (2010). The longitudinal relations among dimensions of parenting styles, sympathy, prosocial moral reasoning, and prosocial behaviors. *Int. J. Behav. Dev.* 35, 116–124. doi: 10.1177/0165025410375921

Carrus, G., Passiatore, Y., Pirchio, S., and Scopelliti, M. (2015). Contact with nature in educational settings might help cognitive functioning and promote positive social behaviour / El contacto con la naturaleza en los contextos educativos podría mejorar el funcionamiento cognitivo y fomentar el comportamiento social positivo. *Psyecology* 6, 191–212. doi: 10.1080/21711976.2015.1026079

Cauley, K., and Tyler, B. (1989). The relationship of self-concept to prosocial behavior in children. *Early Child. Res. Q.* 4, 51–60. doi: 10.1016/S0885-2006(89)90064-1

Chen, X., Tian, L., and Huebner, E. S. (2019). Bidirectional relations between subjective well-being in school and prosocial behavior among elementary school-aged children: a longitudinal study. *Child Youth Care Forum*. 49, 77–95. doi: 10.1007/s10566-019-09518-4

Collie, R. J., Martin, A. J., Roberts, C. L., and Nassar, N. (2018). The roles of anxious and prosocial behavior in early academic performance: a population-based study examining unique and moderated effects. *Learn. Individ. Differ.* 62, 141–152. doi: 10.1016/j.lindif.2018.02.004

Crust, L., McKenna, J., Spence, J., Thomas, C., Evans, D., and Bishop, D. (2014). The effects of playground markings on the physical self-perceptions of 10–11-year-old school children. *Phys. Educ. Sport Pedag.* 19, 179–190. doi: 10.1080/17408989.2012.732565

Dadvand, P., Nazelle, A. D., Triguero-Mas, M., Schembari, A., Cirach, M., et al. (2012a). Surrounding greenness and exposure to air pollution during pregnancy: an analysis of personal monitoring data. *Environ. Health Perspect.* 120, 1286–1290. doi: 10.1289/ehp.1104609

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., et al. (2015). Green spaces and cognitive development in primary school children. *Proc. Natl. Acad. Sci. U.S.A.* 112, 7937–7942. doi: 10.1073/pnas.1503402112

Dadvand, P., Sunyer, J., Basagaña, X., Ballester, F., Lertxundi, A., Fernández-Somoano, A., et al. (2012b). Surrounding greenness and pregnancy outcomes in four Spanish birth cohorts. *Environ. Health Perspect.* 120, 1481–1487. doi: 10.1289/ehp.1205244

Davies, K., Tropp, L. R., Aron, A., Pettigrew, T. F., and Wright, S. C. (2011). Cross-group friendships and intergroup attitudes: a meta-analytic review. *Pers. Soc. Psychol. Rev.* 15, 332–351. doi: 10.1177/1088868311411103

de Leeuw, R. N. H., Kleemans, M., Rozendaal, E., Anschütz, D. J., and Buijzen, M. (2015). The impact of prosocial television news on children's prosocial

behavior: an experimental study in the netherlands. *J. Child. Med.* 9, 419–434. doi: 10.1080/17482798.2015.1089297

de Vries, S., van Dillen, S. M. E., Groenewegen, P. P., and Spreeuwenberg, P. (2013). Streetscape greenery and health: stress, social cohesion and physical activity as mediators. *Soc. Sci. Med.* 94, 26–33. doi: 10.1016/j.socscimed.2013.06.030

Dennis, M., and James, P. (2016). User participation in urban green commons: exploring the links between access, voluntarism, biodiversity and well being. *Urban Forest. Urban Green.* 15, 22–31. doi: 10.1016/j.ufug.2015.11.009

Di Bartolomeo, G., and Papa, S. (2017). The effects of physical activity on social interactions: the case of trust and trustworthiness. *J. Sports Econ.* 20, 50–71. doi: 10.1177/1527002517717299

Dinnie, E., Brown, K. M., and Morris, S. (2013). Community, cooperation and conflict: negotiating the social well-being benefits of urban greenspace experiences. *Landsc. Urban Plan.* 112, 1–9. doi: 10.1016/j.landurbplan.2012.12.012

Dopko, R. L., Capaldi, C. A., and Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: a preliminary investigation. *J. Environ. Psychol.* 63, 134–138. doi: 10.1016/j.jenvp.2019.05.002

Dunfield, K. A. (2014). A construct divided: prosocial behavior as helping, sharing, and comforting subtypes. *Front. Psychol.* 5:958. doi: 10.3389/fpsyg.2014.00958

Eigenschenk, B., Thomann, A., McClure, M., Davies, L., Gregory, M., Dettweiler, U., et al. (2019). Benefits of outdoor sports for society. a systematic literature review and reflections on evidence. *Int. J. Environ. Res. Public Health* 16:937. doi: 10.3390/ijerph16060937

Eisenberg, N., Spinrad, T. L., and Knafo-Noam, A. (2015). "Prosocial development," in *Handbook of Child Psychology and Developmental Science,* ed *R. M. Lerner* (John Wiley & Sons), 1—47.

Eldeirawi, K., Kunzweiler, C., Zenk, S., Finn, P., Nyenhuis, S., Rosenberg, N., et al. (2019). Associations of urban greenness with asthma and respiratory symptoms in Mexican American children. *Ann. Allergy Asthma Immunol.* 122, 289–295. doi: 10.1016/j.anai.2018.12.009

Fabes, R. A., Hanish, L. D., Martin, C. L., Moss, A., and Reesing, A. (2012). The effects of young children's affiliations with prosocial peers on subsequent emotionality in peer interactions. *Br. J. Dev. Psychol. 30*, 569–585. doi: 10.1111/j.2044-835X.2011.02073.x

Feng, X., and Astell-Burt, T. (2017a). Do greener areas promote more equitable child health? *Health Place* 46, 267–273. doi: 10.1016/j.healthplace.2017.05.006

Feng, X., and Astell-Burt, T. (2017b). Is neighborhood green space protective against associations between child asthma, neighborhood traffic volume and area safety? Multilevel analysis of 4,447 Australian Children. *J. Transport. Health* 5, S40–S41. doi: 10.1016/j.jth.2017.05.328

Feng, X., and Astell-Burt, T. (2017c). The relationship between neighbourhood green space and child mental wellbeing depends upon whom you ask: multilevel evidence from 3083 children aged 12-13 years. *Int. J. Environ. Res. Public Health* 14:235. doi: 10.3390/ijerph14030235

Feng, X., and Astell-Burt, T. (2017d). Residential green space quantity and quality and child well-being: a longitudinal study. *Am. J. Prev. Med.* 53, 616–624. doi: 10.1016/j.amepre.2017.06.035

Feng, X., and Astell-Burt, T. (2018). Residential green space quantity and quality and symptoms of psychological distress: a 15-year longitudinal study of 3897 women in postpartum. *BMC Psychiatry* 18:348. doi: 10.1186/s12888-018-1926-1

Ferreira, T., Cadima, J., Matias, M., Vieira, J. M., Leal, T., and Matos, P. M. (2016). Preschool Children's prosocial behavior: the role of mother–child, father–child and teacher–child relationships. *J. Child Family Stud.* 25, 1829–1839. doi: 10.1007/s10826-016-0369-x

Flouri, E., Midouhas, E., and Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *J. Environ. Psychol.* 40, 179–186. doi: 10.1016/j.jenvp.2014.06.007

Flouri, E., and Sarmadi, Z. (2016). Prosocial behavior and childhood trajectories of internalizing and externalizing problems: the role of neighborhood and school contexts. *Dev. Psychol.* 52, 253–258. doi: 10.1037/dev0000076

Flynn, E., Ehrenreich, S. E., Beron, K. J., and Underwood, M. K. (2015). Prosocial behavior: long-term trajectories and psychosocial outcomes. *Soc. Dev.* 24, 462–482. doi: 10.1111/sode.12100

Fortuna, K., and Knafo, A. (2014). "Parental and genetic contributions to prosocial behavior during childhood," in *Prosocial Development: A Multidimensional Approach*, eds L. M. Padilla-Walker and G. Carlo (New York, NY: Oxford University Press), 70–89.

Francis, J., Wood, L. J., Knuiman, M., and Giles-Corti, B. (2012). Quality or quantity? *Exploring the relationship between public open space attributes and mental health in perth, western Australia. Soc. Sci. Med.* 74, 1570–1577. doi: 10.1016/j.socscimed.2012.01.032

Fujisawa, K. K., Kutsukake, N., and Hasegawa, T. (2008). Reciprocity of prosocial behavior in Japanese preschool children. *Int. J. Behav. Dev.* 32, 89–97. doi: 10.1177/0165025407084055

Gallitto, E., and Leth-Steensen, C. (2019). Moderating effect of trait emotional intelligence on the relationship between parental nurturance and prosocial behaviour. *J. Adolesc.* 74, 113–119. doi: 10.1016/j.adolescence.2019.04.008

Garaigordobil, M. (2009). A comparative analysis of empathy in childhood and adolescence: gender differences and associated socio-emotional variables. *Int. J. Psychol. Psychol. Ther.* 9, 217–235. Available online at: https://psycnet.apa.org/record/2009-09327-006

Gerbino, M., Zuffiano, A., Eisenberg, N., Castellani, V., Luengo Kanacri, B. P., Pastorelli, C., et al. (2018). Adolescents' prosocial behavior predicts good grades beyond intelligence and personality traits. *J. Pers.* 86, 247–260. doi: 10.1111/jopy.12309

Goldy, S. P., and Piff, P. K. (2020). Toward a social ecology of prosociality: why, when, and where nature enhances social connection. *Curr. Opin. Psychol.* 32, 27–31. doi: 10.1016/j.copsyc.2019.06.016

Goodman, R. (1997). The strengths and difficulties questionnaire: a research note. *J. Child Psychol. Psychiatry* 38, 581–586.

Greitemeyer, T. (2011). Effects of prosocial media on social behavior:when and why does media exposure affect helping and aggression? *Curr. Direct. Psychol. Sci.* 20, 251–255. doi: 10.1177/0963721411415229

Gustin, K., Tofail, F., Vahter, M., and Kippler, M. (2018). Cadmium exposure and cognitive abilities and behavior at 10 years of age: a prospective cohort study. *Environ. Int.* 113, 259–268. doi: 10.1016/j.envint.2018.02.020

Hammond, S. I., Waugh, W., Satlof-Bedrick, E., and Brownell, C. A. (2015). "Prosocial behavior during childhood and cultural variations," in *International Encyclopedia of the Social and Behavioral Sciences, 2nd Edn,* ed J. D. Wright (Oxford: Elsevier), 228–232.

Hartig, T., Mitchell, R., Vries, S.,d., and Frumkin, H. (2014). Nature and health. *Annu. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Hay, D. F. (1994). Prosocial development. *J. Child Psychol. Psychiatry* 35, 29–71. doi: 10.1111/j.1469-7610.1994.tb01132.x

Hay, D. F., and Cook, K. V. (2007). "The transformation of prosocial behavior from infancy to childhood," in *Socioemotional Development in the Toddler Years: Transitions and Transformations*, eds. C. A. Brownell and C. B. Kopp (New York, NY: Guilford Press), 100–131.

Hay, D. F., Payne, A., and Chadwick, A. (2004). Peer relations in childhood. *J. Child Psychol. Psychiatry* 45, 84–108. doi: 10.1046/j.0021-9630.2003.00308.x

Healy, S., and Garcia, J. M. (2019). Psychosocial correlates of physical activity participation and screen-time in typically developing children and children on the autism spectrum. *J. Dev. Phys. Disab.* 31, 313–328. doi: 10.1007/s10882-018-9642-9

Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., et al. (2018). Linking green space to neighborhood social capital in older adults: the role of perceived safety. *Soc. Sci. Med.* 207, 38–45. doi: 10.1016/j.socscimed.2018.04.051

Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., and Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: a systematic review. *PLoS ONE* 13:e0203000. doi: 10.1371/journal.pone.0203000

Hur, M., Nasar, J. L., and Chun, B. (2010). Neighborhood satisfaction, physical and perceived naturalness and openness. *J. Environ. Psychol.* 30, 52–59. doi: 10.1016/j.jenvp.2009.05.005

Israel, S., Hasenfratz, L., and Knafo-Noam, A. (2015). The genetics of morality and prosociality. *Curr. Opin. Psychol.* 6, 55–59. doi: 10.1016/j.copsyc.2015.03.027

Jennings, V., and Bamkole, O. (2019). The relationship between social cohesion and urban green space: an avenue for health promotion. *Int. J. Environ. Res. Public Health* 16:452. doi: 10.3390/ijerph16030452

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Kazmierczak, A. (2013). The contribution of local parks to neighbourhood social ties. *Landsc. Urban Plan.* 109, 31–44. doi: 10.1016/j.landurbplan.2012.05.007

Knafo, A., Zahn-Waxler, C., Van Hulle, C., Robinson, J. L., and Rhee, S. H. (2008). The developmental origins of a disposition toward empathy: genetic and environmental contributions. *Emotion* 8, 737–752. doi: 10.1037/a0014179

Knafo-Noam, A., Uzefovsky, F., Israel, S., Davidov, M., and Zahn-Waxler, C. (2015). The prosocial personality and its facets: genetic and environmental architecture of mother-reported behavior of 7-year-old twins. *Front. Psychol.* 6:112. doi: 10.3389/fpsyg.2015.00112

Kok, R., Prinzie, P., Bakermans-Kranenburg, M. J., Verhulst, F. C., White, T., Tiemeier, H., et al. (2018). Socialization of prosocial behavior: gender differences in the mediating role of child brain volume. *Child Neuropsychol.* 24, 723–733. doi: 10.1080/09297049.2017.1338340

Kondo, M. C., Fluehr, J. M., McKeon, T., and Branas, C. C. (2018). Urban green space and its impact on human health. *Int. J. Environ. Res. Public Health* 15:445. doi: 10.3390/ijerph15030445

Kuh, D., Ben-Shlomo, Y., Lynch, J., Hallqvist, J., and Power, C. (2003). Life course epidemiology. *J. Epidemiol. Commun. Health* 57, 778–783. doi: 10.1136/jech.57.10.778

Lai, F. H, Siu, A. M, and Shek, D. T. (2015). Individual and social predictors of prosocial behavior among Chinese adolescents in Hong Kong. *Front. Pediatr.* 3:39. doi: 10.3389/fped.2015.00039

Lee, A. C., and Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *J. Public Health* 33, 212–222. doi: 10.1093/pubmed/fdq068

Lee, C.-T., Padilla-Walker, L. M., and Memmott-Elison, M. K. (2016). The role of parents and peers on adolescents' prosocial behavior and substance use. *J. Soc. Pers. Relat.* 34, 1053–1069. doi: 10.1177/0265407516665928

Leventhal, K. S., Gillham, J., DeMaria, L., Andrew, G., Peabody, J., and Leventhal, S. (2015). Building psychosocial assets and wellbeing among adolescent girls: a randomized controlled trial. *J. Adolesc.* 45, 284–295. doi: 10.1016/j.adolescence.2015.09.011

Liao, J., Zhang, B., Xia, W., Cao, Z., Zhang, Y., Liang, S., et al. (2019). Residential exposure to green space and early childhood neuro development. *Environ. Int.* 128, 70–76. doi: 10.1016/j.envint.2019.03.070

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., et al. (2017). Exploring pathways linking greenspace to health: theoretical and methodological guidance. *Environ. Res.* 158, 301–317. doi: 10.1016/j.envres.2017.06.028

Marselle, M. R., Irvine, K. N., Lorenzo-Arribas, A., and Warber, S. L. (2014). Moving beyond green: exploring the relationship of environment type and indicators of perceived environmental quality on emotional well-being following group walks. *Int. J. Environ. Res. Public Health* 12, 106–130. doi: 10.3390/ijerph120100106

Mayfield, C. A., Child, S., Weaver, R. G., Zarrett, N., Beets, M. W., and Moore, J. B. (2017). Effectiveness of a playground intervention for antisocial, prosocial, and physical activity behaviors. *J. School Health* 87, 338–345. doi: 10.1111/josh.12506

McCormack, G. R., Rock, M., Toohey, A. M., and Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: a review of qualitative research. *Health Place* 16, 712–726. doi: 10.1016/j.healthplace.2010.03.003

McCormick, R. (2017). Does access to green space impact the mental well-being of children: a systematic review. *J. Pediatr. Nurs.* 37, 3–7. doi: 10.1016/j.pedn.2017.08.027

McEachan, R. R. C., Yang, T. C., Roberts, H., Pickett, K. E., Arseneau-Powell, D., Gidlow, C. J., et al. (2018). Availability, use of, and satisfaction with green space, and children's mental wellbeing at age 4 years in a multicultural, deprived, urban area: results from the Born in Bradford cohort study. *Lancet. Planet Health* 2, e244–e254. doi: 10.1016/s2542-5196(18)30119-0

Meleady, R., and Seger, C. R. (2016). Imagined contact encourages prosocial behavior towards outgroup members. *Group Process. Intergr. Relations* 20, 447–464. doi: 10.1177/1368430215612225

Moeijes, J., van Busschbach, J. T., Bosscher, R. J., and Twisk, J. W. R. (2018). Sports participation and psychosocial health: a longitudinal observational study in children. *BMC Public Health* 18:702. doi: 10.1186/s12889-018-5624-1

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., and The, P. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med.* 6:e1000097. doi: 10.1371/journal.pmed.1000097

National Institutes of Health (2019). *Study Quality Assessment Tools.* US Department of Health and Human Services. Available online at: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools (accessed September 7, 2019).

Obsuth, I., Eisner, M. P., Malti, T., and Ribeaud, D. (2015). The developmental relation between aggressive behaviour and prosocial behaviour: a 5-year longitudinal study. *BMC Psychol.* 3:16. doi: 10.1186/s40359-015-0073-4

Odgers, C. L., Caspi, A., Bates, C. J., Sampson, R. J., and Moffitt, T. E. (2012). Systematic social observation of children's neighborhoods using google street view: a reliable and cost-effective method. *J. Child Psychol. Psychiatry* 53, 1009–1017. doi: 10.1111/j.1469-7610.2012.02565.x

Oerlemans, A. M., Rommelse, N. N. J., Buitelaar, J. K., and Hartman, C. A. (2018). Examining the intertwined development of prosocial skills and ASD symptoms in adolescence. *Eur. Child Adolesc. Psychiatry* 27, 1033–1046. doi: 10.1007/s00787-018-1114-3

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., et al. (2016). Attention restoration theory: a systematic review of the attention restoration potential of exposure to natural environments. *J. Toxicol. Environ. Health Part B* 19, 305–343. doi: 10.1080/10937404.2016.1196155

Oldfield, J., Humphrey, N., and Hebron, J. (2016). The role of parental and peer attachment relationships and school connectedness in predicting adolescent mental health outcomes. *Child Adolesc. Mental Health* 21, 21–29. doi: 10.1111/camh.12108

Oviedo, L. (2016). Religious attitudes and prosocial behavior: a systematic review of published research. *Religion Brain Behav.* 6, 169–184. doi: 10.1080/2153599X.2014.992803

Park, S. A., Cho, M. K., Yoo, M. H., Kim, S. Y., Im, E. A., Song, J. E., et al. (2016). Horticultural activity program for improving emotional intelligence, prosocial behavior, and scientific investigation abilities and attitudes in kindergarteners. *Hort Technol.* 26, 754–761. doi: 10.21273/HORTTECH03489-16

Pastorelli, C., Lansford, J. E., Luengo Kanacri, B. P., Malone, P. S., Di Giunta, L., Bacchini, D., et al. (2016). Positive parenting and children's prosocial behavior in eight countries. *J. Child Psychol. Psychiatry Allied Dis.* 57, 824–834. doi: 10.1111/jcpp.12477

Pawlowski, T., Schüttoff, U., Downward, P., and Lechner, M. (2016). Can sport really help to meet the millennium development goals? *Evidence from children in Peru. J. Sports Econ.* 19, 498–521. doi: 10.1177/1527002516661601

Pettygrove, D. M., Hammond, S. I., Karahuta, E. L., Waugh, W. E., and Brownell, C. A. (2013). From cleaning up to helping out: parental socialization and children's early prosocial behavior. *Infant. Behav. Dev.* 36, 843–846. doi: 10.1016/j.infbeh.2013.09.005

Piliavin, J. (2001). "Altruism and prosocial behavior, sociology of," in *International Encyclopedia of the Social and Behavioral Sciences,* eds N. J. Smelser and P. B. Baltes *(Oxford: Elsevier Science Ltd)*. 411–415.

Piotrowski, J. T., Vossen, H. G. M., and Valkenburg, P. M. (2015). "Media and child development," in *International Encyclopedia of the Social & Behavioral Sciences, 2nd Edn,* ed *J. D. Wright (Oxford: Elsevier),* 1–10.

Proctor, C., and Linley, P. A. (2014). "Life satisfaction in youth," in *Increasing Psychological well-being in Clinical and Educational Settings: Interventions and Cultural Contexts*, eds G. A. Fava and C. Ruini (New York, NY: Springer Science + Business Media), 199–215.

Prot, S., Gentile, D. A., Anderson, C. A., Suzuki, K., Swing, E., Lim, K. M., et al. (2014). Long-term relations among prosocial-media use, empathy, and prosocial behavior. *Psychol. Sci.* 25, 358–368. doi: 10.1177/0956797613503854

Qureshi, F., Koenen, K. C., Tiemeier, H., Williams, M. A., Misra, S., and Kubzansky, L. D. (2019). Childhood assets and cardiometabolic health in adolescence. *Pediatrics* 143:e20182004. doi: 10.1542/peds.2018-2004

Ren, Y., Yao, X., Liu, Y., Liu, S., Li, X., Huang, Q., et al. (2019). Outdoor air pollution pregnancy exposures are associated with behavioral problems in China's preschoolers. *Environ. Sci. Pollut. Res. Int.* 26, 2397–2408. doi: 10.1007/s11356-018-3715-2

Richardson, E. A., Pearce, J., Shortt, N. K., and Mitchell, R. (2017). The role of public and private natural space in children's social, emotional and behavioural development in Scotland: a longitudinal study. *Environ. Res.* 158, 729–736. doi: 10.1016/j.envres.2017.07.038

Richman, C. L., Berry, C., Bittle, M., and Himan, K. (1988). Factors related to helping behavior in preschool-age children. *J. Appl. Dev. Psychol.* 9, 151–165. doi: 10.1016/0193-3973(88)90020-2

Roemmich, J. N., Epstein, L. H., Raja, S., Yin, L., Robinson, J., and Winiewicz, D. (2006). Association of access to parks and recreational facilities with the physical activity of young children. *Prev. Med.* 43, 437–441. doi: 10.1016/j.ypmed.2006.07.007

Sanders, T., Feng, X., Fahey, P. P., Lonsdale, C., and Astell-Burt, T. (2015). The influence of neighbourhood green space on children's physical activity and screen time: findings from the longitudinal study of Australian children. *Int. J. Behav. Nutr. Phys. Act.* 12:126. doi: 10.1186/s12966-015-0288-z

Schwartz, A. J., Dodds, P. S., O'Neil-Dunne, J. P. M., Danforth, C. M., and Ricketts, T. H. (2019). Visitors to urban greenspace have higher sentiment and lower negativity on Twitter. *People Nat.* 1, 476–485. doi: 10.1002/pan3.10045

Sefcik, J. S., Kondo, M. C., Klusaritz, H., Sarantschin, E., Solomon, S., Roepke, A., et al. (2019). Perceptions of nature and access to green space in four urban neighborhoods. *Int. J. Environ. Res. Public Health* 16:2313. doi: 10.3390/ijerph16132313

Silke, C., Brady, B., Boylan, C., and Dolan, P. (2018). Factors influencing the development of empathy and pro-social behaviour among adolescents: a systematic review. *Child. Youth Serv. Rev.* 94, 421–436. doi: 10.1016/j.childyouth.2018.07.027

Singer, D. G., Singer, J. L., D'Agnostino, H., and DeLong, R. (2009). Children's pastimes and play in sixteen nations: is free-play declining? *Am. J. Play* 1, 283–312. Available online at: https://eric.ed.gov/?id=EJ1069041

Smith, E. P., Witherspoon, D. P., Bhargava, S., and Bermudez, J. M. (2019). Cultural values and behavior among African American and European American children. *J. Child Family Stud.* 28, 1236–1249. doi: 10.1007/s10826-019-01367-y

Sobko, T., Jia, Z., and Brown, G. (2018). Measuring connectedness to nature in preschool children in an urban setting and its relation to psychological functioning. *PLoS ONE* 13:e0207057. doi: 10.1371/journal.pone.0207057

Strife, S., and Downey, L. (2009). Childhood development and access to nature: a new direction for environmental inequality research. *Organ. Environ.* 22, 99–122. doi: 10.1177/1086026609333340

Su, J. G., Jerrett, M., de Nazelle, A., and Wolch, J. (2011). Does exposure to air pollution in urban parks have socioeconomic, racial or ethnic gradients? *Environ. Res.* 111, 319–328. doi: 10.1016/j.envres.2011.01.002

Swit, C. (2012). *Relational aggression and prosocial behaviours in Australian preschool* children. *Aust. J. Early. Child.* 37, 30–34. doi: 10.1177/183693911203700305

Taylor, L., and Hochuli, D. F. (2017). Defining greenspace: multiple uses across multiple disciplines. *Landsc. Urban Plan.* 158, 25–38. doi: 10.1016/j.landurbplan.2016.09.024

Tischer, C., Gascon, M., Fernández-Somoano, A., Tardón, A., Lertxundi Materola, A., Ibarluzea, J., et al. (2017). Urban green and grey space in relation to respiratory health in children. *Eur. Respir. J.* 49:1502112. doi: 10.1183/13993003.02112-2015

Twohig-Bennett, C., and Jones, A. (2018). The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ. Res.* 166, 628–637. doi: 10.1016/j.envres.2018.06.030

Ulrich, R. S. (1983). "Aesthetic and affective response to natural environment," in *Behavior and the Natural Environment,* eds I. *Altman and J. F. Wohlwill (Boston, MA: Springer US),* 85–125.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

Van Aart, C. J. C., Michels, N., Sioen, I., De Decker, A., Bijnens, E. M., Janssen, B. G., et al. (2018). Residential landscape as a predictor of psychosocial stress in the life course from childhood to adolescence. *Environ. Int.* 120, 456–463. doi: 10.1016/j.envint.2018.08.028

van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., and Maas, J. (2015). Health benefits of green spaces in the living environment: a systematic review of epidemiological studies. *Urban Forest.Urban Green.* 14, 806–816. doi: 10.1016/j.ufug.2015.07.008

van Dijk-Wesselius, J. E., Maas, J., Hovinga, D., van Vugt, M., and van den Berg, A. E. (2018). The impact of greening schoolyards on the appreciation, and physical, cognitive and social-emotional well-being of schoolchildren: a prospective intervention study. *Landsc. Urban Plan.* 180, 15–26. doi: 10.1016/j.landurbplan.2018.08.003

van Dillen, S. M. E., de Vries, S., Groenewegen, P. P., and Spreeuwenberg, P. (2012). Greenspace in urban neighbourhoods and residents' health: adding quality to quantity. *J. Epidemiol. Commun. Health* 66:e8. doi: 10.1136/jech.2009.104695

Vanaken, G. J., and Danckaerts, M. (2018). Impact of green space exposure on children's and adolescents' mental health: a systematic review. *Int. J. Environ. Res. Public Health* 15:2668. doi: 10.3390/ijerph15122668

Vilar, M. M., Corell, L., and Merino, C. (2019). Systematic review of prosocial behavior *measures* 37, 349–377. doi: 10.18800/psico.201901.012

Villeneuve, P. J., Ysseldyk, R. L., Root, A., Ambrose, S., DiMuzio, J., Kumar, N., et al. (2018). Comparing the normalized difference vegetation index with the google street view measure of vegetation to assess associations between greenness, walkability, recreational physical activity, and health in Ottawa, Canada. *Int. J. Environ. Res. Public Health* 15:1719. doi: 10.3390/ijerph15081719

Ward, J. S., Duncan, J. S., Jarden, A., and Stewart, T. (2016). The impact of children's exposure to greenspace on physical activity, cognitive development, emotional wellbeing, and ability to appraise risk. *Health Place* 40, 44–50. doi: 10.1016/j.healthplace.2016.04.015

Weinstein, B. D., and Bearison, D. J. (1985). Social interaction, social observation, and cognitive development in young children. *Eur. J. Soc. Psychol.* 15, 333–343.

Wentzel, K. (2015). "Prosocial behaviour and schooling," in *Encyclopedia on Early Childhood Development,* eds R. Tremblay, M. Boivin, and R. Peters. (The Centre of Excellence for Early Childhood Development (CEECD)). Available online at: http://www.child-encyclopedia.com/prosocial-behaviour/according-experts/prosocial-behaviour-and-schooling

Whitten, T., Stevens, R., Ructtinger, L., Tzoumakis, S., Green, M. J., Laurens, K. R., et al. (2018). Connection to the natural environment and well-being in middle childhood. *Ecopsychology* 10, 270–279. doi: 10.1089/eco.2018.0010

Williams, A., O'Driscoll, K., and Moore, C. (2014). The influence of empathic concern on prosocial behavior in children. *Front. Psychol.* 5:425. doi: 10.3389/fpsyg.2014.00425

Wittek, R., and Bekkers, R. (2015). "Altruism and prosocial behavior, sociology of," in *International Encyclopedia of the Social & Behavioral Sciences, 2nd Edn*, ed *J. D. Wright (Oxford: Elsevier),* 579–583.

Yang, Y., Li, W., Sheldon, K. M., and Kou, Y. (2019). Chinese adolescents with higher social dominance orientation are less prosocial and less happy: a value-environment fit analysis. *Int. J. Psychol.* 54, 325–332. doi: 10.1002/ijop.12474

Zhang, J. W., Piff, P. K., Iyer, R., Koleva, S., and Keltner, D. (2014). An occasion for unselfing: Beautiful nature leads to prosociality. *J. Environ. Psychol.* 37, 61–72. doi: 10.1016/j.jenvp.2013.11.008

Zhang, Y., Van den Berg, A. E., Van Dijk, T., and Weitkamp, G. (2017). Quality over quantity: contribution of urban green space to neighborhood satisfaction. *Int. J. Environ. Res. Public Health* 14:535. doi: 10.3390/ijerph14050535

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 06 August 2020
doi: 10.3389/fpsyg.2020.01986

Nature Reappraisers, Benefits for the Environment: A Model Linking Cognitive Reappraisal, the "Being Away" Dimension of Restorativeness and Eco-Friendly Behavior

Angelo Panno[1†], Annalisa Theodorou[2*†], Giuseppe Carrus[2], Claudio Imperatori[1], Giuseppina Spano[3] and Giovanni Sanesi[3]*

[1] Department of Human Science, Cognitive and Clinical Psychology Laboratory, European University of Rome, Rome, Italy, [2] Department of Education, Experimental Psychology Laboratory, Roma Tre University, Rome, Italy, [3] Department of Agricultural and Environmental Science, University of Bari, Bari, Italy

OPEN ACCESS

Edited by:
Bernardo Hernández, University of La Laguna, Spain

Reviewed by:
Joel Martínez-Soto, University of Guanajuato, Mexico
Andres Ried, Pontificia Universidad Católica de chile, Chile

***Correspondence:**
Angelo Panno
angelo.panno@unier.it
Annalisa Theodorou
annalisa.theodorou@uniroma3.it

[†]*These authors share first authorship*

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *06 May 2020*
Accepted: *17 July 2020*
Published: *06 August 2020*

Citation:
Panno A, Theodorou A, Carrus G, Imperatori C, Spano G and Sanesi G (2020) Nature Reappraisers, Benefits for the Environment: A Model Linking Cognitive Reappraisal, the "Being Away" Dimension of Restorativeness and Eco-Friendly Behavior. Front. Psychol. 11:1986. doi: 10.3389/fpsyg.2020.01986

In the last decades, an increasingly prominent role has been given to the motivational factors that can promote pro-environmental behavior. In this contribution, we focus on the role of the individual's ability to shape the emotions originating from nature in engaging in pro-environmental behavior. In particular, we expect that an emotion regulation strategy as cognitive reappraisal should positively predict pro-environmental behavior, through enhanced perceived restorativeness attributed to the natural environment in terms of the experience of "being away." One-hundred and fifteen visitors to an urban park (Parco Nord Milano) filled out a questionnaire including measures of cognitive reappraisal, the experience of "being away," and pro-environmental behavior while in the park. Results confirmed that cognitive reappraisal was positively and significantly related to pro-environmental behavior. Importantly, the indirect effect of cognitive reappraisal on pro-environmental behavior through the experience of "being away" was significant. Findings suggest the importance of implementing interventions aimed at promoting the habitual use of cognitive reappraisal to enhance the experience of "being away" and, thus, sustain pro-environmental behavior.

Keywords: restorativeness, being away, nature, pro-environmental behavior, cognitive reappraisal, emotion regulation

> *"We trace out all the veins of the earth, and yet, living upon it, undermined as it is beneath our feet, are astonished that it should occasionally cleave asunder or tremble: as though, forsooth, these signs could be any other than expressions of the indignation felt by our sacred parent!"*
>
> – Pliny the Elder

INTRODUCTION

Nature is uncontrollable; however, humankind has a direct impact on some catastrophic natural phenomena. In the last decades, the race for irrepressible productivity resulted in human interference with the course of nature in many essential life processes such as climate change (Crowley, 2000), biodiversity (Hughes et al., 2003), and hydrogeological instability (Vilardo et al., 2009). As Pliny the Elder already claimed in ancient times, we are often ignorant

of the catastrophic consequences of human actions and underestimate the enormous importance of the natural environment for human life. In this contribution, we highlight that just as anti-environmental behavior traces back to recklessness and heedlessness, the origins of pro-environmental behavior can be found in the *awareness* of the benefits of nature for the individual's life.

Awareness, or the ability to be efficiently sensitive to environmental clues, has been related especially to the way individuals regulate their emotions (Gross and John, 2003). Emotions are automatic responses to environmental stimuli, in which individuals may intervene in modulating their intensity and quality (Gross, 1998). Pieces of evidence have shown how a successful management of emotions can boost pro-environmental attitudes and behavior (Aguilar-Luzón et al., 2014; Robinson et al., 2019). In particular, a pioneering study demonstrated how cognitive reappraisal, defined as the tendency to change the way one thinks of a situation to alter the emotional response linked to it, promotes pro-environmental behavior (Panno et al., 2015). Through reappraisal, individuals may elaborate and more deeply understand the emotions elicited from the natural environment, enhancing the likelihood to protect it by engaging in pro-environmental behavior.

In the present research, we intend to shed light on the mechanism between cognitive reappraisal and pro-environmental behavior. In doing so, we will refer to the concept of restorativeness attributed to a natural environment (Hartig and Mang, 1991) namely the individual's recognition of the beneficial effect of the natural environment. In doing so, we focus on one particular dimension of restorativeness, namely the perception of "being away" experienced in the natural setting. Specifically, we hypothesize that the more the habitual use of the cognitive reappraisal strategy in everyday life, the higher the engagement in pro-environmental behavior. Importantly, the habitual use of reappraisal should promote pro-environmental behavior *through* the enhanced individual perception of restorativeness attributed to the natural environment in terms of the "being away" experience.

Reappraisers and Pro-environmental Behavior: A Particular Sensitivity

Emotions are important carriers of environmental information (Gross, 1998). Within the realm of emotion regulation strategies particular attention is given to the way individuals "shape" their emotions. Cognitive reappraisal has been defined as a strategy that aims at reconstructing an emotionally charged situation in a way that alters its emotional impact (Gross and John, 2003). As compared to other strategies, cognitive reappraisal has the advantage of being able to intervene on the emotional response to cues before it is fully experienced (Ochsner and Gross, 2008). This early regulation allows more complete control and is more likely to prevent adverse emotional states, as compared to a delayed intervention strategy such as emotional suppression (Wallace-Hadrill and Kamboj, 2016; Dryman and Heimberg, 2018).

The cognitive reappraisal strategy is not a simple concept as it involves at least two mechanisms that correspond to two separate neurological substrates (Buhle et al., 2014). These latter are (a) finding an alternative interpretation of a situation and (b) detaching oneself from a situation that generates an intense emotional state (Ochsner and Gross, 2008). Either way the core element of this strategy is the powerful role of the cognitive reinterpretation of external, but also internal, cues with the specific goal to augment or reduce the emotional charge of circumstances (McRae et al., 2012). Cognitive reappraisal has been demonstrated to sustain psychological well-being by reducing anxiety and depression, and thus resulting in satisfaction with life (Gross and John, 2003; Moore et al., 2008; Hu et al., 2014).

The advantages of cognitive reappraisal are not only related to individual control over emotions. In fact, important results of the adoption of this strategy are extended to the individual's understanding of the external environment. Emotions are responses to stimuli and individuals who can understand them better are more likely to decode the feedbacks that the environment sends. This mechanism should allow a deeper connection with the environment. In this regard, studies on the way individuals interact with their social environment demonstrated that cognitive reappraisal leads to more positive social relationships than the emotional suppression strategy (Butler et al., 2003; Gross and John, 2003). This would be so because of the enhanced ability to correctly process social information (Gross and John, 2003; Manera et al., 2014) and, by diminishing the ambiguity of the social interaction (Yurtsever, 2008) lead to a better adaptation.

As individuals who habitually use cognitive reappraisal engage in positive prosocial behavior through their efficient reading of the social environment, likewise a correct interpretation of cues originating from natural environments has been demonstrated to lead to higher engagement in pro-environmental behavior (Panno et al., 2015). In other words, we argue that the key role of cognitive reappraisal would be the higher recognition of the personal positive experience related to immersion in the natural environment. Past research showed how awareness of the environmental related issues does not always result in higher engagement in pro-environmental behavior. Indeed, it seems that the role of awareness is effective only when it can stimulate a higher sensitivity in terms of higher environmental related emotions (Hungerford and Volk, 1990; Carmi et al., 2015).

It is well-known that emotions such as guilt and worry constitute an important predictor that indicates whether the individual would engage in pro-environmental behavior (Bamberg and Möser, 2007; Ojala, 2007; Carrus et al., 2008). Importantly, we argue that it is not the emotions *per se*, but the way individuals manage their emotions that impact on the likelihood to adopt pro-environmental behavior. Successful processes of identifying and regulating emotions have been seen as motivational triggers to enhance pro-environmental intentions and behavior (Carmi et al., 2015). For instance, reflecting on worries as a coping strategy reduces this potentially counter-productive state, allowing individuals to learn from the situation. This mechanism, in turn, leads to important pro-environmental behavior (Ojala, 2007). In this regard, we propose that an emotion regulation strategy (i.e., cognitive reappraisal) that allows one to

rethink one's personal experiences gives to the individual a higher awareness of the benefits of nature. This enhanced awareness should lead, in turn, to higher sensitivity in relation to the natural environment. Thus, we expect:

H1: Higher habitual use of cognitive reappraisal will result in higher pro-environmental behavior reported.

The Experience of Being Away as the Transporter of the Positive Effect of Cognitive Reappraisal on Pro-environmental Behavior

In a relative recent study, it has been shown that cognitive reappraisal promotes pro-environmental behavior through heightened perceptions of climate change (Panno et al., 2015). The basic idea was that the habitual use of cognitive reappraisal makes individuals more sensitive to environmental clues signaling climate change such as, for instance, an increase in the temperatures. This enhanced consideration would transfer to a higher reactivity to these particular cues, consequently traducing in behavior that could reduce the individual footprint on the natural environment. Following the same reasoning, another mechanism through which cognitive reappraisal may relate to pro-environmental behavior is the attention given to the internal cues that originate in response to the natural environment and the subsequent recognition of its value. This particular ability falls within the definition of what has been called restorativeness.

The concept of restorativeness attributed to a natural environment has been defined as both emotional and cognitive responses elicited by contact with nature (Berto, 2014; Martínez-Soto and González-Santos, 2020). In particular, it has been argued that the restorative quality of nature lies in the possibility to suspend direct, and costly, attention, determining an opportunity for cognitive recovery (Kaplan, 1995; Van den Berg et al., 2007). A particular process involved in restorativeness is what has been called the experience of "being away" (Kaplan and Kaplan, 1989; Hartig et al., 1996). This perception is defined as the feeling of psychological distance from daily demanding routines. It comprises the feeling of avoiding environmental distractions, of escaping from one's routine, and of suspending the possibly costly process of pursuing specific purposes (Hartig et al., 1996).

Restorativeness has been positively related to indicators of physical and psychological health (Hartig et al., 2014; Carrus et al., 2015; McMahan and Estes, 2015). In this regard, past research demonstrated how some individual differences can either diminish or enhance the perceived restorativeness of a natural environment (Korpela et al., 2001; Scopelliti et al., 2016; Berto et al., 2018). For instance, the habitual use of specific emotion regulation strategies or even personality traits may intervene in determining perceived restorativeness (Korpela et al., 2001, 2008; Johnsen, 2013). Restorativeness, as a quality attributed to a natural environment, is related to the individual capacity to fully understand the potentiality of exposure to nature (Carrus et al., 2017). In particular, individuals who feel more connected with nature report higher levels of restorativeness (Berto et al., 2018; Mena-García et al., 2020).

There is reason to hypothesize that individuals who exhibit higher habitual use of cognitive reappraisal would engage more in the process of elaborating and recognizing the utility of the natural environment, meaning its value for one's personal restorativeness. In our reasoning, we focus particularly on the dimension of "being away." As it has been argued, this dimension is related to the individual recognition of the utility of the natural setting as a way to "escape" from costly distractions and demands coming from one's daily routines (Staats, 2012). In this regard, we believe that, among others, is this dimension that is the most related to the individual ability to be aware of the importance and value of the natural environment. Therefore, individuals who report higher habitual use of cognitive reappraisal should show a higher appreciation of the natural potentiality to restore in terms of "being away" from duties and demands. Accordingly:

H2: Higher habitual use of cognitive reappraisal strategy will lead to higher experience of "being away" attributed to the natural environment.

Studies demonstrated that higher perceived restorativeness attributed to the natural environment is associated with higher pro-environmental beliefs and behavior (Hartig et al., 2001; Collado and Corraliza, 2015, 2017). It has been argued that restorativeness may function as a motivational factor that could determine the choice to adopt a positive behavior toward the environment (Berto and Barbiero, 2017). Indeed, embracing the utility of nature should motivate individuals to engage in behaviors that could protect it. Thus, our third prediction is that the more the perceived utility of nature in terms of the "being away" experience, the higher the engagement in pro-environmental behavior:

H3: Higher perceived experience of "being away" will predict higher pro-environmental behavior reported.

In sum, in line with previous mediational studies on the topic (Van den Berg et al., 2003; Johnsen, 2013) the purpose of the present study is to test a mediational model. The hypothesis is that cognitive reappraisal positively predicts pro-environmental behavior through the awareness of the utility of the natural environment for one's life in reference to the "being away" experience. The rationale is that, through their cognitive reappraisal, individuals have the opportunity to better understand the positive cues prompted by the natural environment and feel more connected with it. Thus, they would appreciate nature more and feel more restored by exposure to nature. This sense of restoration would then augment the relative importance of defending the environment, leading to more pro-environmental behavior. Therefore, our fourth and last prediction is:

H4: Cognitive reappraisal positively predicts the engagement in pro-environmental behavior through the enhanced experience of "being away."

Following the importance of parks for individual restoration (Peschardt and Stigsdotter, 2013) we tested our hypotheses on

a sample of visitors to Parco Nord Milano (PNM). PNM is a public park located in the north-east side of the metropolitan area of Milan (see **Figure 1**). The park covers more than 600 ha; about 100 ha are forests; the remaining part is covered by fields (211 ha), social allotments (2.1 ha), hedges (0.84 ha), rows of trees (14.4 ha), recreational facilities, small lakes, gray infrastructures (schools, hospital, private airport) and agricultural areas. PNM is an important forestation started since 1983. PNM represents a specific type of Nature Based Solution (NBS) (European Commission, 2015) and consists of reclaimed post-industrial or uncultivated lands (Sanesi et al., 2007).[1] We asked participants to report their perceived experience of "being away" attributed to the park and collected measures of cognitive reappraisal and pro-environmental behavior.

MATERIALS AND METHODS

Participants

One-hundred and fifteen participants visiting PNM participated in the study on a voluntary basis. To be confident in the soundness of the results that we found, we then performed a *post hoc* power analysis using the R application written by Schoemann et al. (2017). In line with a previous study (Panno et al., 2015) detecting a small-medium correlation between cognitive reappraisal (IV) and pro-environmental behavior (DV), we then set small-medium correlations between the independent and the dependent variable (i.e., 0.25) and between the independent variable and the mediator (being away) (i.e., 0.30). We also set a large correlation (i.e., 0.40) between the mediator and the dependent variable. Moreover, we chose values of 5,000 for the total number of power analysis replications and values of 20,000 for the number of coefficients draws per replication (Schoemann et al., 2017). The analysis revealed a statistical power of 0.88 with a sample size of 115 participants.

The sample covered a wide age range (19–81 years). The mean age of the sample was 43.27 years (SD = 16.96). The gender composition was also balanced (49% women). The education level of participants varied from primary school to university degree as follows: 10% primary school and secondary school, 38% high school, 50% university degree. They reported their employment status as follows: 52% intellectual work, 10% manual work, 10% student, 18% retired, and 4% unemployed. The household composition of the sample was as follows: 47% stated living along with partner and children, 21% stated living along with partner but without children, 9% stated having a partner (not living together) and 15% of the sample was single. Research data are available on request without restrictions.

Procedure and Measures

Data were collected through a paper and pencil questionnaire that included variables concerning socio-demographics, as well

[1] http://parconord.milano.it/

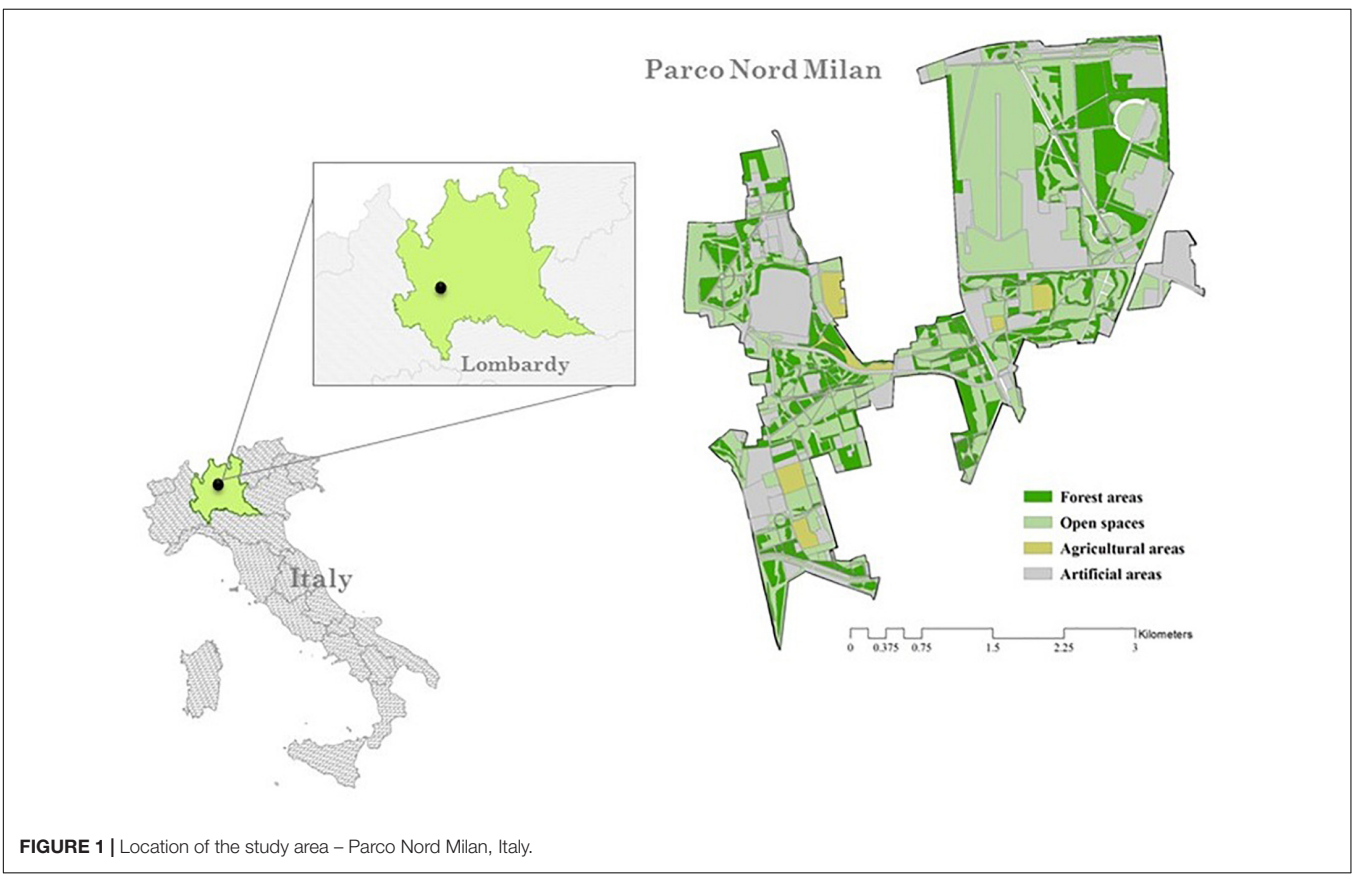


FIGURE 1 | Location of the study area – Parco Nord Milan, Italy.

as psychological constructs. The questionnaire was administered by trained research assistants who approached participants at PNM, asking them to voluntarily take part in a survey on issues related to green spaces and well-being. Participants individually filled in the questionnaire in a time limit of about 15 min, and were not given any financial compensation. Individuals were asked to answer to the questionnaire basis on their everyday experience, while for the "being away" experience individuals were given specific instructions to refer to their experience while in PNM. The questionnaires were collected in September 2015. They were assured anonymity about their responses. All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The article does not refer to any studies with animals performed by any of the authors.

Because this study was part of a larger survey aimed at investigating other factors unrelated to the aims of the present study (e.g., perception of an increase in the temperatures), we then measured some constructs with the sub-scale reflecting the dimension of our interest (e.g., cognitive reappraisal of emotion regulation questionnaire) and an abbreviated measure of pro-environmental behavior. We assessed people's cognitive reappraisal strategy by using the cognitive reappraisal dimension of the short Italian version of the Emotion Regulation Questionnaire (it is composed of four items; Balzarotti, 2019). Respondents rated the extent to which they agree with self-descriptive statements reflecting cognitive reappraisal. An example of item: "*When I want to feel more positive emotion, I change the way I'm thinking about the situation*." Ratings were made on a 5-point Likert type scale, with the response anchored at the ends with 1 (strongly disagree) and 5 (strongly agree) (M = 2.92, SD = 0.72; α = 0.8 and ω = 0.8; Dunn et al., 2014; see also Hayes and Coutts, 2020 for more details).

The being away dimension of the Perceived Restorativeness measure was assessed through all of three items of this sub-scale of the Perceived Restorativeness Scale – Short Version (Scopelliti et al., 2012; Pasini et al., 2009). The short version of the PRS scale has been validated in Italian and English. The being away sub-scale is one of the four PRS dimensions reported by Pasini et al. (2009). An example of item: "*To get away from things that usually demand my attention I like to go to places like this*" Ratings were made on a 5-point Likert type scale, with the response anchored at the ends with 1 (strongly disagree) and 5 (strongly agree) (M = 3.38, SD = 0.79; α = 0.7 and ω = 0.7).

Due to the time limit to administer the questionnaire, only one restorative dimension has been assessed. The wording of being away items explicitly links the park's restorative qualities to benefits for people (e.g., *to stop thinking about the things that I must get done I like to go to places like this* – being away item). In other words, it is a PRS dimension focusing on the properties of the park in giving rise to cognitive restoration (i.e., the benefits for people); whereas other dimensions, such as coherence, concern mainly the physical qualities of the park and the link of such qualities with the benefits for individuals is not explicit in the wording of the items (e.g., *There is a clear order in the physical arrangement of places like this* – coherence item). Thus, the "being away" dimension better captures the link between the restorative quality of the park and benefits for people.

To assess pro-environmental behavior, we used five items measuring people's tendency to engage in eco-friendly behavior. Some instances of item are: "*Recycle paper, plastic, and metal*," "*Avoid using public transportation*" (reverse score), "*Replace incandescent light bulbs with CFLs*" (Panno et al., 2018). A composite score of these items indicated environmentally responsible behavior that people adopt in order to reduce their ecological footprint. Ratings were made on a 5-point Likert type scale, with the response anchored at the ends with 1 (strongly disagree) and 5 (strongly agree) (M = 3.26, SD = 0.59; α = 0.6 and ω = 0.6.

Statistical Analysis

To investigate the relationships among cognitive reappraisal, being away, and pro-environmental behavior, we firstly computed the zero-order correlations among these and socio-demographic variables. We then used the PROCESS macro (Hayes, 2012) which allowed us to test the role of being away as a mediator of the relationship between cognitive reappraisal and pro-environmental behavior. This macro tested the steps of mediation (see also Baron and Kenny, 1986). First, we tested the total effect of cognitive reappraisal on pro-environmental behavior (step 1). In the second step, we tested the effect of cognitive reappraisal on being away, meaning the effect of the predictor on the mediator (path *a* – see **Figure 2**). In the third model (step 3 and 4), we posited cognitive reappraisal and being away as predictors of pro-environmental behavior, testing simultaneously both effects of the mediator on the outcome (path *b* – see **Figure 2**) and the direct effect of the predictor on the outcome (path c' – see **Figure 2**). Lastly, we tested the significance of the indirect effect.

We included socio-demographic variables (i.e., gender, age, household composition, education level, employment status) in the mediation analysis to control for potential confounding variables in the results of the study. A bootstrapping procedure (with 5,000 bootstrap samples) to estimate 95% confidence intervals (95% CI) was used. According to Preacher and Hayes (2008) a 95% CI that does not include zero provides evidence of a significant indirect effect. The bootstrapping procedure has been suggested to represent the most trustworthy test for assessing the effects of mediating models (Hayes and Scharkow, 2013 for a recent review). The 0.05 level of significance was adopted throughout all analyses.

RESULTS

As shown in **Table 1**, cognitive reappraisal was positively and significantly correlated with pro-environmental behavior. This latter result supports the positive total effect of cognitive reappraisal on pro-environmental behavior hypothesized in H1 (step 1). In addition, the experience of "being away" was also positively and significantly related to pro-environmental behavior. Our results also showed that cognitive reappraisal was

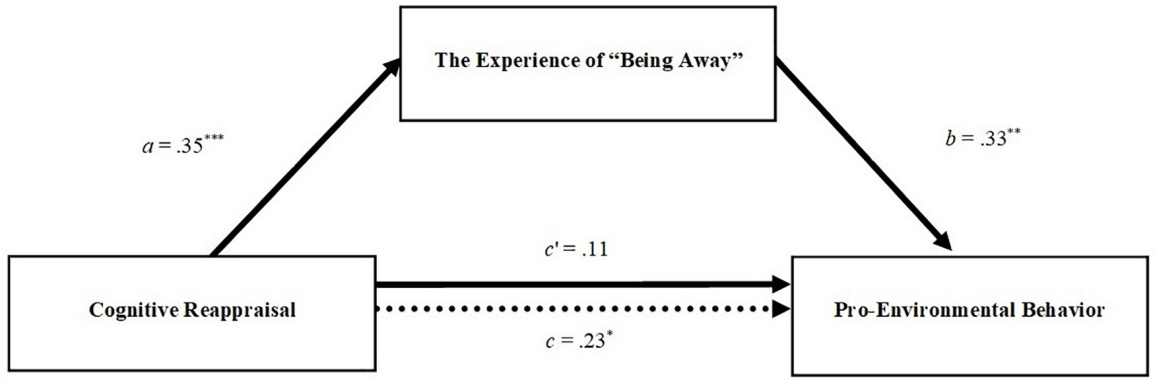


FIGURE 2 | Path coefficients for mediation analysis in the study. Dotted line denotes the effect of cognitive reappraisal strategy on pro-environmental behavior, when the experience of "being away" is not included as a mediator. a, b, c, and c′ are standardized OLS regression coefficients. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

TABLE 1 | Means, standard deviations, and intercorrelations among variables investigated in the study.

	1	2	3	4	5	6	7	8
1. Cognitive reappraisal	1							
2. Being away	0.35***	1						
3. Pro-environmental behavior	0.24*	0.36***	1					
4. Age	−0.02	−0.12	0.09	1				
5. Gender	0.01	0.25**	0.04	−0.18	1			
6. Education	0.17	0.06	0.18	−0.34***	0.14	1		
7. Household composition	0.16	0.26**	0.07	−0.47***	0.04	0.11	1	
8. Employment status	0.05	0.03	−0.08	−0.45***	0.14	0.53***	0.06	1

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

significantly and positively correlated with the experience of "being away." The effect sizes of these relationships were around the moderate effect size threshold as they ranged from $r = 0.24$ to $r = 0.36$ (Cohen, 1988; see **Table 1**).

To understand the mechanisms underlying the relationships between cognitive reappraisal strategy, the experience of "being away," and pro-environmental behavior, we tested the mediation hypothesis. The mediation model was estimated to derive the total, direct, and indirect associations of cognitive reappraisal strategy with pro-environmental behavior through the experience of "being away." We estimated the indirect effect of cognitive reappraisal on pro-environmental behavior, quantified as the product of the OLS regression coefficient estimating the experience of "being away" from cognitive reappraisal strategy (path *a* in **Figure 2** – step 2), and the OLS regression coefficient estimating pro-environmental behavior from the experience of "being away," controlling for cognitive reappraisal (path *b* in **Figure 2** – step 3 and path *c*′ in **Figure 2** – step 4). Overall, these results revealed that both paths *a* and *b* were significant. Indeed, cognitive reappraisal positively predicted the experience of "being away" confirming H2. In turn, controlling for cognitive reappraisal, the experience of "being away" positively predicted pro-environmental behavior confirming H3.

As the last step, we proceeded to test the indirect effect of cognitive reappraisal on pro-environmental behavior. In this regard, a bias-corrected bootstrap-confidence interval (CI) for the product of paths *a* and *b* that does not include zero provides evidence of a significant indirect effect (Preacher and Hayes, 2008). Using the PROCESS macro with 5,000 bootstrap samples, our results revealed a significant positive indirect effect of cognitive reappraisal on pro-environmental behavior through the experience of "being away" (point estimate = 0.113; 95% CI = 0.023–0.226). This latter finding confirmed the hypothesized indirect effect that cognitive reappraisal shows on pro-environmental behavior through enhanced experience of "being away" reported in H4.

Since participants' gender and age, as well as other socio-demographic variables could be related to both the experience of "being away" and pro-environmental behavior, we also tested a mediating model which included gender (men coded as 1 and women coded as 2), age, education, household composition, and employment status as covariates. The relationships between cognitive reappraisal, the experience of "being away," and pro-environmental behavior did not substantially change after controlling for the effect of all these covariates (point estimate = 0.118; 95% CI = 0.011–0.260). Interestingly, we found a significant positive effect of gender on the experience of "being away" ($\beta = 0.24$, $p < 0.05$), with women perceiving more experience of "being away" than men. We also found a significant effect of age and education on

pro-environmental behavior with older ($\beta = 0.30$, $p < 0.05$) and well-educated ($\beta = 0.32$, $p < 0.05$) people being more environmentally oriented.

DISCUSSION

In recent years, the negative impact of anthropic activity on the natural environment has been becoming more and more obvious (Spano et al., 2020). In light of the changes in several natural processes we experience nowadays, the importance of shedding light on the antecedent of pro-environmental behavior represents a current challenge (Gifford and Nilsson, 2014). In this regard, we claimed that an important factor that can motivate people to engage in pro-environmental behavior is the awareness of the positive benefits of nature. Specifically, we proposed a mediational model. We hypothesized that using an emotional regulation strategy as cognitive appraisal, individuals may be more in tune with the natural environment and, as a consequence, engage more in pro-environmental behavior. Indeed, through cognitive reappraisal, individuals may appreciate more the value of the time spent surrounded by nature, as indicated by a higher perceived experience of "being away." This latter, in turn, should enhance engagement in pro-environmental behavior. The overarching message of this work is that cognitive reappraisal (i.e., a coping strategy) copes with the need to shift the attention from daily routine demanding cognitive efforts to the potentially restorative environment (Kaplan, 1995). This rationale is in line with a coping strategy that may bring the individual to use the park as a means to regulate distress arising through daily routine (e.g., things that usually demand attention; Ochsner and Gross, 2008; Buhle et al., 2014).

Our first hypothesis stated that the higher the habitual use of cognitive reappraisal, the higher the pro-environmental behavior reported. This hypothesis was confirmed by the data. Indeed, in line with previous findings (Panno et al., 2015) there was a positive association between the two variables. Cognitive reappraisal intervenes in the way individuals adapt to their environment (Keltner and Gross, 1999). Having the possibility to rationally shape the emotions seems to lead the way to higher importance attributed to the engagement in pro-environmental behavior. This result attests that the well-known benefits of habitual use of cognitive reappraisal in individual psychological and social adaptation may extend to adaptation to the natural environment.

Our second hypothesis was that the more the habitual use of cognitive reappraisal, the more the perceived restorativeness attributed to the natural environment in terms of the experience of "being away." This hypothesis was confirmed by the data. Indeed, it seems that a greater understanding of the benefits of the environment, achieved through the cognitive reappraisal strategy, sustains the experience of escaping from costly routines and finding "restorativeness" in the natural park. Our third hypothesis was that the more the experience of "being away" attributed to the natural environment, the more the pro-environmental behavior reported. This prediction was confirmed by the data as well. Therefore, a positive experience of stay in the park related with the importance given to the behavioral choices that could protect the natural environment.

Lastly, our fourth hypothesis was that cognitive reappraisal exerts its role in sustaining pro-environmental behavior through an enhanced experience of "being away." This latter hypothesis was confirmed by a significant indirect effect; importantly, when considering the experience of "being away," the effect of cognitive reappraisal disappeared, suggesting that the totality of the effect of cognitive reappraisal on pro-environmental behavior passes through the experience of "being away." These latter findings constitute the most innovative contribution of this research. In fact, as the role of cognitive reappraisal in pro-environmental behavior is just beginning to be studied, it is important to shed light on the mechanism through which it can sustain them. In this regard, it seems that the experience of "being away" plays a central role. Processing social information more effectively results in better social functioning (Gross and John, 2003). Likewise, it seems that the way individuals elaborate cues originating from nature enhances their engagement in pro-environmental behavior: a sort of "natural" functioning. Ultimately, engaging in this behavior is likely to benefit the individual him or herself (Suárez-Varela et al., 2016; Schmitt et al., 2018). Moreover, some socio-demographic variables showed a significant effect on the experience of "being away" as well as pro-environmental behavior. Indeed, these results pointed out that women perceived more benefits, in terms of the experience of "being away," than men. Finally, older and well-educated people would seem to be more environmentally oriented. Thus, these findings mark again the role of education in the promotion of environmentalism and the relevance of the relationship between elderly and younger people in the stimulation of a pro-environmental stance in society at large.

This research is not free of limitations. First of all, the cross-sectional nature of the research makes it impossible to ascertain causal relationships. Thus, future studies with experimental or longitudinal designs are needed in order to test causation. Moreover, cross-sectional designs could give rise to common method variance issue. Thus, although such an issue should not undermine novel research avenues, future studies should investigate these relationships through experimental designs. Secondly, the peculiar features of PNM may limit the generalization of our model to other urban parks and other natural areas. In particular, the emotional response to the natural setting offered by an urban park may differ from the experience of wilder natural settings. Thus, future studies can test our model with reference to wilder natural areas, such as forests. Due to the narrowed time limit that we had to administer the questionnaire, in the current study we sought to assess the constructs of interest through some dimensions of the respective scale (e.g., we only assessed the cognitive reappraisal dimension of the emotion regulation questionnaire). Clearly, these results provide a first step in this avenue of research and future studies using the full scale of the constructs may add robustness to these findings. For example, future studies should use the full version of the PRS scale.

From a theoretical point of view, it has been noted that urban parks can cause ambiguous feelings in the city's inhabitants

(Burgess et al., 1988). During the stay in urban parks, positive feelings may be accompanied by negative feelings (e.g., fear for one's own safety, perception of low control on the environment, and reduction of personal comfort; Bonnes et al., 2011). The conjunction of negative and positive emotions is important for engaging in pro-environmental behavior (Ojala, 2007). It is possible that both explicit and implicit mechanisms are involved in this process, as suggested by previous studies in different domains, such as esthetic preference (e.g., Mastandrea et al., 2011; Mastandrea and Maricchiolo, 2014). Thus, future research could address the specific role of cognitive reappraisal on both positive and negative feelings originating from the park experience and their relationship with pro-environmental behavior. The present work might have relevant applied implications. For instance, future research could explore the possibility of designing cognitive reappraisal trainings (Denny and Ochsner, 2014) through natural settings. Such a line of research could shed light on common motivational factors underlying the relationship between perceived natural restorativeness in terms of the experience of "being away" and pro-environmental behavior. Moreover, such interventions might be adopted in school settings to promote an environmentalist attitude among the young.

CONCLUSION

In conclusion, understanding the way individuals "sense" their environment is important in order to predict their behavior. A deeper understanding of this mechanism is essential in order to design increasingly sophisticated interventions aimed at enhancing pro-environmental behavior. First and foremost, particular attention needs to be directed towards those factors that can be sustained and promoted through training. This study's results point to an emotion regulation strategy as cognitive reappraisal as a possible target of psychological intervention. If future studies could confirm the study findings, these latter could have an important implication in interventions aimed at sustaining pro-environmental choices. In fact, as an emotion regulation strategy, the habitual use of cognitive reappraisal is susceptible to change: it can be sustained and taught to promote pro-environmental behavior.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

All procedures performed in studies involving human participants were conducted in accordance with the ethical standards of the institutional and national research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AP: conceptualization. AP and CI: methodology. AP, GSp, and CI: statistical analysis. GSp: data acquisition. AT and AP: writing–first draft and final draft of the manuscript. GC and GSa: review and editing. All authors contributed to the article and approved the submitted version.

FUNDING

This work was carried out under the project "Establishing Urban FORest based solutions In Changing Cities (EUFORICC) and financially supported by the Ministry of Education, University and Research (MIUR) of Italy (PRIN 20173RRN2S).

REFERENCES

Aguilar-Luzón, M. C., Calvo-Salguero, A., and Salinas, J. M. (2014). Beliefs and environmental behavior: the moderating effect of emotional intelligence. *Scand. J. Psychol.* 55, 619–629. doi: 10.1111/sjop.12160

Balzarotti, S. (2019). The emotion regulation questionnaire: factor structure and measurement invariance in an Italian sample of community dwelling adults. *Curr. Psychol.* doi: 10.1007/s12144-019-00426-3 [Epub ahead of print].

Bamberg, S., and Möser, G. (2007). Twenty years after hines, Hungerford, and Tomera: a new meta-analysis of psycho-social determinants of pro-environmental behaviour. *J. Environ. Psychol.* 27, 14–25. doi: 10.1016/j.jenvp.2006.12.002

Baron, R. M., and Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. *J. Pers. Soc. Psychol.* 51, 1173–1182. doi: 10.1037/0022-3514.51.6.1173

Berto, R. (2014). The role of nature in coping with psycho-physiological stress: a literature review on restorativeness. *Behav. Sci.* 4, 394–409. doi: 10.3390/bs4040394

Berto, R., and Barbiero, G. (2017). How the psychological benefits associated with exposure to nature can affect pro-environmental behavior. *Ann. Cogn. Sci.* 1:336. doi: 10.36959/447/336

Berto, R., Barbiero, G., Barbiero, P., and Senes, G. (2018). An individual's connection to nature can affect perceived restorativeness of natural environments. some observations about biophilia. *Behav. Sci.* 8:34. doi: 10.3390/bs8030034

Bonnes, M., Passafaro, P., and Carrus, G. (2011). The ambivalence of attitudes toward urban green areas: between proenvironmental worldviews and daily residential experience. *Environ. Behav.* 43, 207–232. doi: 10.1177/0013916509354699

Buhle, J. T., Silvers, J. A., Wage, T. D., Lopez, R., Onyemekwu, C., Kober, H., et al. (2014). Cognitive reappraisal of emotion: a meta-analysis of human neuroimaging studies. *Cereb. Cortex* 24, 2981–2990. doi: 10.1093/cercor/bht154

Burgess, J., Harrison, C. M., and Limb, M. (1988). People, parks and the urban green: a study of popular meanings and values for open spaces in the city. *Urban Stud.* 25, 455–473. doi: 10.1080/00420988820080631

Butler, E. A., Egloff, B., Wilhelm, F. H., Smith, N. C., Erickson, E. A., and Gross, J. J. (2003). The social consequences of expressive suppression. *Emotion* 3, 48–67. doi: 10.1037/1528-3542.3.1.48

Carmi, N., Arnon, S., and Orion, N. (2015). Transforming environmental knowledge into behavior: the mediating role of environmental emotions. *J. Environ. Educ.* 46, 183–201. doi: 10.1080/00958964.2015.1028517

Carrus, G., Passafaro, P., and Bonnes, M. (2008). Emotions, habits and rational choices in ecological behaviours: the case of recycling and use of public transportation. *J. Environ. Psychol.* 28, 51–62. doi: 10.1016/j.jenvp.2007.09.003

Carrus, G., Passiatore, Y., Pirchio, S., and Scopelliti, M. (2015). El contacto con la naturaleza en los contextos educativos podría mejorar el funcionamiento cognitivo y fomentar el comportamiento social positivo. *Psyecology* 6:e026079. doi: 10.1080/21711976.2015.1026079

Carrus, G., Scopelliti, M., Panno, A., Lafortezza, R., Colangelo, G., Pirchio, S., et al. (2017). A different way to stay in touch with "Urban Nature": the perceived restorative qualities of botanical gardens. *Front. Psychol.* 8:914. doi: 10.3389/fpsyg.2017.00914

Cohen, J. (1988). *Statistical Power Analysis For The Behavioral Sciences*, 2nd Edn, New York, NY: Academic Press.

Collado, S., and Corraliza, J. A. (2015). Children's restorative experiences and self-reported environmental behaviors. *Environ. Behav.* 47, 38–56. doi: 10.1177/0013916513492417

Collado, S., and Corraliza, J. A. (2017). Children's perceived restoration and pro-environmental beliefs. *J. Asian Behav. Stud.* 2:1. doi: 10.21834/jabs.v2i2.176

Crowley, T. J. (2000). Causes of climate change over the past 1000 years. *Science* 289, 270–277. doi: 10.1126/science.289.5477.270

Denny, B. T., and Ochsner, K. N. (2014). Behavioral effects of longitudinal training in cognitive reappraisal. *Emotion* 14, 425–433. doi: 10.1037/a0035276

Dryman, M. T., and Heimberg, R. G. (2018). Emotion regulation in social anxiety and depression: a systematic review of expressive suppression and cognitive reappraisal. *Clin. Psychol. Rev.* 65, 17–42. doi: 10.1016/j.cpr.2018.07.004

Dunn, T. J., Baguley, T., and Brunsden, V. (2014). From alpha to omega: a practical solution to the pervasive problem of internal consistency estimation. *Br. J. Psychol.* 105, 399–412. doi: 10.1111/bjop.12046

European Commission (2015). *Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities Final Report of the Horizon 2020 Expert Group on "Nature-Based Solutions and Re-Naturing Cities*. Brussels: European Commission.

Gifford, R., and Nilsson, A. (2014). Personal and social factors that influence pro-environmental concern and behaviour: a review. *Int. J. Psychol.* 49, 141–157. doi: 10.1002/ijop.12034

Gross, J. J. (1998). Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *J. Pers. Soc. Psychol.* 74, 224–237. doi: 10.1037/0022-3514.74.1.224

Gross, J. J., and John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *J. Pers. Soc. Psychol.* 85, 348–362. doi: 10.1037/0022-3514.85.2.348

Hartig, T., Kaiser, F. G., and Bowler, P. A. (2001). Psychological restoration in nature as a positive motivation for ecological behavior. *Environ. Behav.* 33, 590–607. doi: 10.1177/00139160121973142

Hartig, T., Korpela, K., Evans, G. W., and Gärling, T. (1996). Validation of a measure of perceived environmental restorativeness. *J. Environ. Educ.* 32, 1–64.

Hartig, T., and Mang, M. (1991). Restorative effects of natural environment experiences. *Environ. Behav.* 23, 3–26. doi: 10.1177/0013916591231001

Hartig, T., Mitchell, R., de Vries, S., and Frumkin, H. (2014). Nature and health. *Annu. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Hayes, A. F. (2012). *PROCESS: A Versatile Computational Tool For Observed Variable Mediation, Moderation, And Conditional Process Modeling. White Pap. 1-39*. Available online at: http://www.afhayes.com/public/process2012.pdf (accessed August 10, 2017).

Hayes, A. F., and Coutts, J. J. (2020). Use omega rather than cronbach's alpha for estimating reliability. *Bull. Commun. Methods Measur.* 14, 1–24. doi: 10.1080/19312458.2020.1718629

Hayes, A. F., and Scharkow, M. (2013). The relative trustworthiness of inferential tests of the indirect effect in statistical mediation analysis: does method really matter? *Psychol. Sci.* 24, 1918–1927. doi: 10.1177/0956797613480187

Hu, T., Zhang, D., Wang, J., Mistry, R., Ran, G., and Wang, X. (2014). Relation between emotion regulation and mental health: a meta-analysis review. *Psychol. Rep.* 114, 341–362. doi: 10.2466/03.20.PR0.114k22w4

Hughes, T. P., Baird, A. H., Bellwood, D. R., Card, M., Connolly, S. R., Folke, C., et al. (2003). Climate change, human impacts, and the resilience of coral reefs. *Science* 301, 929–933. doi: 10.1126/science.1085046

Hungerford, H. R., and Volk, T. L. (1990). Changing learner behavior through environmental education. *J. Environ. Educ.* 21, 8–21. doi: 10.1080/00958964.1990.10753743

Johnsen, S. A. K. (2013). Exploring the use of nature for emotion regulation: associations with personality, perceived stress, and restorative outcomes. *Nord. Psychol.* 65, 306–321. doi: 10.1080/19012276.2013.851445

Kaplan, R., and Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective*. New York, NY: Cambridge University Press.

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Keltner, D., and Gross, J. J. (1999). Functional accounts of emotions. *Cogn. Emot.* 13, 467–480. doi: 10.1080/026999399379140

Korpela, K. M., Hartig, T., Kaiser, F. G., and Fuhrer, U. (2001). Restorative experience and self-regulation in favorite places. *Environ. Behav.* 33, 572–589. doi: 10.1177/00139160121973133

Korpela, K. M., Ylén, M., Tyrväinen, L., and Silvennoinen, H. (2008). Determinants of restorative experiences in everyday favorite places. *Health Place* 14, 636–652. doi: 10.1016/j.healthplace.2007.10.008

Manera, V., Samson, A. C., Pehrs, C., Lee, I. A., and Gross, J. J. (2014). The eyes have it: the role of attention in cognitive reappraisal of social stimuli. *Emotion* 14, 833–839. doi: 10.1037/a0037350

Martínez-Soto, J., and González-Santos, L. (2020). Affective psychological restoration through mediated exposure to the environment (Restauración psicológica afectiva a partir de la exposición mediada del ambiente). *Psyecology* 2020, 1–30. doi: 10.1080/21711976.2020.1730133

Mastandrea, S., Bartoli, G., and Carrus, G. (2011). The automatic aesthetic evaluation of different art and architectural styles. *Psychol. Aesthet. Creat.* 5, 126–134. doi: 10.1037/a0021126

Mastandrea, S., and Maricchiolo, F. (2014). Implicit and explicit aesthetic evaluation of design objects. *Art Percept.* 2, 141–162. doi: 10.1163/22134913-00002015

McMahan, E. A., and Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: a meta-analysis. *J. Posit. Psychol.* 10, 507–519. doi: 10.1080/17439760.2014.994224

McRae, K., Ciesielski, B., and Gross, J. J. (2012). Unpacking cognitive reappraisal: goals, tactics, and outcomes. *Emotion* 12, 250–255. doi: 10.1037/a0026351

Mena-García, A., Olivos, P., Loureiro, A., and Navarro, O. (2020). Effects of contact with nature on connectedness, environmental identity and evoked contents (Efectos del contacto con la naturaleza en conectividad, identidad ambiental y contenidos evocados). *Psyecology* 11, 21–36. doi: 10.1080/21711976.2019.1643663

Moore, S. A., Zoellner, L. A., and Mollenholt, N. (2008). Are expressive suppression and cognitive reappraisal associated with stress-related symptoms? *Behav. Res. Ther.* 46, 993–1000. doi: 10.1016/j.brat.2008.05.001

Ochsner, K. N., and Gross, J. J. (2008). Cognitive emotion regulation: insights from social cognitive and affective neuroscience. *Curr. Dir. Psychol. Sci.* 17, 153–158. doi: 10.1111/j.1467-8721.2008.00566.x

Ojala, M. (2007). Confronting macrosocial worries: worry about environmental problems and proactive coping among a group of young volunteers. *Futures* 39, 729–745. doi: 10.1016/j.futures.2006.11.007

Panno, A., Carrus, G., Maricchiolo, F., and Mannetti, L. (2015). Cognitive reappraisal and pro-environmental behavior: the role of global climate change perception. *Eur. J. Soc. Psychol.* 45, 858–867. doi: 10.1002/ejsp.2162

Panno, A., Giacomantonio, M., Carrus, G., Maricchiolo, F., Pirchio, S., and Mannetti, L. (2018). Mindfulness, pro-environmental behavior, and belief in climate change: the mediating role of social dominance. *Environ. Behav.* 50, 864–888. doi: 10.1177/0013916517718887

Pasini, M., Berto, R., Scopelliti, M., and Carrus, G. (2009). Measuring the restorative value of the environment: contribution to the validation of the Italian version of the perceived restorativeness Scale. *Boll. Psicol. Appl.* 257, 3–11.

Peschardt, K. K., and Stigsdotter, U. K. (2013). Associations between park characteristics and perceived restorativeness of small public urban green spaces. *Landsc. Urban Plan.* 112, 26–39. doi: 10.1016/j.landurbplan.2012.12.013

Preacher, K. J., and Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behav. Res. Methods* 3, 879–891. doi: 10.3758/BRM.40.3.879

Robinson, A. C., Downey, L. A., Ford, T. C., Lomas, J. E., and Stough, C. (2019). Green teens: Investigating the role of emotional intelligence in adolescent environmentalism. *Pers. Individ. Dif.* 138, 225–230. doi: 10.1016/j.paid.2018.10.009

Sanesi, G., Lafortezza, R., Marziliano, P. A., Ragazzi, A., and Mariani, L. (2007). Assessing the current status of urban forest resources in the context of Parco Nord, Milan, Italy. *Landsc. Ecol. Eng.* 3, 187–198. doi: 10.1007/s11355-007-0031-2

Schmitt, M. T., Aknin, L. B., Axsen, J., and Shwom, R. L. (2018). Unpacking the relationships between pro-environmental behavior, life satisfaction, and perceived ecological threat. *Ecol. Econ.* 143, 130–140. doi: 10.1016/j.ecolecon.2017.07.007

Schoemann, A. M., Boulton, A. J., and Short, S. D. (2017). Determining power and sample size for simple and complex mediation models. *Soc. Psychol. Pers. Sci.* 8, 379–386. doi: 10.1177/1948550617715068

Scopelliti, M., Carrus, G., Adinolfi, C., Suarez, G., Colangelo, G., Lafortezza, R., et al. (2016). Staying in touch with nature and well-being in different income groups: the experience of urban parks in Bogotá. *Landsc. Urban Plan.* 148, 139–148. doi: 10.1016/j.landurbplan.2015.11.002

Scopelliti, M., Carrus, G., Cini, F., Mastandrea, S., Ferrini, F., Lafortezza, R., et al. (2012). "Biodiversity, perceived restorativeness, and benefits of nature," in *Vulnerability, Risks, And Complexity: Impacts Of Global Change On Human Habitats*, eds S. Kabisch, A. Kunath, P. Schweizer-Ries, and A. Steinführer (Gottingen: Hogrefe), 255–269.

Spano, G., Giannico, V., Elia, M., Bosco, A., Lafortezza, R., and Sanesi, G. (2020). Human health-environment interaction science: an emerging research paradigm. *Sci. Total Environ.* 704:358. doi: 10.1016/j.scitotenv.2019.135358

Staats, H. (2012). "Restorative environments," in *The Oxford Handbook of Environmental and Conservation Psychology*, ed. S. Clayton (New York, NY: Oxford University Press), 445–458. doi: 10.1093/oxfordhb/9780199733026.013.0024

Suárez-Varela, M., Guardiola, J., and González-Gómez, F. (2016). Do Pro-environmental behaviors and awareness contribute to improve subjective well-being? *Appl. Res. Qual. Life* 11, 429–444. doi: 10.1007/s11482-014-9372-9

Van den Berg, A. E., Hartig, T., and Staats, H. (2007). Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. *J. Soc. Issues* 63, 79–96. doi: 10.1111/j.1540-4560.2007.00497.x

Van den Berg, A. E., Koole, S. L., and van der Wulp, N. Y. (2003). Environmental preference and restoration:(How) are they related? *J. Environ. Psychol.* 23, 135–146. doi: 10.1016/S0272-4944(02)00111-1

Vilardo, G., Ventura, G., Terranova, C., Matano, F., and Nardò, S. (2009). Ground deformation due to tectonic, hydrothermal, gravity, hydrogeological, and anthropic processes in the Campania Region (Southern Italy) from permanent scatterers synthetic aperture radar interferometry. *Remote Sens. Environ.* 113, 197–212. doi: 10.1016/j.rse.2008.09.007

Wallace-Hadrill, S. M. A., and Kamboj, S. K. (2016). The impact of perspective change as a cognitive reappraisal strategy on affect: a systematic review. *Front. Psychol.* 7:1715. doi: 10.3389/fpsyg.2016.01715

Yurtsever, G. (2008). Negotiators' profit predicted by cognitive reappraisal, suppression of emotions, misrepresentation of information, and tolerance of ambiguity. *Percept. Mot. Skills* 106, 590–608. doi: 10.2466/PMS.106.2.590-608

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

SYSTEMATIC REVIEW
published: 30 September 2020
doi: 10.3389/fpsyg.2020.02200

An Actual Natural Setting Improves Mood Better Than Its Virtual Counterpart: A Meta-Analysis of Experimental Data

Matthew H. E. M. Browning[1]*, *Nathan Shipley*[2], *Olivia McAnirlin*[1], *Douglas Becker*[2], *Chia-Pin Yu*[3,4], *Terry Hartig*[5,6] *and Angel M. Dzhambov*[7]

[1] Virtual Reality and Nature Lab, Department of Parks, Recreation and Tourism Management, Clemson University, Clemson, SC, United States, [2] Department of Natural Resources and Environmental Science, University of Illinois at Urbana-Champaign, Champaign, IL, United States, [3] Department of Environmental Health, Harvard T.H. Chan School of Public Health, Boston, MA, United States, [4] School of Forestry and Resource Conservation, National Taiwan University, Taipei, Taiwan, [5] Institute for Housing and Urban Research, Uppsala University, Uppsala, Sweden, [6] Department of Psychology, Uppsala University, Uppsala, Sweden, [7] Department of Hygiene and Ecomedicine, Faculty of Public Health, Medical University of Plovdiv, Plovdiv, Bulgaria

OPEN ACCESS

Edited by:
Payam Dadvand, Instituto Salud Global Barcelona (ISGlobal), Spain

Reviewed by:
Jason Duvall, University of Michigan, United States
Simon Bell, University of Edinburgh, United Kingdom

***Correspondence:**
Matthew H. E. M. Browning
mhb2@clemson.edu

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *19 April 2020*
Accepted: *05 August 2020*
Published: *30 September 2020*

Citation:
Browning MHEM, Shipley N, McAnirlin O, Becker D, Yu C-P, Hartig T and Dzhambov AM (2020) An Actual Natural Setting Improves Mood Better Than Its Virtual Counterpart: A Meta-Analysis of Experimental Data. Front. Psychol. 11:2200. doi: 10.3389/fpsyg.2020.02200

Accumulating evidence indicates that simulated natural settings can engage mechanisms that promote health. Simulations offer alternatives to actual natural settings for populations unable to travel outdoors safely; however, few studies have contrasted the effects of simulations of natural settings to their actual outdoor counterparts. We compared the impacts of simulated and actual natural settings on positive and negative affect (mood) levels using a pooled sample of participants enrolled in extant experimental studies. Relevant articles were identified from a review of research published/in press by March 2020 and updated during the peer review of the current study. Of 16 articles identified, 6 met the inclusion criteria and administered a single cross-cutting, standardized instrument [the Positive and Negative Affect Schedule (PANAS)] before and after exposure. Random effects meta-analysis of pooled effects showed that positive affect increased in the actual settings but not in their simulated counterparts (Hedge's $g = 0.87$; 95% CI, 0.54, 1.20). We observed little difference in effects on negative affect change scores ($g = -0.28$; 95% CI, −0.62, 0.06), with studies generally showing reductions in negative affect in both settings. Further research with additional populations, settings, antecedent conditions, and durations would provide a more robust understanding of differences in effects between these two ways to enhance mood by viewing nature.

Keywords: green space, virtual reality, emotion, mental health, environmental simulations, restorative environments, systematic review

INTRODUCTION

Health benefits of visits to natural settings are unavailable for many people. Urbanities often do not have ready access to public or private green space where they can recreate outdoors (Beyer et al., 2018; Haydock and Moran, 2019). Hospital patients, nursing home residents, physically disabled adults, and prison inmates spend even greater shares of their time indoors. Special circumstances,

like the shelter-in-place orders issued during the 2020 COVID-19 pandemic, may restrict access to outdoor settings even for people who could otherwise enjoy them. Without access to natural settings, people may forgo myriad health benefits—from reduced mortality and diabetes rates to improved mental and cardiovascular function (Hartig et al., 2014, 2020; Twohig-Bennett and Jones, 2018).

Ample evidence suggests that nature simulations can, under some conditions, support processes that promote health. More than 100 experiments report that pictures, videos, or immersive virtual environments with natural elements boosted mood, enhanced executive cognitive functions, promoted physiological stress recovery or reduced pain with little to no side effects (Browning et al., 2020a). Yet, how and to what extent simulations replicate the benefits of actual natural settings remain essentially unknown. More knowledge in this regard would help research and practice communities to better understand the circumstances in which simulation-based interventions can and cannot offer benefits like those described in the broader nature-and-health field.

How might simulated natural settings yield benefits like those found with exposure to actual nature? Examination of the conceptual framework developed by a panel of experts on the health benefits of nature exposure is helpful for comparing the expected benefits from simulated and actual settings (Markevych et al., 2017). This framework explains three sets (domains) of pathways that explain the health benefits of natural settings, including reducing harm (the "mitigation" domain), restoring capacities (the "restoration" domain), and building capacities (the "instoration" domain). Both actual and simulated settings can support the renewal of depleted adaptive resources, as through stress recovery and directed attention restoration (pathways within the restoration domain). Other mechanisms may be less likely to be activated in simulations, including reducing air and noise pollution (mitigation pathways) and promoting physical activity and social contacts (instoration pathways) (see **Figure 1**). Simulations could activate mitigation and instoration pathways if they masked noise in loud environments (e.g., hemodialysis centers; Burrows et al., 2020), accompanied vigorous walking on treadmills or cycling on stationary trainers (Howard, 2017; Birenboim et al., 2019), or supported interactions between multiple users (White et al., 2018; Riva et al., 2020). However, the vast majority of simulations today offer passive single-person experiences with only audio input, only visual input, or a combination of the two (LaValle, 2017). They, therefore, presumably work primarily through restoration pathways, with restoration broadly conceived to include recovery from boredom and understimulation as well as from efforts to meet excessive demands (Ulrich, 1983; Frankenhaeuser and Johansson, 1986).

To our knowledge, only two reviews have examined the effects of simulated vs. actual exposure to nature, but their conclusions on this topic are limited (McMahan and Estes, 2015; Lahart et al., 2019). Few of the included experiments directly compared the effects of viewing the exact same setting in both a simulation and outdoors. Presenting the same setting in both experimental conditions (actual and simulated) strengthens the internal validity of results, in that differences in outcomes between conditions cannot be attributed to differences between the settings presented (Rossetti and Hurtubia, 2020).

Here, we employed a meta-analytical approach to compare the effects of actual and simulated natural settings on human health/well-being. Because this approach was applied to an emerging topic (Browning et al., 2020a), we conducted a review that included the greatest number of studies possible despite the likelihood that the number of eligible studies would be small. Accordingly, we aimed to provide a benchmark for the current state of evidence upon which future research can build, together with an initial framing of the research problem and articulation of relevant methodological issues.

METHODS

Study Protocol

This meta-analysis originated from a systematic review conducted by some of the coauthors here, which is described elsewhere (Browning et al., 2020a). The review and this meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Moher et al., 2009).

Conducting Study Protocol and Search Strategy

We identified the bulk of relevant papers by consulting the results of the former large systematic review by Browning et al. (2020a), in which the authors conducted an extensive keyword search in Scopus, PubMed, and Web of Science for articles that were published or in press by January, 2019 and that referenced natural settings and simulations in their titles, abstracts, or keywords (see **Table S1** for list of keywords). Articles were included in that review if they met the following criteria: (A) participants had been exposed to at least one simulated natural setting, such as a photograph, slideshow, video, or immersive virtual environment (i.e., 360° video or computer-generated three-dimensional environment); (B) researchers measured at least one human health or cognitive performance outcome; and (C) researchers compared the results of different treatments using inferential statistics.

We then followed the methods from another meta-analysis on the effects of environmental exposure on human health to select which health/well-being outcome measure(s) to analyze (Radke et al., 2020). For selection, an outcome should show sensitivity to short-term exposure to natural settings that over time could cumulatively affect health in lasting ways. It should also indicate changes that could follow from either type of exposure (actual or simulated) and which would reflect the operation of any of the multiple pathways that could become engaged (instoration, restoration, and mitigation). Positive and negative affect (mood) met these criteria and were chosen to analyze. Stress reduction/buffering also met these criteria but were measured with disparate measures in the former systematic review, including self-report measures or indices and physiological measures, making meta-analyses not possible. Our selection of outcome (mood) also built on findings of the

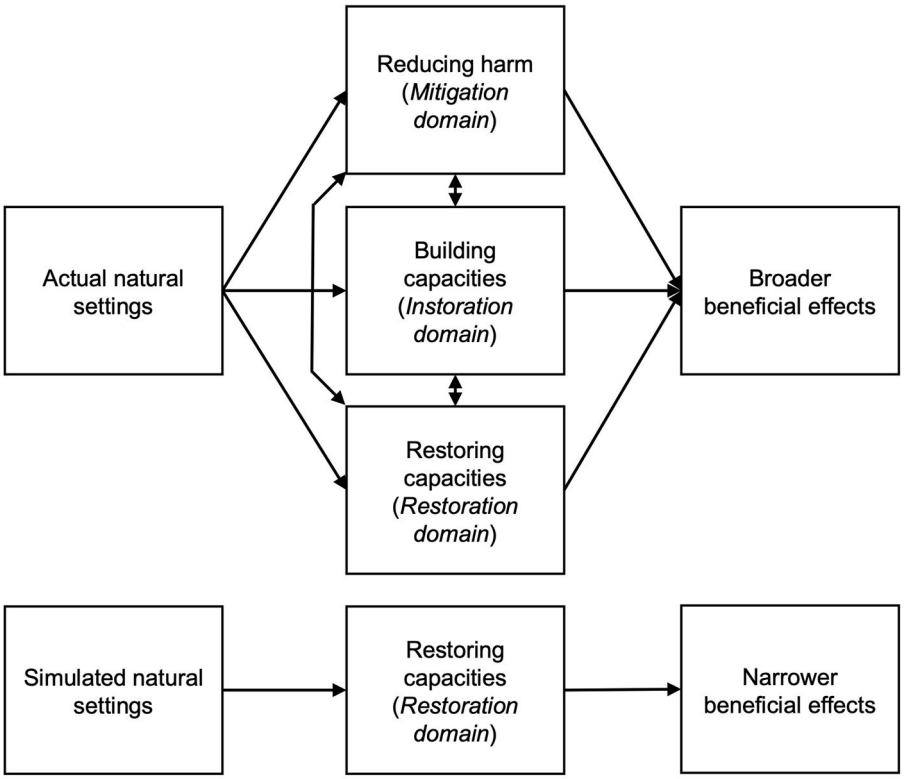


FIGURE 1 | Actual natural settings may activate more pathway domains that promote beneficial health effects than do simulated natural settings. Model adapted from Markevych et al. (2017).

only review that examined the topic of exposure to simulated vs. actual nature and was published before the current study began (McMahan and Estes, 2015)[1]. All aspects of mood were considered—including affective arousal and valence or combinations of these—as long as attributes were measured with standardized self-report instruments with demonstrated construct validity, criterion validity, reliability, and sensitivity to change (Coste et al., 1997).

Next, we narrowed the sample of articles identified in the review by Browning et al. (2020a) to those that might be used to address our specific objectives. Three inclusion criteria were added: (A) researchers reported changes in mood before and after exposure to at least one simulated natural landscape using a standardized measure; (B) researchers employed a simulation of a natural setting that was the same—or very similar—to the actual setting used in the same study; and (C) exposures to the simulated and actual settings had similar durations.

To ensure that our results were comprehensive and up to date, we reviewed several other sources of data and published articles. First, we sought unpublished datasets to identify and overcome publication bias and increase the precision of our reported meta-effects (Dickersin et al., 1994; Card, 2015). Unpublished data were solicited with postings on five prominent scientific and professional listservs and emails to colleagues of the coauthors of the current study. Second, we included a supplemental keyword search for dissertations and theses using ProQuest. These types of reports can contain valuable data on emerging areas of research (Card, 2015). Third, we examined the citations of two narrative reviews. One considered the health benefits of simulated natural settings in virtual reality (White et al., 2018). The other reviewed experiments that tested the transferability of findings from laboratory simulation studies to actual *in situ* field studies (Rossetti and Hurtubia, 2020).

Extracting Data

Article identification and data extraction were independently performed by two of the study authors. Disagreements were resolved through discussion among three members of the research team attending to data extraction. The interrater reliability was 100% agreement ($k = 1.0$) (Belur et al., 2018). Codes for article inclusion/exclusion and data from included articles were entered into a standard data extraction spreadsheet in Microsoft Excel for Mac (Redmond, WA, USA). Variables extracted are covered in the next section.

Analyzing Data

We compared mood changes using standardized mean difference scores (Higgins and Green, 2011b; Card, 2015). These scores

[1]A systematic review on all health effects associated with outdoor "green" exercise versus indoor exercise with simulations of natural settings was published after the current study began (Lahart et al., 2019).

were calculated using the mean difference divided by the standard deviation (Higgins and Green, 2011b). Mean difference scores were calculated as the mean change (postexposure mean minus the preexposure mean) for the actual setting minus the mean change for the simulated setting. The standard deviations were calculated using the formula provided in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2011b):

$$SD_{Change} = \sqrt{SD^2_{Baseline} + SD^2_{Final} - (2 \times Corr \times SD_{Baseline} \times SD_{Final})}$$

Here, SD_{Change} is the standard deviation of the change in one of the experimental conditions (actual or simulated nature). $SD_{Baseline}$ is the standard deviation of the prescore, and SD_{Final} is the standard deviation of the postscore. *Corr* is the correlation between the pre- and postscores.

We pooled the data and estimated an overall effect size using a random-effects model fitted with maximum-likelihood estimation to capture both the sampling error and the between-study variability. As a sensitivity analysis, we also employed the inverse variance heterogeneity model (IVhet), which is believed to yield more conservative effect estimates (Doi et al., 2017). The mean effect was expressed as a standardized Hedge's *g*, which is a less biased measure than Cohen's *d* for the small number of samples that we expected in this emerging research topic (Rosenthal, 2009; Card, 2015). Values below 0.2 represent a small effect size, below 0.5 represent a medium effect size, and values above 0.8 represent a large effect size (Hedges and Olkin, 2014). As a sensitivity analysis, we used the leave-one-out method to check the robustness of the pooled effect estimate after excluding the estimate from any given study (Dzhambov and Lercher, 2019).

Heterogeneity between study effect sizes was tested using Cochran's *Q* statistic and evaluated using the I^2 statistic (Higgins and Green, 2011b). A significant *Q* statistic indicates that there is substantial heterogeneity between studies, and the I^2 statistic helps interpret the proportion of overall variability that can be attributed to between-study heterogeneity. Values for I^2 below 30 indicate that little total variability is attributable to between-study heterogeneity; values between 30 and 60 represent moderate levels of heterogeneity; and from 60 to 100, substantial levels (Higgins and Green, 2011a).

Detecting Publication Bias

We employed the Doi plot for detection of publication bias (Furuya-Kanamori et al., 2018). Doi plots are variants of the normal quintile vs. effect plot—the former plots a rank-based measure of precision (Z score) instead of the standard error against effect size. Plot asymmetry was quantified with the Luis Furuya-Kanamori (LFK) index (Furuya-Kanamori et al., 2018, 2020). A symmetrical, mountain-like Doi plot and an LFK index $<|1|$ indicate no asymmetry. An LFK index between $|1|$ and $|2|$ indicates minor asymmetry, and an LFK index $>|2|$ indicates major asymmetry (Furuya-Kanamori et al., 2018).

Evaluating Quality of Evidence

Our approach to evaluating methodological biases addressed the relevant domains in the Cochrane Collaboration's tool for assessing risk of bias in intervention studies (Higgins et al., 2011). These included random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, reporting bias, and other biases (see **Table S2** for details). Each article received one of three scores for each domain: (1) low risk, which describes bias(es) that would be unlikely to alter the results seriously; (2) unclear risk, which describes bias(es) that raise some doubt about the results; or (3) high risk, which describes bias(es) that may alter the results seriously.

After bias evaluation, the quality of evidence across studies was synthesized to determine the strength of evidence for mood differences between actual and simulated natural settings. We employed a method that was adapted to the framework developed by Radke et al. (2020), which in turn was informed by the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) approach (Balshem et al., 2011). Radke et al. (2020) examined six attributes of associations between environmental exposure data and health outcomes that could be used to support causation: consistency, exposure–response relationships, strength of association, temporal relationship, biological plausibility, and coherence. Here, we considered only experimental studies with pretest–posttest designs and, therefore, selected only those additional attributes relevant to the current meta-analysis: consistency (similarity of results across studies) and strength of association (effect magnitude and precision of reported results).

After considering these attributes, the strength of evidence for the difference between each mood outcome under consideration was assigned a score of *Robust*, *Moderate*, *Slight*, *Indeterminate*, or *Compelling evidence for no effect*. The highest two categories describe evidence that strongly supports a difference in mood change between exposures. These two are differentiated by the quantity and quality of information available to rule out alternative explanations for the results. The middle two categories describe evidence for which uncertainties prevent drawing a conclusion in either direction. These categories are limited by low numbers of studies or substantial heterogeneity across studies. The final category describe a situation where several high confidence studies show null results.

Software

Data analyses were conducted in R version 3.6.1 (Vienna, Austria). Effect size calculations, meta-analysis, and publication bias tests were conducted using the "metaphor" package version 2.1-0 (Viechtbauer, 2010). The IVhet meta-analysis and publication bias tests were conducted in MetaXL v. 5.3 (EpiGear International Pty Ltd, Sunrise Beach, Queensland, Australia).

RESULTS

Study Selection

Twelve articles identified in the systematic review by Browning et al. (2020a) were relevant. Three more were identified through

listserv postings, contact with colleagues, dissertation searches, and narrative reviews. One more was identified while the current study was in peer review. Of these 16 relevant studies, one was excluded because they varied the duration of treatments between actual and simulated conditions (Ryan et al., 2010). Seven were excluded because they did not use standardized measures of mood and/or were not designed to assess change in affect across a defined exposure (Hartig et al., 1997; Kahn et al., 2008; Huang, 2009; Mayer et al., 2009; Kjellgren and Buhrkall, 2010; Lassonde et al., 2012; Yin et al., 2018). Two more were excluded because they would have introduced substantial heterogeneity in models; one study used a unique mood measurement that contrasted with the bulk of the other included articles (Gatersleben and Andrews, 2013), and the other (Plante et al., 2006) measured an entirely different dimension of mood: activation rather than valence (Kensinger and Corkin, 2004).

Our final sample consisted of six studies (Brooks et al., 2017; Calogiuri et al., 2018; Olafsdottir et al., 2018; Chirico and Gaggioli, 2019; Browning et al., 2020b; Nukarinen et al., 2020). All included studies used the same cross-cutting measure of mood—the Positive and Negative Affect Schedule (PANAS)—to measure changes in negative and positive affect levels. See **Figure 2** for an overview of the process by which articles were identified and considered for inclusion.

Study Characteristics

Table 1 shows the sample, study design, and simulation characteristics of the articles included in the meta-analysis. Samples consisted primarily of young adults with a pooled age of 24, weighted by sample size (standard deviation, 2.3). All studies were conducted in Global North countries and used relatively small sample sizes (24–82). Computer monitors were used in two studies, and head-mounted displays (HMDs) were used in four studies. HMDs can be used to project 360-videos of actual natural settings captured with fish-eye lenses cameras or computer-generated virtual environments (for a review of both techniques, see Browning et al., 2020c; Joseph et al., 2020). No study attempted to induce acute stress or attentional fatigue before the environmental exposure so that effects could more readily be understood as restorative. One of the HMD studies reported that 19 of 26 participants experienced cybersickness (Calogiuri et al., 2018). Cybersickness involves symptoms similar to those of motion sickness that can be caused either by vestibular stimulation (physical movement) or visual stimulation (observed movement) in HMDs (LaViola, 2000). Symptoms may include eye strain, headache, pallor, sweating, dryness of the mouth, fullness of the stomach, disorientation, vertigo, ataxia (lack of coordination), nausea, vomiting, dizziness, salivation, and burping (LaViola, 2000; Davis et al., 2014). No adverse effects were reported in other simulations.

Synthesized Findings

We found a large difference between the positive affect change scores for the different settings ($g = 0.87$, $z = 5.16$, $p < 0.001$, 95% CI = 0.54, 1.20, see **Figure 3**). More specifically, the actual setting promoted beneficial changes in positive affect much more than the simulated setting. Little difference between setting types was observed for the negative affect change scores ($g = -0.28$, $z = -1.62$, $p = 0.10$, 95% CI = −0.62, 0.06, see **Figure 4**). The differences in change scores for the simulated and actual settings are provided for each experiment in **Table S3**. One can see there that, for positive affect, a difference in change scores typically shows increases from actual settings and decreases from simulated settings; that is, it appears that the simulated settings tended to reduce feeling attentive, active, alert, excited, enthusiastic, determined, inspired, proud, interested, and/or strong, while actual settings had the opposite effect. In contrast, both settings tended to show decreases in negative affect including feeling afraid, ashamed, distressed, guilty, hostile, irritable, jittery, nervous, scared, and/or upset. Removal of any single study did not change the conclusions; differences in effects between actual and natural settings for positive affect remained statistically significant and effect sizes remained large, and differences in effects for negative affect remained marginal/non-significant (see **Table S4**). Change scores showed moderate heterogeneity for negative affect [$Q(5) = 12.2$, $p = 0.033$, $I^2 = 50.7\%$, $T2 = 0.09$] and positive affect [$Q(5) = 11.0$, $p = 0.052$, $I^2 = 44.7\%$, $T2 = 0.07$].

Publication Bias

Doi plots showed symmetric spread of effect sizes against Z scores, suggesting no substantive publication bias (see **Figure S1**). This conclusion was supported by the LFK index of 0.55 for positive affect and −1.23 for negative affect.

Quality of Evidence

Nearly all studies suffered from potential biases; none reported blinding participants/personnel to conditions and blinding participants to outcome assessments. However, when viewed more holistically, two studies showed low risk of bias across the majority of bias domains (see **Figure S2**). The remaining four studies showed unclear/high risk of bias in the majority of bias domains.

The evidence for more beneficial change in positive affect for actual vs. simulated natural settings was *Moderate*. Positive affect results showed high consistency and strength of associations; however, there were too few studies and too much heterogeneity to classify the evidence as *Robust*. In contrast, the evidence for differences in negative affect was deemed to be *Slight* due to low consistency and strength of associations.

DISCUSSION

Summary and Interpretation of Main Findings

Simulations of natural settings are increasingly used for health promotion in scenarios where physical exposure is not possible (White et al., 2018). Several years ago, McMahan and Estes (2015) found indirect evidence that the effects of simulated natural settings on mood were smaller than the effects of actual natural settings on mood. The current meta-analysis extends their work by limiting our assessment to studies that directly compared the same (or very similar) settings. We identified 16 studies that have examined this topic but only 6 that have used a cross-cutting,

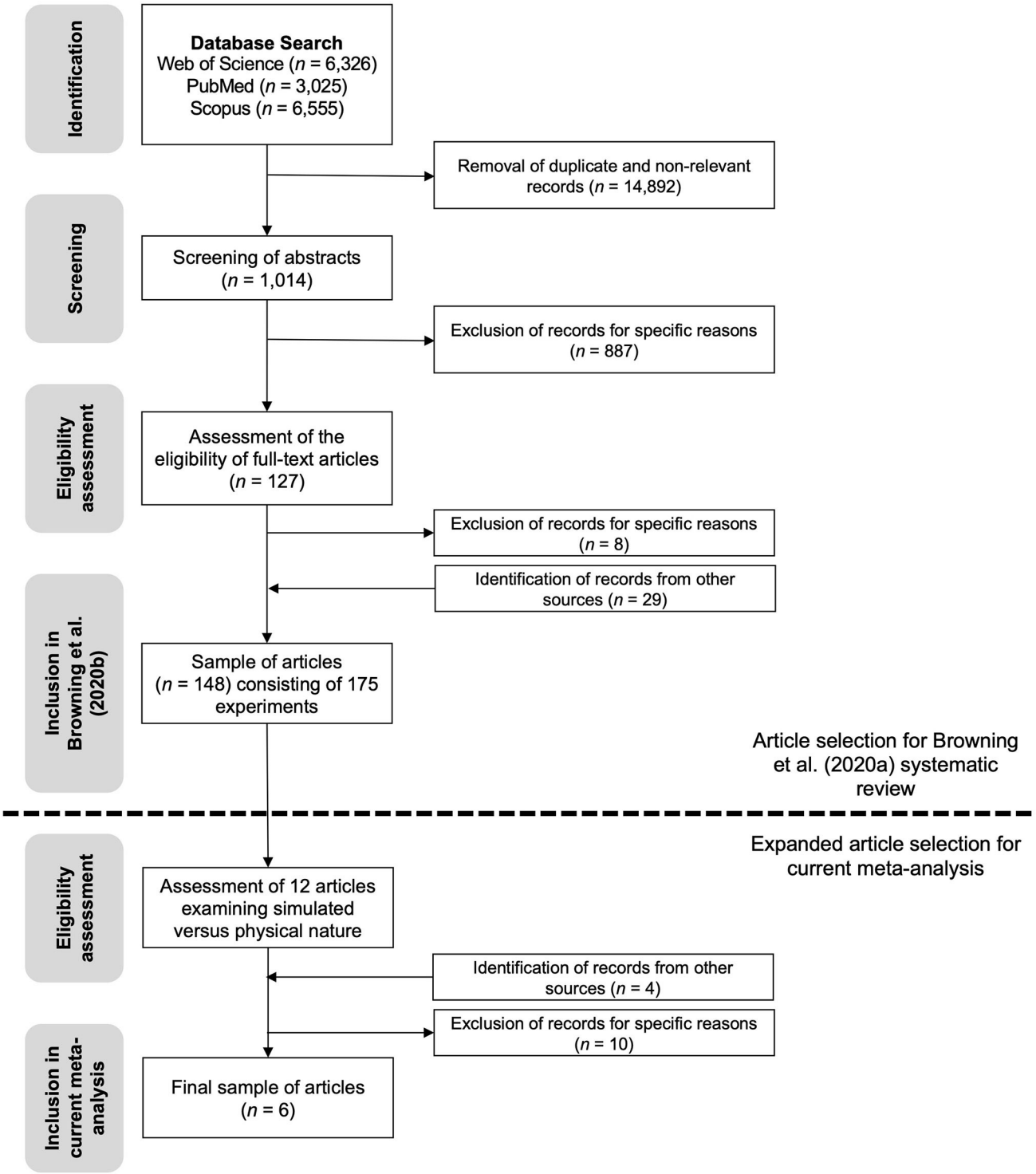


FIGURE 2 | A flowchart of the process by which experiments were selected for inclusion in the systematic review by Browning et al. (2020a) as well as the current meta-analysis.

standardized measure of mood before and after exposure. Pooled change scores showed a large difference between the effects of actual vs. simulated settings on positive affect. There was little difference between settings for negative affect. Although more research is needed in this emerging line of research, the available data indicate that going outdoors into natural settings is likely

TABLE 1 | Characteristics of studies that met the inclusion criteria of the review.

References	*N*	Age (M)	Female (%)	Country	Simulation experience	Simulation duration (min)	Natural setting
Brooks et al. (2017), study 3	47	22	81	Canada	Sitting and watching pictures on computer screen	10	Relatively open landscapes during winter conditions covered with snow and blue skies with evergreen trees in the foreground and low mountains in the background (see p. 97 and Figure 2 in that article)
Calogiuri et al. (2018)[a]	26	26	46	Norway	Walking on treadmill and watching moving 360° video in an HMD	10	Paved trail along lake with brown grass and trees without leaves and partly cloudy blue skies (see pp. 4–5 and Figure 2 in that article)
Olafsdottir et al. (2018)[a]	67	24	69	Iceland	Walking on treadmill and watching moving video shown on television screen	40	Trail through forest dominated by evergreen trees with intermittent views of open natural landscapes including green spaces, moss-covered lava fields, and mountains (see pp. 7–8 and Figure 2 in that article)
Chirico and Gaggioli (2019)	50	24	50	Italy	Sitting and watching stationary 360° video in an HMD	5	Panoramic overlook of scenic lake with mountains (see p. 2 in that article)
Nukarinen et al. (2020)[a]	24	26	54	Finland	Sitting and watching stationary 360° video in an HMD	10	Forest on edge of lake (see p. 3 in that article)
Browning et al. (2020b)	82	20	48	United States	Sitting and watching stationary 360° video in an HMD	6	Moderately dense forest with deciduous trees with small bluff overlooking stream (see p. 13 in that article)

[a] *Three experimental conditions were tested in these studies. We included the effect estimates from the simulated condition that most closely resembled the actual nature condition. HMD, head-mounted display.*

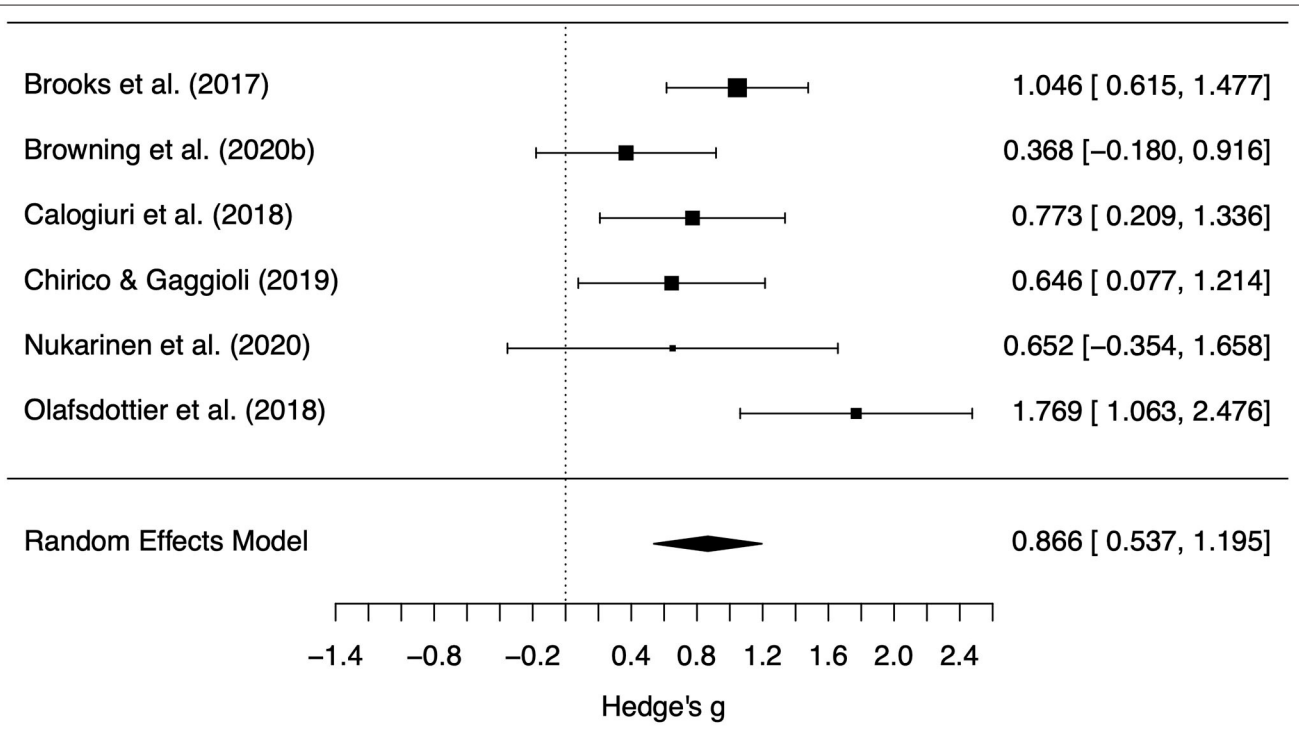


FIGURE 3 | Forest plot of standardized mean difference positive affect change scores between the actual and simulated natural settings. Points indicate the estimated effect for each study with variance estimates indicated by the size of the point and width of the error bars. Scores above 0 indicate greater increase in positive affect in the actual natural setting.

better at supporting mood than remaining indoors in simulated natural settings.

Our central finding—that actual natural settings benefit mood more than simulated natural settings—reflect on the different

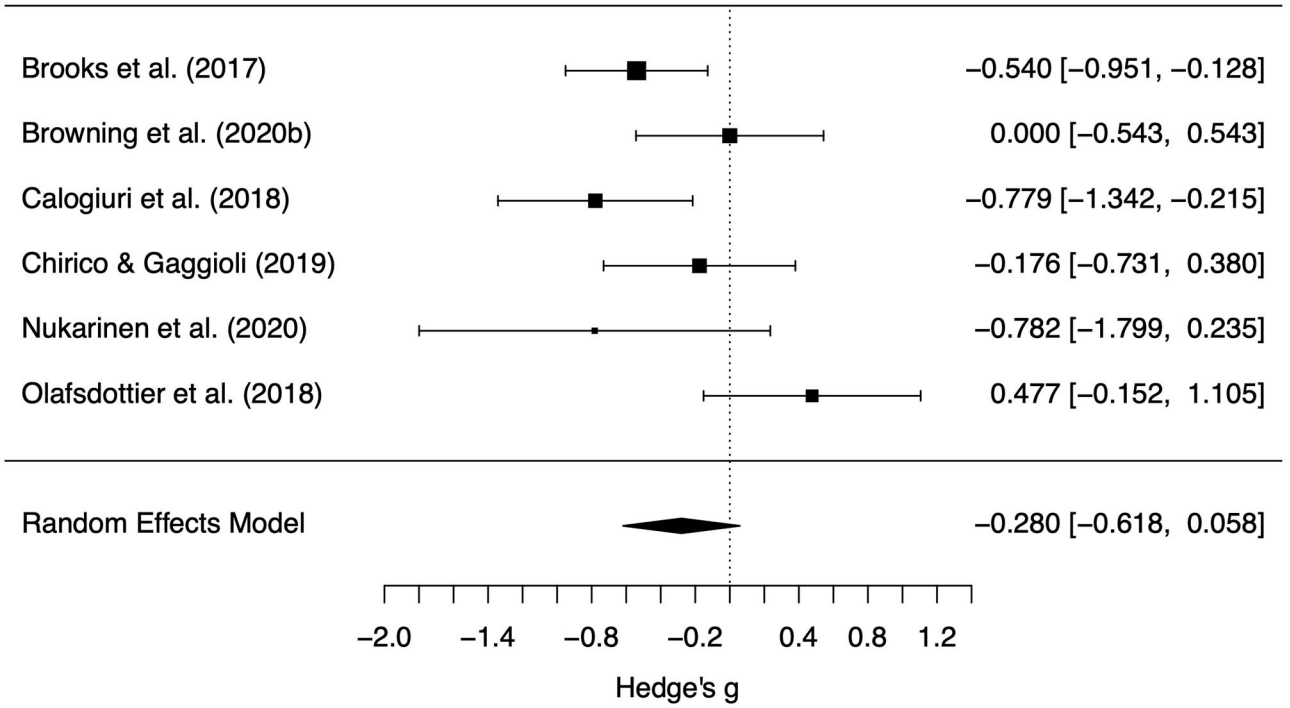


FIGURE 4 | Forest plot of standardized mean difference negative affect change scores between the actual and simulated natural settings. Points indicate the estimated effect for each study with variance estimates indicated by the size of the point and width of the error bars. Scores below 0 indicate greater reduction in negative affect in the actual natural setting.

potential of the two settings to activate pathways that with repeated exposures can cumulatively benefit health. A person who goes outdoors into an actual natural setting can potentially activate pathways to health in three domains: reducing exposure to harmful anthropogenic features of the environment (mitigation), building capacities (instoration), and renewing depleted capacities (restoration) (see **Figure 1**) (Markevych et al., 2017). Enhanced mood may be an active component of a pathway or a concomitant of its operation. The mitigation domain encompasses pathways by which vegetation and other features of a natural setting offer protection from air pollution, noise, heat, visual blight, privacy intrusions, and other harmful features of urban environments in which they might otherwise spend time, during leisure or otherwise (Gopalakrishnan et al., 2019). The instoration domain includes pathways in which natural settings serve as a context for health-promoting behaviors, such as physical activity, social interaction, and exposure to microbial diversity (Dobetsberger and Buchbauer, 2011; Rook et al., 2014; Łaszewska et al., 2018), which in turn modify neurochemical pathways in the gut and brain that appear to stabilize mood (Clarke et al., 2013). The restoration domain includes pathways by which nature experience can promote the renewal of depleted adaptive resources, as through stress recovery and directed attention restoration (Ulrich, 1983; Kaplan, 1995). In the context of nature experience in an actual outdoor setting, pathways in any one domain may become engaged to a greater degree, as when sensory richness and opportunities for exploration sustain engagement with the environment and so a restorative process. In addition, pathways in all three domains may work in mutually reinforcing ways that cannot get realized with simulations (e.g., as when neighbors enjoy their social contact and fresh air when walking together in a nearby park to wind down after a difficult day at work) (Hartig et al., 2014). For these reasons, the benefits of an actual natural setting can be expected to extend beyond the benefits available when only pathways associated with auditory and visual sensory inputs get activated to a lesser degree by simulation technologies (Horiuchi et al., 2014).

The studies we identified in our literature review but excluded from the meta-analysis showed similar findings as our pooled effects—at least for affective valence—which reinforces confidence in our conclusions. Three studies that compared actual nature with its virtual counterpart but were excluded for various reasons (see Methods) also showed stronger mood effects for actual nature than for simulated nature (Hartig et al., 1997; Mayer et al., 2009; Ryan et al., 2010). Findings from other studies that examined differences in affective arousal (i.e., energy and vigor) between actual and simulated natural settings were mixed. One found stronger beneficial effects for actual nature than for simulated nature (Kjellgren and Buhrkall, 2010), but two others showed similar effects between these two types of exposures (Plante et al., 2006; Yin et al., 2018). Collectively, these excluded studies point to our findings with PANAS extending to other measures of mood.

These findings provide evidence for public health messaging that encourages people to go outdoors into natural settings rather than stay indoors, even if simulations of natural settings are

utilized. There are other important outcomes of encouraging people to visit actual natural settings of course. Living vegetation and other features provide myriad ecosystem services beyond the cultural domain that encompasses human health and well-being, such as provisioning of food and clean water (Bratman et al., 2019; Keeler et al., 2019), which can be better realized by local residents if a connection with these settings is built over repeated visitation (Richardson et al., 2016; Colléony et al., 2019; Rosa and Collado, 2019). Finally, ethical sensibilities could encourage the protection of the possibility for other forms of life to develop and thrive, entirely aside from their utility to humans (Leopold, 1949; Hartig, 1993).

However, access to actual natural settings is often not available for shorter and longer periods to many who could benefit from it. Should simulations then be offered as an alternative going outdoors into natural settings? The results we report here encourage caution in this regard; they show that positive affect declined while viewing most of the simulations. This stands in contrast to much other research and encourages questions about differences between the simulations and other methods of the experiments studied here and those used in experiments that found beneficial outcomes. These matters need focused research attention, as the potential for therapeutic applications is great (White et al., 2018). Nevertheless, in contexts such as hospitals and prisons and with social distancing as during the COVID-19 pandemic, simulations may offer the only options for experiencing nature. Indeed, simulations may be safer therapeutic modalities than going outdoors and risking allergies, infectious disease, and accidental injury (Jennings et al., 2019). Simulations also provide the clinician with greater control than they would have with other nature-based therapies, such as forest bathing and park prescriptions, which are challenged by low levels of patience adherence and high levels of heterogeneity regarding the "treatment" patients receive (Kamioka et al., 2012; Crnic and Kondo, 2019). Lastly, simulations are practical; they can be safely and quickly moved from one person or group to another or shared at little/no cost through online streaming. Specific contexts where simulated natural settings may be particularly valuable were recently reviewed by Litleskare et al. (2020) and include palliative treatment in clinical settings, stress management in the workplace, mental health and cognitive development in school settings, and nature experiences for space missions. Personnel in other confined situations such as those found in submarines, Arctic and Antarctic polar bases, and medical imaging equipment like MRIs or CAT scans might also benefit from simulations (Anderson et al., 2017).

Strengths, Limitations, and Future Research Recommendations

The modest number of included studies meant limited representation of natural settings. It also limited our statistical power. Our marginal result for negative affect could have resulted from the high levels of between-study variation. To overcome the low power of classic publication bias tests, we employed a novel method heralded in recent years as a more powerful alternative (Furuya-Kanamori et al., 2018). However, with just six studies, power for these tests was still on the low end; thus, there could still have been publication bias in the studies identified above. Additional studies that directly compare mood effects between actual and simulated nature would provide more robust meta-analytic findings as a result of lower levels of heterogeneity.

The sample size was in part a result of our least common denominator research design approach. We included studies with only pre- and post-condition measures of PANAS. Like all studies, meta-analyses require a degree of researcher decision-making that can influence the results. We chose our inclusion/exclusion criteria because, based on our critical review, it allowed the greatest number of effects from experimental studies to pool together. It is worthwhile to investigate whether the employment of meta-analytic approaches could result in pooled effects that diverge from what a larger (less restricted) body of literature generally shows. Therefore, there is value in examination by other researchers of the effects of actual vs. simulated nature not only on other dimensions of mood but also on human health/well-being more generally.

The circumstances under which simulations can reliably engender desired beneficial outcomes warrant further research. Needed studies would address not only the features of the simulations (e.g., sampling of environmental features, quality of representation of the actual environment, and degree of immersion) and the features of the context in which they get presented (e.g., activity and duration) but also the circumstances and needs of those who would view them vs. entering an actual setting. For example, none of the experiments we reviewed had a stress or mental fatigue induction prior to the environmental treatment. This lack of a need to renew depleted resources may have led those participants to dislike their simulation experience rather than enjoy it as a restorative respite. Similarly, some populations, such as prisoners, may find that simulations only remind them of constraints they cannot escape; they may resent the simulations rather than appreciate them (Moran, 2019).

Further research on the relative benefits of simulated and actual nature should also employ stronger study designs. When possible, blinding to comparisons may help. Actual exposure as studied here generally requires that people travel to a natural setting. These pretreatment exposures could have initiated activation of pathways that primed participants to respond to natural settings differently. Such effects would have been difficult to replicate for the simulation conditions without also providing the participant with exposure to actual settings, thereby combining portions of exposure types. One method that was developed by Chirico and Gaggioli (2019) and that helps overcome this potential bias is to bring all participants to an outdoor location and then ask them to take part in their assigned condition: donning a head-mounted display or focusing on the actual setting before them, for example. Of course, participants ultimately understood that they were watching a simulation—not observing the actual landscape outdoors—when the headset was turned on. Reducing bias, therefore, may be only partially solved in studies that compare simulated and actual natural settings through between-subjects experimental design in which participants are blinded to the conditions other participants are assigned.

Our study also had several strengths; most notably, our meta-analytic approach allowed us to calculate the effect size describing mood changes in ways that other approaches (i.e., narrative and systematic reviews) would not have been able to do. In addition, the chosen outcomes—negative and positive affect—are sensitive to the operation of multiple pathways by which nature exposures and experiences can influence health, and they showed more consistent effects following short-term exposure to physical natural settings than other intermediate psychological or physiological outcomes that cumulatively over time affect health in lasting ways (McMahan and Estes, 2015; Kondo et al., 2018). Moreover, positive change in mood is a prevalent outcome of diverse leisure activities, valuable in its own right and for the persistent influence it exerts on postleisure behavioral processes of relevance to adaptive functioning and health (Hull, 2018). Presumably, then, just as mood levels change more strongly in actual nature, diverse other outcomes are likely better realized by going outdoors.

CONCLUSION

In closing, we recognize the promise of simulation technology and currently participate in its further development, for example as a means to represent alternative future environments that would result from different planning choices (Lindal and Hartig, 2013, 2015; Joseph et al., 2020). However, we think that decision-makers and the publics they serve should appreciate the limits of simulations identified here and avoid assuming they can simply substitute for the real thing.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

AUTHOR CONTRIBUTIONS

MB: conceptualization, methodology, investigation, resources, data curation, writing, visualization, supervision, and project administration. NS: methodology, software, validation, formal analysis, investigation, data curation, writing, and visualization. TH: critical review and writing. DB: software, data curation, and writing. C-PY: critical review and writing, OM: data curation and writing. AD: methodology, software, validation, formal analysis, investigation, and writing. All authors contributed to the article and approved the submitted version.

FUNDING

AD's work on this publication was partially supported by the National program Young Scientists and Postdoctoral Candidates of the Ministry of Education and Science, Bulgaria.

ACKNOWLEDGMENTS

The authors would like to thank Fatemeh Saeidi-Rizi, Hyunseo Yoon, and Yue Pei for assisting with screening titles, abstract, and full texts; applying inclusion and exclusion criteria; and extracting and checking data for the larger systematic review that led to the identification of the studies reported here. The authors would also like to thank Editage.com for their editorial services on an early version of this manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.02200/full#supplementary-material

REFERENCES

Anderson, A. P., Mayer, M. D., Fellows, A. M., Cowan, D. R., Hegel, M. T., and Buckey, J. C. (2017). Relaxation with immersive natural scenes presented using virtual reality. *Aerospace Medicine Human Perform.* 88, 520–526. doi: 10.3357/AMHP.4747.2017

Balshem, H., Helfand, M., Schünemann, H. J., Oxman, A. D., Kunz, R., Brozek, J., et al. (2011). GRADE guidelines: 3. Rating the quality of evidence. *J. Clin. Epidemiol.* 64, 401–406. doi: 10.1016/j.jclinepi.2010.07.015

Belur, J., Tompson, L., Thornton, A., and Simon, M. (2018). Interrater reliability in systematic review methodology: exploring variation in coder decision-making. *Sociol. Methods Res.* 13:9372. doi: 10.1177/0049124118799372

Beyer, K., Szabo, A., Hoormann, K., and Stolley, M. (2018). Time spent outdoors, activity levels, and chronic disease among American adults. *J. Behav. Med.* 41, 494–503. doi: 10.1007/s10865-018-9911-1

Birenboim, A., Dijst, M., Ettema, D., de Kruijf, J., de Leeuw, G., and Dogterom, N. (2019). The utilization of immersive virtual environments for the investigation of environmental preferences. *Landsc. Urban Plan* 189, 129–138. doi: 10.1016/j.landurbplan.2019.04.011

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., et al. (2019). Nature and mental health: an ecosystem service perspective. *Sci. Adv.* 5:eaax0903. doi: 10.1126/sciadv.aax0903

Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., and Sevigny, P. (2017). Nature-related mood effects: Season and type of nature contact. *J. Environ. Psych.* 54, 91–102. doi: 10.1016/j.jenvp.2017.10.004

Browning, M., Mimnaugh, K. J., van Riper, C. J., Laurent, H. K., and LaValle, S. M. (2020b). Can simulated nature support mental health? Comparing short, single-doses of 360-degree nature videos in virtual reality with the outdoors. *Front. Psychol.* doi: 10.3389/fpsyg.2020.02200

Browning, M., Saeidi-Rizi, F., McAnirlin, O., Yoon, H., and Pei, Y. (2020a). The role of methodological choices in the effects of experimental exposure to simulated natural landscapes on human health and cognitive performance: a systematic review. *Environ. Behav.* 7, 1–43. doi: 10.1177/0013916520906481

Browning, M., Suppakittpaisarn, P., Jiang, S., and Joseph, A. (2020c). Human health assessments of green infrastructure designs using virtual reality. *Landsc. Archit.* 27. doi: 10.14085/j.fjyl.2020.09.0000.15

Burrows, B., Browning, M., Solai, K., Fast, D., Litbarg, N. O., Moskowitz, J. T., et al. (2020). "Fully immersive virtual reality-based mindfulness intervention in hemodialysis patients: a pilot study assessing safety and utility," in *Proceedings from the 2020 American Society of Nephrology Kidney; 2020, Fully Online Meeting*.

Calogiuri, G., Litleskare, S., Fagerheim, K. A., Rydgren, T. L., Brambilla, E., and Thurston, M. (2018). Experiencing nature through immersive virtual environments: environmental perceptions, physical engagement, and

affective responses during a simulated nature walk. *Front. Psychol.* 8:8661. doi: 10.3389/fpsyg.2017.02321

Card, N. A. (2015). *Applied Meta-Analysis for Social Science Research*. New York, NY: Guilford Publications.

Chirico, A., and Gaggioli, A. (2019). When virtual feels real: comparing emotional responses and presence in virtual and natural environments. *Cyberpsychol. Behav. Soc. Netw.* 22, 220–226. doi: 10.1089/cyber.2018.0393

Clarke, G., Grenham, S., Scully, P., Fitzgerald, P., Moloney, R. D., Shanahan, F., et al. (2013). The microbiome-gut-brain axis during early life regulates the hippocampal serotonergic system in a sex-dependent manner. *Mol. Psychiatry* 18, 666–673. doi: 10.1038/mp.2012.77

Colléony, A., White, R., and Shwartz, A. (2019). The influence of spending time outside on experience of nature and environmental attitudes. *Landsc. Urban Plan* 187, 96–104. doi: 10.1016/j.landurbplan.2019.03.010

Coste, J., Guillemin, F., Pouchot, J., and Fermanian, J. (1997). Methodological approaches to shortening composite measurement scales. *J. Clin. Psychol.* 50, 247–252. doi: 10.1016/S0895-4356(96)00363-0

Crnic, M., and Kondo, M. C. (2019). Nature rx: Reemergence of pediatric nature-based therapeutic programs from the late 19th and early 20th centuries. *Am. J. Public Health* 109, 1371–1378. doi: 10.2105/AJPH.2019.305204

Davis, S., Nesbitt, K., and Nalivaiko, E. (2014). "A systematic review of cybersickness," in *Proceedings from the 2014 Conference on Interactive Entertainment; 2014 Dec*, New York, New York, USA. 1–9.

Dickersin, K., Scherer, R., and Lefebvre, C. (1994). Identifying relevant studies for systematic reviews. *BMJ* 309:1286. doi: 10.1136/bmj.309.6964.1286

Dobetsberger, C., and Buchbauer, G. (2011). Actions of essential oils on the central nervous system: an updated review. *Flavour Fragr. J.* 26, 300–316. doi: 10.1002/ffj.2045

Doi, S. A. R., Furuya-Kanamori, L., Thalib, L., and Barendregt, J. J. (2017). Meta-analysis in evidence-based healthcare: A paradigm shift away from random effects is overdue. *Int. J. Evid. Based Healthc.* 15, 152–160. doi: 10.1097/XEB.0000000000000125

Dzhambov, A. M., and Lercher, P. (2019). Road traffic noise exposure and birth outcomes: an updated systematic review and meta-analysis. *IJERPH* 16, 2522–20. doi: 10.3390/ijerph16142522

Frankenhaeuser, M., and Johansson, G. (1986). Stress at work: psychobiological and psychosocial aspects. *Appl. Psychol.* 35, 287–299. doi: 10.1111/j.1464-0597.1986.tb00928.x

Furuya-Kanamori, L., Barendregt, J. J., and Doi, S. A. R. (2018). A new improved graphical and quantitative method for detecting bias in meta-analysis. *Int. J. Evid. Based Healthc* 16, 195–203. doi: 10.1097/XEB.0000000000000141

Furuya-Kanamori, L., Xu, C., Lin, L., Doan, T., Chu, H., Thalib, L., et al. (2020). P value-driven methods were underpowered to detect publication bias: analysis of Cochrane review meta-analyses. *J. Clin. Epidemiol.* 118, 86–92. doi: 10.1016/j.jclinepi.2019.11.011

Gatersleben, B., and Andrews, M. (2013). When walking in nature is not restorative-The role of prospect and refuge. *Health Place* 20, 91–101. doi: 10.1016/j.healthplace.2013.01.001

Gopalakrishnan, V., Ziv, G., and Bakshi, B. R. (2019). Role of vegetation in mitigating air emissions across industrial sites in the US. *ACS Sustainable Chem. Eng.* 7, 3783–3791. doi: 10.1021/acssuschemeng.8b04360

Hartig, T. (1993). Nature experience in transactional perspective. *Landsc. Urban Plan* 25, 17–36. doi: 10.1016/0169-2046(93)90120-3

Hartig, T., Astell-Burt, T., Bergsten, Z., Amcoff, J., Mitchell, R. J., and Feng, X. (2020). Associations between greenspace and mortality vary across contexts of community change: a longitudinal ecological study. *J. Epi. Comm. Health* 74, 1–7. doi: 10.1136/jech-2019-213443

Hartig, T., Korpela, K. M., Evans, G. W., and Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing Planning Res.* 14, 175–194. doi: 10.1080/02815739708730435

Hartig, T., Mitchell, R. J., de Vries, S., and Frumkin, H. (2014). Nature and health. *Ann. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Haydock, D., and Moran, A. (2019). *Modern Indoor Living can be Bad for Your Health: New YouGov Survey Sheds Light on Risk of the "Indoor Generation." www.velux.com*, 1–2. Available online at: https://www.veluxusa.com/media/press-kits/indoor-generation (accessed September 10 2019).

Hedges, L. V., and Olkin, I. (2014). *Statistical Methods for Meta-Analysis*. Orlando, FL: Academic Press.

Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., et al. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 343:d5928. doi: 10.1136/bmj.d5928

Higgins, J. P. T., and Green, S. (2011a). "Identifying and measuring heterogeneity," in *Cochrane Handbook for Systematic Reviews of Interventions*, eds J. P. T. Higgins and S. Green (The Cochrane Collaboration).

Higgins, J. P. T., and Green, S. (2011b). "Imputing standard deviations for changes from baseline," in *Cochrane Handbook for Systematic Reviews of Interventions*, eds J. P. T. Higgins and S. Green (The Cochrane Collaboration), 1–3.

Horiuchi, M., Endo, J., Takayama, N., Murase, K., Nishiyama, N., Saito, H., et al. (2014). Impact of viewing vs. not viewing a real forest on physiological and psychological responses in the same setting. *IJERPH* 11, 10883–10901. doi: 10.3390/ijerph111010883

Howard, M. C. (2017). A meta-analysis and systematic literature review of virtual reality rehabilitation programs. *Comput. Human Behav.* 70, 317–327. doi: 10.1016/j.chb.2017.01.013

Huang, S.-C. L. (2009). The validity of visual surrogates for representing waterscapes. *Landscape Res.* 34, 323–335. doi: 10.1080/01426390902867984

Hull, R. B. IV. (2018). Mood as a product of leisure: causes and consequences. *JLR* 22, 99–111. doi: 10.1080/00222216.1990.11969818

Jennings, V. L., Browning, M., and Rigolon, A. (2019). "Friend or foe? An overview of the services and disservices from urban green spaces," in *Urban Green Spaces Public Health and Sustainability in the United States*, edsV. L. Jennings, M. Browning, and A. Rigolon (Cham: Springer International Publishing), 7–30.

Joseph, A., Browning, M., and Jiang, S. (2020). Using immersive virtual environments (IVEs) to conduct environmental design research: A primer and decision framework. *HERD* 13, 11–25. doi: 10.1177/1937586720924787

Kahn, P. H. Jr., Friedman, B., Gill, B., Hagman, J., Severson, R. L., et al. (2008). A plasma display window?—The shifting baseline problem in a technologically mediated natural world. *J. Environ. Psych.* 28, 192–199. doi: 10.1016/j.jenvp.2007.10.008

Kamioka, H., Tsutani, K., Mutoh, Y., Honda, T., Shiozawa, N., Park, S., et al. (2012). A systematic review of randomized controlled trials on curative and health enhancement effects of forest therapy. *PRBM.* 5, 85–11. doi: 10.2147/PRBM.S32402

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *J. Environ. Psych.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Keeler, B. L., Hamel, P., McPhearson, T., Hamann, M. H., Donahue, M. L., Prado, K. A. M., et al. (2019). Social-ecological and technological factors moderate the value of urban nature. *Nature Sustainability* 2, 1–10. doi: 10.1038/s41893-018-0202-1

Kensinger, E. A., and Corkin, S. (2004). Two routes to emotional memory: distinct neural processes for valence and arousal. *Proc. Natl. Acad. Sci. U.S.A.* 101, 3310–3315. doi: 10.1073/pnas.0306408101

Kjellgren, A., and Buhrkall, H. (2010). A comparison of the restorative effect of a natural environment with that of a simulated natural environment. *J. Environ. Psych.* 30, 464–472. doi: 10.1016/j.jenvp.2010.01.011

Kondo, M. C., Fluehr, J., McKeon, T., and Branas, C. C. (2018). Urban green space and its impact on human health. *IJERPH* 15, 1–28. doi: 10.3390/ijerph15030445

Lahart, I., Darcy, P., Gidlow, C. J., and Calogiuri, G. (2019). The effects of green exercise on physical and mental wellbeing: a systematic review. *IJERPH* 16, 1352–26. doi: 10.3390/ijerph16081352

Lassonde, K. A., Gloth, C. A., and Borchert, K. (2012). Windowless classrooms or a virtual window world. *Teaching Psychol.* 39, 262–267. doi: 10.1177/0098628312456618

Łaszewska, K., Goroncy, A., Weber, P., Pracki, T., and Tafil-Klawe, M. (2018). Influence of the spectral quality of light on daytime alertness levels in humans. *Adv. Cogn. Psychol.* 14, 192–208. doi: 10.5709/acp-0250-0

LaValle, S. M. (2017). *Virtual Reality*. Cambridge, UK: Cambridge University Press.

LaViola, J. J. Jr. (2000). A discussion of cybersickness in virtual environments. *SIGCHI Bull.* 32, 47–56. doi: 10.1145/333329.333344

Leopold, A. (1949). *A Sand County Almanac*. New York, NY: Oxford University Press.

Lindal, P. J., and Hartig, T. (2013). Architectural variation, building height, and the restorative quality of urban residential streetscapes. *J. Environ. Psych.* 33, 26–36. doi: 10.1016/j.jenvp.2012.09.003

Lindal, P. J., and Hartig, T. (2015). Effects of urban street vegetation on judgments of restoration likelihood. *Urban Urban Gree* 14, 200–209. doi: 10.1016/j.ufug.2015.02.001

Litleskare, S., E., MacIntyre, T., and Calogiuri, G. (2020). Enable, reconnect and augment: a new era of virtual nature research and application. *IJERPH* 17, 1–19. doi: 10.3390/ijerph17051738

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., et al. (2017). Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environ. Res.* 158, 301–317. doi: 10.1016/j.envres.2017.06.028

Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., and Dolliver, K. (2009). Why is nature beneficial?: the role of connectedness to nature. *Environ. Behav.* 41, 607–643. doi: 10.1177/0013916508319745

McMahan, E. A., and Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: a meta-analysis. *J. Posit. Psychol.* 10, 507–519. doi: 10.1080/17439760.2014.994224

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Ann. Intern. Med.* 151, 264–9–W64. doi: 10.7326/0003-4819-151-4-200908180-00135

Moran, D. (2019). Back to nature? Attention restoration theory and the restorative effects of nature contact in prison. *Health Place* 57, 35–43. doi: 10.1016/j.healthplace.2019.03.005

Nukarinen, T., Istance, H. O., Rantala, J., Mäkel,ä, J., Korpela, K. M., Ronkainen, K., et al. (2020). *Physiological and Psychological Restoration in Matched Real and Virtual Natural Environments* eds R. Bernhaupt, F. Mueller, D. Verweij, J. Andres, J. McGrenere, A. Cockburn, et al. (Honolulu, HI), 1–8. doi: 10.1145/3334480.3382956

Olafsdottir, G., Cloke, P., Schulz, A., van Dyck, Z., Eysteinsson, T., Thorleifsdottir, B., et al. (2018). Health benefits of walking in nature: a randomized controlled study under conditions of real-life stress. *Environ. Behav.* 23, 1–27.

Plante, T. G., Cage, C., Clements, S., and Stover, A. (2006). Psychological benefits of exercise paired with virtual reality: Outdoor exercise energizes whereas indoor virtual exercise relaxes. *Int. J. Stress Manag.* 13, 108–117. doi: 10.1037/1072-5245.13.1.108

Radke, E. G., Braun, J. M., Nachman, R. M., and Cooper, G. S. (2020). Phthalate exposure and neurodevelopment-A systematic review and meta-analysis of human epidemiological evidence. *Environ. Int.* 137:105408. doi: 10.1016/j.envint.2019.105408

Richardson, M., Cormack, A., McRobert, L., and Underhill, R. (2016). 30 Days wild: Development and evaluation of a large-scale nature engagement campaign to improve well-being. *PLoS ONE* 11:e149777. doi: 10.1371/journal.pone.0149777

Riva, G., Bernardelli, L., Browning, M., Castelnuovo, G., Cavedoni, S., Chirico, A., et al. (2020). COVID feel good - an easy self-help virtual reality protocol to overcome the psychological burden of Coronavirus. *Front. Psychiatry* doi: 10.3389/fpsyt.2020.563319

Rook, G. A., Raison, C. L., and Lowry, C. A. (2014). Microbial "old friends," immunoregulation and socioeconomic status. *Clin. Exp. Immunol.* 177, 1–12. doi: 10.1111/cei.12269

Rosa, C. D., and Collado, S. (2019). Experiences in nature and environmental attitudes and behaviors: Setting the ground for future research. *Front. Psychol.* 10:763. doi: 10.3389/fpsyg.2019.00763

Rosenthal, R. (2009). "Parametric measures of effect size," in *The Handbook of Research Synthesis and Meta-Analysis*, eds H. Cooper and L. V. Hedges (New York, NY: Russell Sage Foundation), 231–244.

Rossetti, T., and Hurtubia, R. (2020). An assessment of the ecological validity of immersive videos in stated preference surveys. *J. Choice Modell.* 34, 1–12. doi: 10.1016/j.jocm.2019.100198

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., and Gagne, M. (2010). Vitalizing effects of being outdoors and in nature. *J. Environ. Psych.* 30, 159–168. doi: 10.1016/j.jenvp.2009.10.009

Twohig-Bennett, C., and Jones, A. (2018). The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ. Res.* 166, 628–637. doi: 10.1016/j.envres.2018.06.030

Ulrich, R. S. (1983). "Aesthetic and affective response to natural environment," in *Behavior and the Natural Environment*, eds I. Altman and J. F. Wohlwill (Boston, MA: Springer), 85–125.

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metafor package. *J. Stat. Softw.* 36, 1–48. doi: 10.18637/jss.v036.i03

White, M. P., Yeo, N., Vassiljev, P., Lundstedt, R., Wallergård, M., Albin, M., et al. (2018). A prescription for "nature" - The potential of using virtual nature in therapeutics. *Neuropsychiatr. Dis. Treat.* 14, 3001–3013. doi: 10.2147/NDT.S179038

Yin, J., Zhu, S., MacNaughton, P., Allen, J. G., and Spengler, J. D. (2018). Physiological and cognitive performance of exposure to biophilic indoor environment. *Build. Environ.* 132, 255–262. doi: 10.1016/j.buildenv.2018.01.006

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 29 October 2020
doi: 10.3389/fpsyg.2020.540872

The Potential Correlation Between Nature Engagement in Middle Childhood Years and College Undergraduates' Nature Engagement, Proenvironmental Attitudes, and Stress

Naomi A. Sachs[1], Donald A. Rakow[2], Mardelle McCuskey Shepley[3] and Kati Peditto[4]*

[1] Department of Plant Science and Landscape Architecture, University of Maryland, College Park, MD, United States, [2] Section of Horticulture, School of Integrative Plant Science, Cornell University, Ithaca, NY, United States, [3] Department of Design and Environmental Analysis, Cornell University, Ithaca, NY, United States, [4] Department of Behavioral Sciences and Leadership, United States Air Force Academy, Colorado Springs, CO, United States

OPEN ACCESS

Edited by:
Giuseppina Spano, University of Bari Aldo Moro, Italy

Reviewed by:
Simon Bell, The University of Edinburgh, United Kingdom
José Gutiérrez-Pérez, University of Granada, Spain

***Correspondence:**
Naomi A. Sachs
nsachs@umd.edu

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *06 March 2020*
Accepted: *05 October 2020*
Published: *29 October 2020*

Citation:
Sachs NA, Rakow DA, Shepley MM and Peditto K (2020) The Potential Correlation Between Nature Engagement in Middle Childhood Years and College Undergraduates' Nature Engagement, Proenvironmental Attitudes, and Stress. Front. Psychol. 11:540872. doi: 10.3389/fpsyg.2020.540872

Introduction: Nature engagement (NE) provides myriad psychological and physiological benefits, many of which begin in childhood and continue into adulthood. Research suggests children who have positive experiences with nature are more likely to continue engaging with nature and have more proenvironmental attitudes (PEAs) as adults. Among the benefits of NE are reduced stress, improved sleep, and improved cognitive performance, all essential criteria for healthy undergraduate life. College students in particular, because of high levels of stress, may benefit from NE, and the frequency and type of their engagement may be impacted by childhood experience.

Objective: This study aimed to better understand the potential correlation between university undergraduates' past NE in their middle childhood years (MCYs) and current NE; past NE and undergraduate PEA; and undergraduate NE and stress levels. We chose to examine the middle childhood and undergraduate years because little research has been conducted on the relationship of NE between these two age groups.

Methods: We used a survey of undergraduate students (n = 309) enrolled at a US university to explore the frequency and types of NE during MCYs, their family and neighborhood demographics, and current levels of NE, PEA, and stress in their undergraduate lives.

Results: Although results indicated a large decrease in NE from middle childhood to undergraduate years for most participants, we found a significant positive correlation between NE during MCYs and undergraduate NE. We found a positive correlation between MCYs NE and undergraduate PEA as well as undergraduate NE and

undergraduate PEA. Contrary to other studies and to our hypothesis, we did not find a correlation between undergraduate NE and reduced stress levels.

Conclusion: This study looked specifically at US undergraduate students to compare their current engagement with and attitudes toward nature and the environment with their nature experiences during their formative MCYs. Our results suggest that it is important for people to have positive experiences with nature in childhood, both for continued NE and to inculcate PEAs in adulthood. These results can help in formulating approaches to improving student well-being at institutions of higher learning.

Keywords: middle childhood, college students, university students, nature engagement, mental health, stress, environmental stewardship, pro-environment attitudes

INTRODUCTION

Physiological and Psychological Benefits of Nature Engagement

Nature engagement (NE) can positively affect overall well-being by reducing stress and anxiety (Frumkin et al., 2017; Markevych et al., 2017; Bratman et al., 2019; Meredith et al., 2020), improving concentration and recall (Strife and Downey, 2009; Bratman et al., 2015), improving sleep patterns (Grigsby-Toussaint et al., 2015), and improving mood and outlook (Ulrich et al., 1991; Kaplan, 1995; Berman et al., 2008; Roe and Aspinall, 2011; Bratman et al., 2012; Brooks et al., 2017). For the purposes of this study, we define NE as *interaction with the natural world and all of its elements* (Zuo et al., 2016). As Zuo et al. (2016) describe, people engage with nature at different levels, from the more passive (looking at or sitting in a natural setting) to the more active (walking in a park or working in a garden). All types and levels of NE can be beneficial to health and well-being.

Various theories have been proposed for the physiological processes underlying these positive effects. Kuo (2015) argued that the mechanism by which NE affects physiological changes may be based on the stimulation of natural killer cells that are associated with boosting immune function. Bratman et al. (2015) identified the basis for changes in mental health to be associated with reduced neural activity in the subgenual prefrontal cortex, resulting in decreased levels of self-reported rumination and improved ability to concentrate.

While engagement with nature provides benefits regardless of age, many researchers are increasingly focusing on the relationship between children and nature. Studies have reported that simply spending time in nature can reduce children's stress levels and improve well-being. Researchers in Denmark found that higher levels of greenness in children's residential neighborhoods are negatively correlated with the likelihood of developing mental health problems later in life (Engemann et al., 2019). Similarly, Wells and Evans (2003) found that among a cohort of rural elementary-aged youth, the impact of life stresses was lower among children with high levels of nearby nature than among those with little nature nearby.

For children, NE can also affect behavioral indicators. In a recent systematic review of literature assessing the relationship between NE and mental health in children and teenagers, Tillmann et al. (2018) found that such engagement positively affected children's emotional well-being, decreased attention deficit disorder and attention-deficit/hyperactivity disorder symptoms, and improved overall mental health. A Dutch study of two meta-analyses of existing literature found a positive correlation between NE and self-regulation in children (Weeland et al., 2019).

Nature Engagement and Developmental Theories

Piaget (1962) described four stages of child development, from infancy through adolescence. Of these, the third stage, Concrete Operations (middle childhood, approximately ages 7–11 years), occurs when a child's thought processes become more mature and logic-based, which allows for greater exploration of the child's environment. Youth at this stage are integrating themselves into both human and natural systems and are making sense of their place in relation to these constructs. As they identify, name, and classify organisms and non-living natural objects, children in the Concrete Operations stage are also enhancing their ability to sort and retain information and ideas (Kellert, 2002). For this study, we chose to focus on this third/Concrete Operations phase because of the importance of this stage in a child's developing relationship with the outside world.

In contrast to Piaget, Erikson (1962) theorized that there are eight developmental stages between birth and age 18 years and categorized the middle childhood years (MCYs) as a stage of conflict between industry (competence) and inferiority (failure). Based on Erikson's theory, McLeod (2018) has posited that as children cope with new learning and social demands, they may recognize their developing relationship with the natural world as a core competency, defined as the healthy balance between adequacy and doubt.

Access to Nature, NE, and Proenvironmental Attitudes in Middle Childhood Years

For the purposes of this study, we have used the term "proenvironmental attitudes" (PEAs), which we define as *concern for the natural environment.* PEAs are viewed as

precursors to "proenvironmental behavior," "environmentalism," and "environmental stewardship" (Wells and Lekies, 2006; Chawla, 2007; Evans et al., 2018).

In their MCYs, young people also become more social, developing peer bonds while remaining dependent on family, and become more confident in their explorations. It appears that unstructured time in nature may be more valuable than structured time at this life stage (Starling, 2011). According to Kellert (2002), children in MCYs are more likely to feel comfortable venturing into unfamiliar natural settings, expanding their knowledge and capacity to cope in these areas without adult supervision. As Chawla (2007) suggests, when children enjoy freedom to explore in nature, they are likely to have the most positive and meaningful experiences.

A number of researchers have found that parental attitudes toward nature impact the time that young children spend in nature (McFarland et al., 2014). Beginning at 7 years of age, children transition to an outward view of the world associated with increased empathy and morality (Mah and Ford-Jones, 2012), which is dependent on parental modeling (Schoeppe et al., 2017). Considerable research in recent years has also focused on children's NE in their MCYs and how their adult models (parents, teachers, and so on) address attitudes toward the natural world. For example, Evans et al. (2018) found that children who grew up with mothers with more PEAs engaged in more proenvironmental behavior as young adults. Researchers in two other studies focused on environmentalists in Norway and Kentucky (Chawla, 2007) and adults in the United Kingdom, Greece, and Slovenia (Palmer et al., 1998) about the roots of their environmental activism. In both studies, participants' two most frequent answers were that their activism was the result of positive experiences of natural areas in childhood and adolescence, and family role models.

In contradiction to these findings, researchers studying middle school students and their parents and teachers in North Carolina found that small class sizes and higher socioeconomic status (SES) translated to NE and PEA later in life, but that parents and role models did not affect later attitudes or behavior (Stevenson et al., 2014). Researchers in another study point out that those growing up in underresourced communities often have less access to and experience with the natural world, resulting in less development of PEAs in adulthood (Powell et al., 2004).

One should not automatically associate proximity to neighborhood nature in childhood with frequency of NE. Soga et al. (2016) found that when undergraduates at a university in Tokyo were surveyed, those students who had grown up in areas with larger amounts of natural greenness did not necessarily report higher nature relatedness. This finding suggests that an individual's positive emotional affinity toward nature is not determined merely by the proximity of natural settings in their surroundings, but also by the frequency and quality of the NE.

Asah et al. (2018) studied the mechanisms through which children experience nature and the longer-term impacts of those experiences. They found that childhood NE on one's own or with friends is strongly associated with both environmental stewardship and commitment to NE in adulthood. However, while childhood NE through family outings predicted adult NE, it was not predictive of adult environmental stewardship.

Relationship Between Childhood, Adolescent, and Young Adult NE and PEAs

Researchers have revealed that both NE and PEAs tend to peak during the MCYs and start to decline in adolescence. In one study (Szagun and Mesenholl, 1993), 12-year-old participants showed higher concern for the environment (PEAs) than 15- and 18-year-olds, whereas in another study (Pol and Castrechini, 2013), 9- to 13-year-olds had the highest PEAs, beliefs, and behaviors of four different age groups.

As young people progress from MCYs through adolescence and into young adulthood, the experiences they had as children help to shape their attitudes and behaviors. Jensen and Olsen (2019) explored the relationship between NE in early childhood (prior to age 11 years) and proenvironmental decision-making as adults. They found that adult respondents who, as children, had participated in nature-related activities with their families at least once a week were more likely to support an expensive clean water initiative than were those who had less frequently engaged with nature. Similarly, Rosa et al. (2018) found that greater contact with nature during childhood was associated with greater NE as an adult, as well as being positively associated with proenvironmental behavior.

Potential Importance of NE for Undergraduate College Students

The topic of the role of nature as children progress into young adulthood as college students is important because of the reports of increased stress, anxiety, and depression in university populations. Undergraduate students in the United States face a plethora of challenges and stress inducers, including financial constraints, academic pressure, social pressures in the age of social media, and grappling with various forms of harassment (Twenge, 2014; Prabhakararao, 2016). Within the 12 months prior to a 2019 survey, US college students reported more than average or tremendous stress (59%), feeling overwhelming anxiety (66%), and hopelessness (56%). Thirteen percent had been diagnosed or treated for depression or anxiety (American College Health Association, 2019). A survey of 139 colleges reported a 30% rise in appointments with counselors between 2009–2010 and 2014–2015, although school enrollments had grown only 5%. Of those students, 61% reported anxiety, 49% depression, and 45% stress (Winerman, 2017). Undergraduate college students could benefit significantly from non-pharmacological mental health treatment modalities such as NE (Meredith et al., 2020).

Impact of MCY Level of Urbanism and Socioeconomic Status on NE and PEAs

Among the considerations in this study is the impact of children's MCY physical environment on their later NE and PEAs as undergraduates. Access to nature is typically more limited in

dense urban areas (Cox et al., 2017). Adults who spent childhood in heavily urbanized environments (high density of buildings) report lower PEAs in adulthood than those who grew up next to natural elements such as flowerbeds and parks (Lohr and Pearson-Mims, 2005). Additionally, access to nature is inequitably distributed across socioeconomic classes (Shanahan et al., 2014). Comparisons between neighborhoods of differing socioeconomic levels have found that children in low-income communities have reduced access to parks and even lower levels of access to parks with play amenities (Rigolon and Flohr, 2014; Oliphant et al., 2019).

Hypotheses and Research Questions

In this study, we used a survey of undergraduate students enrolled at a northeastern US university to explore the association between participants' NE in MCYs (ages 7–11 years) and their current level of NE. We also examined the role of participants' current NE, PEAs, and stress level. We primarily used closed-ended questions for quantitative analysis but included two open-ended questions that would provide a more qualitative view of the study. Based on our literature review, we had four *a priori* hypotheses:

- H1. NE in MCYs is positively correlated with NE in undergraduate years.
- H2. NE in MCYs is positively correlated with PEAs in undergraduate years.
- H3. Undergraduate NE is positively correlated with PEAs in undergraduate years.
- H4. NE in undergraduate years is negatively correlated with undergraduate self-perceived stress.

We were also interested in how participants' physical environment in MCYs was associated with their current degree of NE, which we explored with the following two research questions:

RQ1: perceived level of urbanization in MCYs will be negatively correlated with NE in those years, and RQ2: perceived socioeconomic status (SES) in MCYs will be positively correlated with NE in those years.

MATERIALS AND METHODS

Survey Development and Content

Our literature review informed the structure and questions of the Undergraduate Attitudes Toward Nature Survey (Appendix/**Supplementary Materials**). We first developed the survey in Microsoft Word and then entered it into Qualtrics v3.18, an online survey management platform, for online distribution. This research received approval for exemption from the university's institutional review board in fall 2017.

The survey consisted of 24 questions in three parts: demographics, MCYs, and undergraduate (**Table 1**). The first part asked participants two demographic questions (gender and race/ethnicity). In the second section, five questions addressed the participants' physical environment in their MCYs and included six questions about their level and type of NE. In the third section, nine questions focused on participants' current life as undergraduate students, including what activities they engage in (NE), their concern for the environment (PEAs), and their stress level.

For the first six MCY questions, we asked whether participants had spent at least two of their MCYs in the United States. We focused on the United States to reduce confounding variables. If students answered in the negative, they were routed to the end of the survey. For the SES question, because we were more concerned with *perceived* economic status, we did not define categories by income. In addition, children—including those in high school—typically do not know their precise family income or other economic status (Anderson and Holt, 2017). The final question under the first cluster asked participants, "When you think back to ages 7–11 years, what is the physical environment in which you first picture yourself?" Previous researchers have noted that common early childhood memories are associated with outdoor environments (e.g., Sebba, 1991), and we were interested in exploring this concept qualitatively.

For the six MCY NE questions, we first asked participants to select the nature experiences they had engaged in during ages 7–11 years. Some activities were more recreation-oriented, such as "taking walks in nature" and "going to the beach," whereas others were more "work"-oriented such as "working on a farm" or "helping with a home garden." We asked whether participants had attended a nature-based camp, how frequently they recalled spending time in nature, and how frequently they recalled adults in their lives talking about nature. Finally, we asked participants to choose their three (out of nine) favorite indoor and then their three (out of 11) favorite outdoor activities.

The third part of the survey focused on participants' life as undergraduate students: in addition to undergraduate level and major, we asked a multiple-choice question about ways students sought relief from stress during the semester. Four questions addressed participants' current level of NE. One question asked students whether they were familiar with the university program that prescribes time in nature.

The final two closed-ended questions asked participants to rank on a 1- to 10-point scale (1) their level of concern for the environment (PEAs) and (2) their overall stress level during the semester. Lastly, we asked participants in an open-ended question to provide any additional thoughts on their current relationship with nature.

Pilot Testing

We pilot tested the survey in fall 2017 with a class of approximately 50 undergraduate horticulture students. We distributed paper surveys during class and asked the students to answer the questions and write additional comments about clarity of wording and whether they felt anything was missing or redundant. We then facilitated a follow-up discussion and, as a result, made minor changes, for example, changing "Latino" to "Latinx" and replacing the term "middle childhood years" with the specific ages (7–11 years). The final online survey was sent to five people (students, faculty, and staff) to assess ease of response in Qualtrics format. These two steps enhanced the survey's usability and content validity.

TABLE 1 | Undergraduate nature engagement questionnaire.

Demographics—general
Q1. With what gender do you identify?
Male | Female | Additional gender category | I prefer not to say
Q2. With what group do you identify?
White | Hispanic, Latinx, or Spanish Origin | Black or African American | American Indian or Alaska Native | Asian | Native Hawaiian or Pacific Islander | Middle Eastern or North African | Biracial or multiracial | I prefer not to say
Middle childhood
Q3. During your middle childhood years (ages 7–11 years), did you reside in the continental US for at least 2 years?
Yes | No
Q4. If yes, in what US state did you reside for the longest period during those years?
Q6. Which of the following demographic descriptions best fits where you lived for the longest period during middle childhood?
Urban area | Small city or village | Suburban | Rural
Q7. During your middle childhood years, what was your perception of your family's economic status?
Upper class | Upper middle class | Middle class | Lower middle class | Working class
Q8. When you think back to your middle childhood years, what is the physical environment in which you first picture yourself?
Q9. Which of the following nature experiences did you engage in during your middle childhood years? (select all that apply)
Taking walks in nature | Visiting local parks | Going to the beach | Working on a farm | Helping with a home garden | Hunting and/or fishing | Working with/caring for animals | Other (please specify)
Q10. During your middle childhood years, did you attend a camp that included nature-based activities?
Yes | No
Q11. During your middle childhood years, how frequently do you recall spending time in nature?
Daily | 3–4 times a week | 1–2 times a week | Less than once a week | Almost never
Q12. During your middle childhood years, how frequently do you recall adults in your life (parents, guardians, relatives, teachers) talking about nature or the natural environment?
Daily | 3–4 times a week | 1–2 times a week | Less than once a week | Almost never
Q13. In your middle childhood years, what were your three favorite indoor non–school-related activities? (select three)
Organized sports | Reading | Playing video games | Hanging out with family or friends | Exercise | Artistic expression | Watching TV | Other (please specify)
Q14. In your middle childhood years, what were your three favorite outdoor non–school-related activities? (select three)
Organized sports | Reading | Being outside in nature | Hanging out with family or friends | Exercise | Artistic expression | Working with/caring for animals | Camping | Hunting and/or fishing | Other (please specify)
Undergraduate
Q15. What is your current class year at Cornell?
First year | Sophomore | Junior | Senior | Unspecified
Q16. What is your area of study at Cornell?
Q17. When you are feeling stressed at school, in what ways do you seek relief? (select all that apply)
Talking to friends or family | Using alcohol or drugs | Talking with a counselor | Being outside in nature | Going to parties | Creative expression | Exercising indoors | Exercising outdoors | Frequent eating | Social media | Meditation or prayer | Other (please specify)
Q18. During the semester, how frequently do you take recreational walks in nature on campus?
Daily | 3–4 times a week | 1–2 times a week | Less than once a week | Almost never
Q19. During your time at Cornell, how many afternoon labs or other courses have you taken that involve spending time in nature?
5 or more | 3 to 4 | 1 to 2 | None
Q20. During your time at Cornell, have you heard of the NatureRx program?
Yes | Not sure | No
Q21. Among the many economic, social, and political issues in the US, how would you rank your concern for the environment?
1 = the environment is not important, 10 = very important
Q22. On a scale of 1 to 10, how would you describe your overall stress level during the semester?
1 = the least stressed, 10 = most stressed
Q23. Please provide any additional thoughts regarding your current relationship with nature.

Dissemination

Announcements about the survey were sent to all undergraduate students at this campus via an e-newsletter. Students 18 years or older were encouraged to participate with an incentive of "$1.00 off a cup of coffee or tea" from an on-campus café/restaurant. The first announcement was sent out on Monday, February 26, 2018. Reminders were sent on March 5, 7, 12, and 19. The survey was closed on March 30, 2018.

Demographic Composition

Gender

The majority of survey participants identified as female (83.8%), followed by 15.3% of participants identifying as male, two participants selecting an "additional gender category/identity," and one participant selecting "I prefer not to say" (**Table 2**). Compared to the undergraduate university population in fall 2017 (52% female), a substantially higher proportion of females completed this questionnaire. We found no statistical associations with these moderating variables.

Race/Ethnicity

The majority of participants identified as white (51.4%), followed by Asian (27.8%), Hispanic, Latinx or Spanish (10.6%), biracial or multiracial (4.2%), and Black or African American (3.3%). This sample more closely mirrors the composition of the fall 2017 undergraduate population, although the proportion of white students in the university population is lower (38%). Underrepresented minority students (Black, Hispanic, American Indian, Hawaiian/Pacific Islander, or multiracial students) comprised 22% of the undergraduate population in 2017 and 20% of the survey respondents (**Table 2**).

TABLE 2 | Frequency statistics by demographic variables.

Characteristic	*n*	%
Gender		
Male	47	15.3
Female	258	83.5
Additional gender category/identity	2	0.6
I prefer not to say	1	0.3
Racial composition		
White	185	51.4
Asian	100	27.8
Hispanic, Latinx, or Spanish Origin	38	10.6
Biracial or multiracial	15	4.2
Black or African American	12	3.3
Native Hawaiian or Pacific Islander	4	1.1
Middle Eastern or North African	3	0.8
American Indian or Alaska Native	1	0.3
I prefer not to say	1	0.3
None of these	1	0.3
Childhood region—by climate (ages 7–11 years)		
Northeast	173	61.0
West	31	11.0
Southeast	22	7.7
Central	14	5.0
Midwest	13	4.7
Northwest	12	4.3
South	10	3.6
Southwest	8	2.5
Plains and Rockies	1	0.4
Level of urbanism—by development (ages 7–11 years)		
Urban	70	22.7
Small city or village	40	13.0
Suburban	174	56.5
Rural	24	7.8
Perceived childhood economic status (ages 7–11 years)		
Upper class	14	4.6
Upper middle class	124	40.4
Middle class	128	41.7
Lower middle class	21	6.8
Working class	20	6.5

MCY Environment

The majority of participants had lived in the United States for at least 2 years during ages 7–11 years; 22 participants (7%) had not, and these 22 questionnaires were excluded from statistical analysis. Thirty-five states and the District of Columbia were represented. The highest proportion of participants (31.3%) reported having lived primarily in New York during MCYs. New Jersey and California were each represented by 30 participants (10.6%). This reflects the undergraduate university population, in which most students are from New York State (25%), the Middle States (MD, PA, NJ, DE, DC; 13%), and the West (11%). **Table 2** reflects the composition of participants by NOAA Climate Region.

When considering the population and SES of their childhood environment, most participants represented suburban and urban areas (56.5 and 22.7%, respectively), and only 7.8% of students were from rural areas. Most participants perceived their family's SES during MCYs as either middle class (41.7%) or upper middle class (40.1%).

A χ^2 goodness-of-fit test suggests that suburban students who perceive themselves to be upper or upper middle class are overrepresented in this sample, whereas urban students of upper or upper middle class are underrepresented, as are suburban students of lower-middle and working class. Although not representative of an evenly distributed population, the sample is relatively representative of the university population in which the average family income of students is in the 79th percentile nationally, and nearly two-thirds of students are from the top 20% nationally in family income. Only 3.8% of students at this university are from the bottom 20% of family income nationally (citation Cornell University, 2020).

Analytic Approach

A total of 362 Qualtrics surveys were filled out. Surveys less than 90% complete and that had taken fewer than 118 seconds to complete were omitted, resulting in a total of 309 surveys used for statistical analysis. Quantitative data were analyzed using Statistical Package for Social Sciences (SPSS) v23. Qualitative data were analyzed using Atlas.ti v8.

Quantitative Methods

For analyzing binary and Likert scale questionnaire items, differences between groups were assessed with a *t*-test, using *p*-values with equal variances not assumed when necessary. For examining the correlation between two Likert scale items, we reported Kendall τ_b, because this was appropriate for data sets with ties (Agresti, 2002). For correlating Likert scale items and MCY nature experiences (a sum), we similarly reported correlations with Kendall τ_b.

To investigate the relationship between two categorical items, we employed a χ^2 test of association, using adjusted standardized residuals to determine which combinations were overrepresented or underrepresented. When necessary, groups with small numbers were combined to meet assumptions of a χ^2 test of association. In particular, for the SES item, we combined "upper class" with "upper middle class," and combined "lower middle class" with "working class." Bonferroni corrections to alpha levels were performed when multiple tests were conducted.

For H1, "nature engagement (NE) in MCYs is positively correlated with NE in undergraduate years," *NE in MCYs* was operationalized through three questionnaire items:

> Q10: At any time during ages 7–11 years, did you attend a camp that included nature-based activities?
> Q11: During ages 7–11 years, how frequently do you recall spending time in nature?
> Q12: During ages 7–11 years, how frequently do you recall adults in your life (parents, guardians, relatives, teachers) talking about nature or the natural environment?

NE in undergraduate years was operationalized through two questionnaire items:

> Q18: During the semester, how frequently do you take recreational walks in nature on or off campus?
> Q19: During the semester, how frequently do you engage in other nature-related activities (e.g., sailing, cycling, skiing, etc.)?

For H2 ("NE in MCYs is positively correlated with PEAs in undergraduate years") and H3 ("Undergraduate NE is positively correlated with PEAs in undergraduate years"), *PEAs in undergraduate years* was operationalized with the questionnaire item:

> Q21: Among the many economic, social, and political issues in the United States, how would you rank your concern for the environment? (1 = the environment is not important, 10 = the environment is very important)

For H4, "NE in undergraduate years is negatively correlated with undergraduate self-perceived stress," *stress level* was operationalized with the following questionnaire item:

> Q22: On a scale of 1–10, how would you describe your overall stress level during the semester? (1 = the least stressed, 10 = most stressed)

Qualitative Methods

Qualitative data collected during this study included answers to two open-ended survey items. In the MCYs section, "When you think back to ages 7–11 years, what is the physical environment in which you first picture yourself?" This question ties back to H1, which addresses NE in early childhood. In the undergraduate section, the final survey question was: "Please provide any additional thoughts regarding your current relationship with nature." This allowed us to capture any additional qualitative data that might add context to the quantitative findings.

Three hundred thirty-nine participants (95%) provided a response to the first open-ended question. Most responses were short phrases or sentences, averaging 7.3 words per response. Following Saldaña (2013), a member of the research team identified codes from the data and organized those codes into eight categories (**Figure 2**). One hundred fifty-four participants (43%) responded to the final/second open-ended question. Because of the smaller number of responses, we did not conduct the Saldaña method of qualitative analysis on this question.

RESULTS

Relationship Between NE in Middle Child Years and NE in Undergraduate Years (H1)

There was a notable decrease in NE from MCYs to college years. The majority of participants engaged with nature during MCYs at least three to four times a week, although most undergraduates reported current NE as less than once a week (**Figure 1**).

Similarly, undergraduates who recalled adults frequently talking about nature reported greater NE now (recreational walks, $\tau_b = 0.157$, $p = 0.001$, other nature activities, $\tau_b = 0.214$, $p < 0.001$). Although attending a nature camp was not significantly correlated with frequency of nature walks now, $t(305) = -0.90$, $p = 0.369$, there was a significant correlation between camp attendance and frequency of other undergraduate nature activities: participants who went to camp in MCYs engaged in other nature activities as undergraduates more frequently (mean = 4.49) than those who did not attend camp (mean = 4.12), $t(222.9) = -3.14$, $p = 0.002$.

The qualitative question regarding early memories of nature provided more detail on NE in MCYs. Within the eight categories identified during the analysis, four themes emerged: environmental features (artifacts and nature), activity (recreation and obligation), subjective features (emotion and aesthetics), and setting (physical setting and participants). This relationship is represented in **Figure 2**.

Environmental features included physical characteristics of both the built and natural environment, for example, "Cornfields outside my house, and the creek nearby!" Subjective features were emotional or aesthetic, such as this statement by a participant: "Peaceful and comfortable." References to activities addressed both recreation and obligation, like "I was working outside of my family's dairy farm." Statements related to the setting included the setting itself and the participants, such as the case in this quote: "Playing in our yard or street with neighbors."

These themes represent components of the childhood nature experience, including environmental features, subjective features, activity, and setting. When viewed through the lens of the childhood physical environment (rural, suburban, small city, urban), the quality of the childhood experience depends somewhat on the level of development in a participant's community. Survey participants from rural settings more

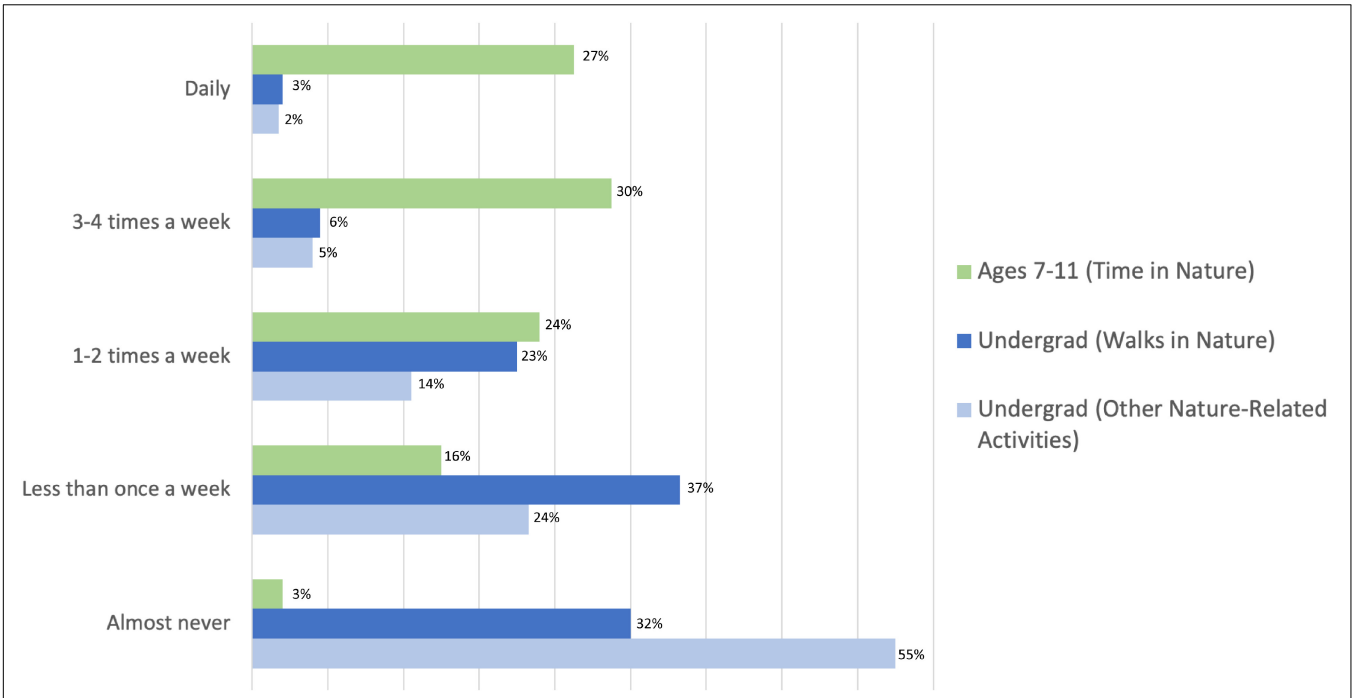


FIGURE 1 | Frequency of nature engagement decreases from childhood to undergraduate years. Supporting H1, participants who engaged with nature (NE) more frequently in MCYs engaged with nature more frequently as undergraduates (recreational walks, $\tau_b = 0.223$, $p < 0.001$, and other nature-related activities as undergraduates, $\tau_b = 0.306$, $p < 0.001$). *Post hoc* tests revealed that participants who engaged with nature daily in MCYs were more likely to engage with nature as undergraduates [take nature walks or engage in other nature-related activities one to two times a week (adjusted $R = 3.1$ and 4.3, respectively)].

frequently described the natural features of their MCY environments, with the number of references to artificial features increasing as the environment was increasingly urbanized.

Relationship Between NE in MCYs and PEAs in Undergraduate Years (H2)

Supporting H2, there was a positive correlation between participants who engaged more with nature in MCYs and undergraduate PEAs, $\tau_b = 0.169$, $p < 0.001$. Results from the survey also suggest children who heard adults talk about nature more frequently ranked higher with PEAs, $\tau_b = 0.158$, $p = 0.001$. Camp attendance in MCYs, however, was not correlated with increased PEA, $t(305) = 0.41$, $p = 0.68$.

Relationship Between Undergraduate NE and Undergraduate PEAs (H3)

Supporting H3, participants who engaged with nature as undergraduates reported greater PEAs (walked more in nature, $\tau_b = 0.139$, $p = 0.003$, and engaged in other nature-related activities, $\tau_b = 0.132$, $p = 0.007$).

Relationship Between Undergraduate NE and Undergraduate Stress Level (H4)

Students described the strategies and activities they engaged in to relieve stress (**Figure 3**). Being outside in nature was exceeded only by talking to friends or family. Nevertheless, contrary to H4, we found no significant correlation with participants' NE (walk more in nature or engage in other nature-related activities) and self-reported stress level, $p > 0.05$.

The final open-ended question provided insight regarding the lack of current NE and, perhaps, the lack of correlation with stress levels. In 34 of the open-ended responses, students said that they "wished" they could spend more time in nature or "should" spend more time in nature. The two largest reported barriers were time ($n = 35$) and weather ($n = 21$). Other barriers included lack of transportation off campus, fear of insects, worry about sun damage, and stress itself (n = 11). As one student articulated, "Paradoxically, the more I would like to be in touch with nature (during periods of stress), the less able I am to actually explore it."

Several students mentioned the beauty of the campus and surrounding environment as an initial draw and an asset during times of stress: (1) "I love it. It brings me joy and peace and comfort. A very significant factor in my choice to attend Cornell was it's [*sic*] natural beauty and the availability of the forest both on campus and in nearby locations." (2) "When I visited Cornell I knew it was the perfect place for me in part because of the extensive opportunities for outdoor activities in nature. However, I don't spend enough time in nature during the semester, even though it has a great calming effect on me. I lazily resort to things I can access more easily, such as my computer, for stress relief." (3) "I don't have time to go outside purely to enjoy the outdoors, but I enjoy walking between classes and stargazing at night on my way home. Part of the reason

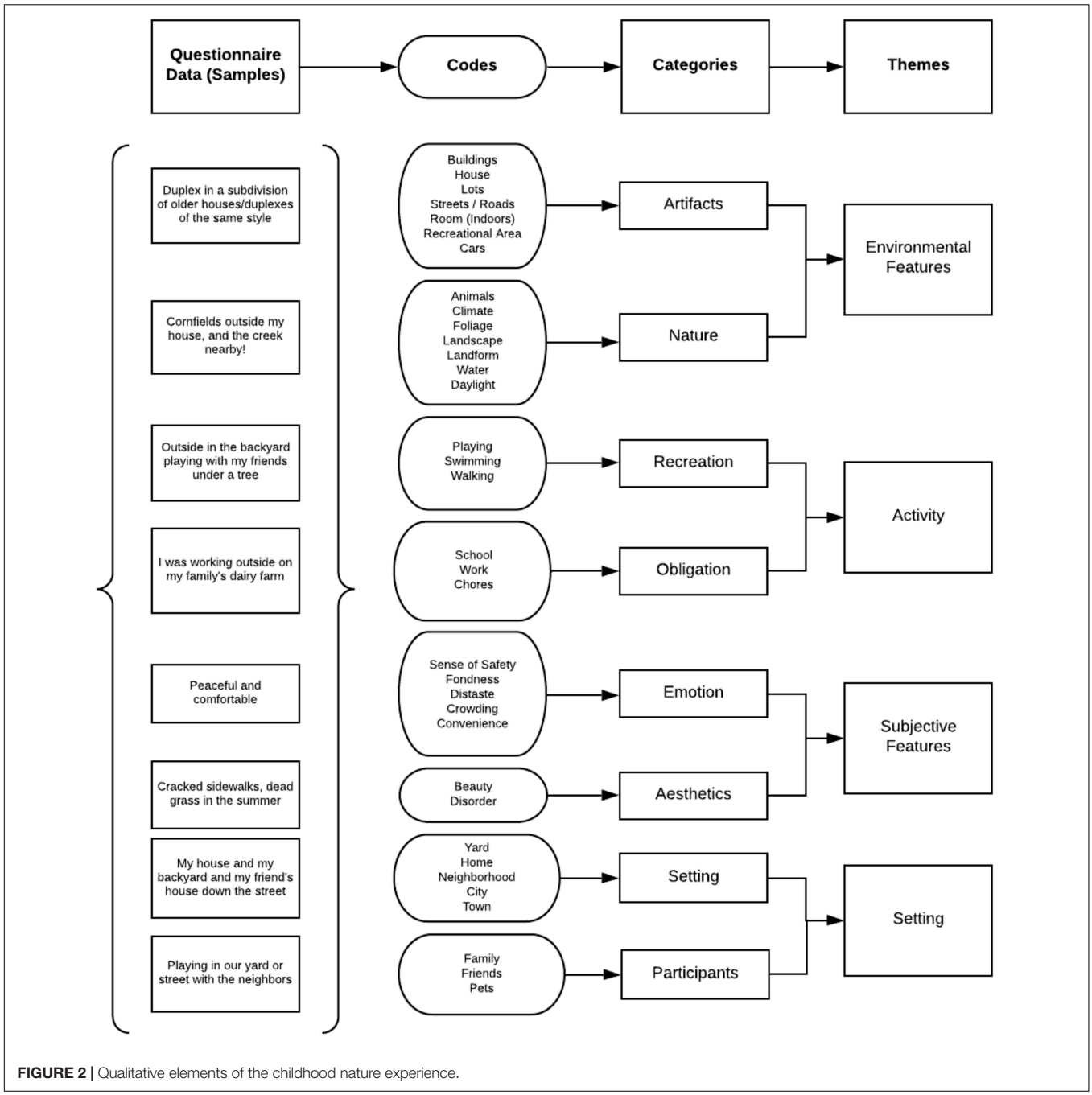


FIGURE 2 | Qualitative elements of the childhood nature experience.

I moved to Ithaca was to get away from the city and immerse myself in nature."

Perceived Levels of MCY Urbanization and Socioeconomic Status and NE (RQ1, RQ2)

As suggested by RQ1, there was a negative relationship between residing in an urban environment and NE in MCYs. Participants who reported frequent MCY NE tended to be from more rural communities, $\tau_b = -0.27$, $p < 0.001$. *Post hoc*-adjusted residuals suggest participants from rural areas were most likely to engage with nature daily in MCYs (adjusted $R = 5.5$), whereas participants from urban areas were most likely to engage with nature less than once a week (adjusted $R = 4.6$). Participants who attended a nature camp grew up in a more rural environment (mean = 2.57) than participants who did not attend a nature camp (mean = 2.33), $t(179.786) = -3.14$, $p = 0.041$. Participants who recalled adults frequently talking about nature in MCYs tended to be from more rural communities, $\tau_b = 0.153$, $p = 0.002$.

Participants who went to a nature camp grew up in a higher socioeconomic class (mean = 2.58) than those who did

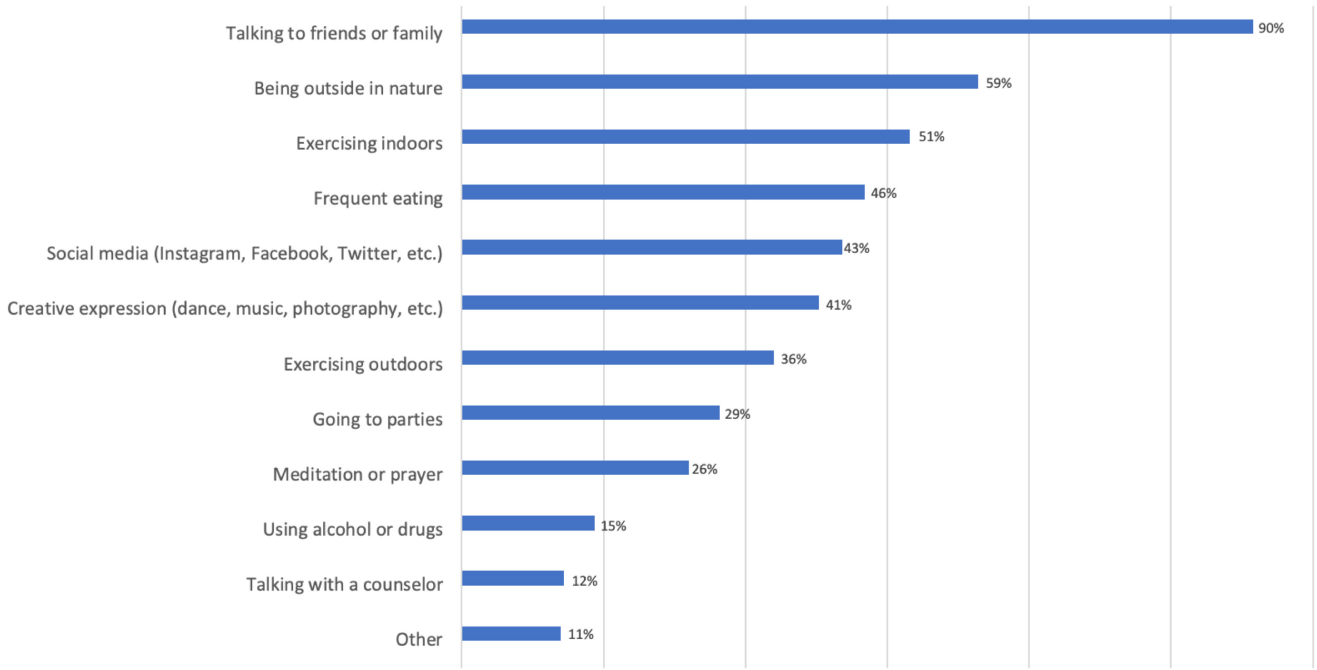


FIGURE 3 | Stress relief strategies and activities (undergraduate).

not go to a nature camp (mean = 2.96), $t(304) = -3.50$, $p = 0.001$. Participants who recalled adults frequently talking about nature also tended to be from a higher SES, $\tau_b = 0.118$, $p = 0.015$. There was not, however, a significant correlation between SES and NE in MCYs, $\tau_b = 0.087$, $p = 0.075$ (RQ2).

In summary, contrary to RQ1, there was no significant negative correlation between MCY residency in an urban setting and current undergraduate NE as reported in frequency of nature walks, $\tau_b = -0.037$, $p = 0.451$, or current frequency of other nature-related activities, $\tau_b = -0.067$, $p = 0.181$. Likewise, there was no significant correlation between MCY SES and frequency of current recreational nature walks (RQ2).

DISCUSSION

Relationship Between NE in Middle Child Years and NE in Undergraduate Years (H1)

Although we found a significant positive correlation between NE during MCYs and NE during undergraduate years, *post hoc* tests revealed a large decrease in NE from MCYs to undergraduate for most participants. The majority of participants engaged with nature during MCYs 3–4 times a week, whereas the majority of participants reported that they now spend time in nature less than once a week. Participation in outdoor activity reliably changes across the lifespan, revealing a demonstrated decline between childhood, adolescence, and young adulthood (Larson et al., 2011).

Relationship Between NE in MCYs and PEAs in Undergraduate Years (H2)

Results suggesting a positive correlation between childhood NE and PEAs in undergraduate years are supported by existing literature. Wells and Lekies (2006) suggest "wild" activities during childhood, including hiking and camping, are positively associated with both adult NE and PEAs. Just as Wells and Lekies (2006) differentiate between "wild" and "domestic" outdoor activities, Ewert et al. (2005) also found a difference in PEAs in university students, depending on the frequency of "consumptive" or "appreciative" outdoor activities during childhood. Although the current study simply asked about walks in nature or other nature-related activities, future research in predictors of college student behaviors may consider differentiating between types of NE.

Relationship Between Undergraduate NE and Undergraduate PEAs (H3)

Even though survey participants engaged with nature much less as undergraduates than they had in MCYs, we nevertheless found a positive correlation between NE as undergraduates and PEAs. This finding is consistent with previous research (Palmer et al., 1998; Chawla, 2007; Rosa and Collado, 2019; Alcock et al., 2020; Whitburn et al., 2020).

Relationship Between Undergraduate NE and Stress (H4)

Although the findings from previous research support the restorative properties of NE regarding stress reduction (e.g.,

Frumkin et al., 2017; Markevych et al., 2017; Bratman et al., 2019; Meredith et al., 2020), results from the current study did not suggest a significant correlation with stress in either direction. This finding was particularly interesting because participants overall ranked "being outside in nature" (a marker of NE) second only to "talking to friends or family" as a way to relieve stress. This suggests some recognition of the restorative value of NE. Nevertheless, NE may be yet another healthy and/or pleasurable behavior that, like adequate sleep, proper nutrition, exercise, and so forth, falls by the wayside during stressful times (Weidner et al., 1996; Britz and Pappas, 2010).

Qualitative responses shed light on the discrepancy and lack of correlation. Some participants reported that they did not see spending time in nature as a "productive" use of their time: "I find that I enjoy nature a lot more when I am unstressed and have a lot of time to relax. I have tried to go hiking or go on walks when I am moderately stressed, but I tend to get too anxious about spending my time unproductively."

Other possible explanations for this outcome include the potential lack of construct validity by using a single questionnaire item to measure stress. Furthermore, the overall high level of stress associated with college student life may have rendered the Likert scale ineffective. A high level of stress might be accepted as normal by many students (Winerman, 2017; American College Health Association, 2019). Future research may consider using a validated measure (perhaps specific to college students) to evaluate stress.

Perceived Level of MCY Urbanization and Socioeconomic Status and NE (RQ1, RQ2)

We found evidence of a relationship between MCY SES, level of urbanization, and MCY NE, such that upper-SES participants reported more NE during MCYs, as did participants from more rural settings. Researchers have found that urban versus rural daily experience impact children's concepts of nature (Collado et al., 2016). These findings did not extend, however, to NE as undergraduates. The intense challenges of university life and efforts toward adaptation may supersede normal behaviors and familial culture. Lifestyle changes have been recorded in freshmen students (Wolf and Kissling, 1984).

Limitations

The survey was administered in the winter of 2018. A better time for distribution would have been in the middle of fall semester when the weather and daylight hours are more conducive to outdoor activities, and before end-of-semester stress inhibits survey participation. It is likely that participants' NE was negatively influenced by the cold weather and short days. In fact, many responses to the final open-ended question mentioned the cold weather as a barrier to NE.

The majority of participants were first-year undergraduates (second-semester freshmen) who may have had less knowledge about where and how to access nature on or off campus. A larger sample of students who had lived in the area longer might have shown a higher level of NE.

Survey participants were a convenience sample of students who opened a community newsletter, saw the survey announcement, and clicked on the link. It is possible that students who were interested in the topic of "nature" were more likely to take the survey. A larger sample size with randomized responses would be ideal.

Results may not be generalizable to other universities. The site for this study was in a cool temperate climate and a rural community with significant access to nature amenities. However, the survey could be administered at other universities in the future. It would be particularly interesting to compare students at 4-year state schools where tuition is lower; compare areas of the country where climate and weather make nature more accessible year-round; and examine the responses of students in more urbanized areas such as New York City, Miami, or Chicago.

CONCLUSION

This study surveyed undergraduate college students at a US university to compare their current engagement with and attitudes about nature with their nature experiences during their formative MCYs. The study confirmed what many other researchers in the United States and internationally have found—that parents or other adult figures who speak about the benefits of time in nature influence children to spend more time outdoors, and that such young people are also more likely to engage with nature as undergraduates than those whose parents less frequently spoke about nature in their MCYs.

Our findings implicate family and peers as important influences in the child's life. The childhood environment is a complex, nested system in which community-level and neighborhood-level interactions impact children (Booth and Crouter, 2001), as well as family-level influences as a child constructs their future engagements and attitudes. In addition, participants from wealthier backgrounds and those from rural settings were more likely to have engaged with nature in MCYs than those from more urban settings or lower SES.

Our findings reinforce the importance of positive nature exposure and engagement in childhood. Whether "working" in nature on a farm or in a home garden, or engaging in more leisure-oriented activities such as going for walks or to the beach, these positive nature experiences may positively impact NE and PEAs in young adulthood.

An unexpected finding is how much less time undergraduate participants in this survey spend in nature currently than in their MCYs. Coupled with the lack of a positive correlation between NE and self-reported stress, one could conclude that undergraduates do not perceive NE as a viable approach to lowering their stress levels. This conclusion is belied by the fact that participants listed "being outside in nature" as the second most important means of reducing stress in their lives and that many participants spoke longingly of nature (wishing they had more time to spend in it or that the weather was more conducive) in their open-ended responses.

A likely explanation for this discrepancy is that students typically face very high levels of stress on a daily basis

and that time in nature alone does not eliminate stress. A number of university counseling centers currently offer "nature prescriptions" as one of several tools that can be used to improve a student's well-being. We recommend that, in doing so, counselors integrate the benefits of NE with other components of overall well-being, including a proper diet, adequate sleep, and healthy socializing. It will also be important to educate students on how to connect with "nearby nature" on campus safely and comfortably in all seasons.

While freshmen did not access nature as frequently as predicted, they indicated the desire to do so. An implication of this study is that engagement with nature should be more thoroughly integrated into freshmen orientation protocols, as well as a prescription proferred by university health clinicians. Outdoor classes, buildings designed with views of nature, and the introduction of indoor plants are other tools to facilitate NE.

Achieving a better understanding of how environmental, familial, and experiential factors from MCYs affect the nature engagement and PEAs of currently enrolled undergraduates can assist college and university counselors to anticipate problematic behavior in individuals before it arises. Given the enormous demands on campus counseling centers, such knowledge could improve the effectiveness of the services provided to undergraduates.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Cornell University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

NS and DR: conceptualization, methodology, investigation, writing – original draft, and writing – review and editing. MS: conceptualization, methodology, writing – original draft, writing – review and editing, and supervision. KP: formal analysis, visualization, writing – original draft, and writing – review and editing. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

A sincere thank-you to Erika Mudrak, statistical consultant at Cornell University Statistical Consulting Unit.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2020.540872/full#supplementary-material

REFERENCES

Agresti, A. (2002). *Categorical Data Analysis*, 2nd Edn. Hoboken, NJ: John Wiley & Sons, Inc. doi: 10.1002/0471249688

Alcock, I., White, M. P., Pahl, S., Duarte-Davidson, R., and Fleming, L. E. (2020). Associations between pro-environmental behaviour and neighbourhood nature, nature visit frequency and nature appreciation: evidence from a nationally representative survey in England. *Environ. Int.* 136:105441. doi: 10.1016/j.envint.2019.105441

American College Health Association (2019). *National Health Assessment II: Reference Group Executive Summary Spring 2019*. Silver Spring, ML: American College Health Association.

Anderson, D. M., and Holt, J. K. (2017). *Research Brief: Do High School Students Know Their Parent's Incomes? IERC Research Brief 2017-3*. Edwardsville, IL: Illinois Education Research Council.

Asah, S. T., Bengston, D. N., Westphal, L. M., and Gowan, C. H. (2018). Mechanisms of children's exposure to nature: predicting adulthood environmental citizenship and commitment to nature-based activities. *Environ. Behav.* 50, 807–836. doi: 10.1177/0013916517718021

Berman, M. G., Jonides, J., and Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychol. Sci.* 19, 1207–1212. doi: 10.1111/j.1467-9280.2008.02225.x

Booth, A., and Crouter, A. C. (eds) (2001). *Does It Take a Village? Community Effects on Children, Adolescents, and Families*. Hove: Psychology Press. doi: 10.4324/9781410600141

Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., De Vries, S., Flanders, J., et al. (2019). Nature and mental health: an ecosystem service perspective. *Sci. Adv.* 5:eaax0903. doi: 10.1126/sciadv.aax0903

Bratman, G. N., Daily, G. C., Levy, B. J., and Gross, J. J. (2015). The benefits of nature experience: improved affect and cognition. *Land. Urban Plan.* 138, 41–50. doi: 10.1016/j.landurbplan.2015.02.005

Bratman, G. N., Hamilton, J. P., and Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Ann. N.Y. Acad. Sci.* 1249, 118–136. doi: 10.1111/j.1749-6632.2011.06400.x

Britz, J., and Pappas, E. (2010). Sources and outlets of stress among university students: correlations between stress and unhealthy habits. *Undergrad. Res. J. Hum. Sci.* 9, 50–55.

Brooks, A. M., Ottley, K. M., Arbuthnott, K. D., and Sevigny, P. (2017). Nature-related mood effects: season and type of nature contact. *J. Environ. Psychol.* 54, 91–102. doi: 10.1016/j.jenvp.2017.10.004

Chawla, L. (2007). Childhood experiences associated with care for the natural world: a theoretical framework for empirical results. *Child. Youth Environ.* 17, 144–170.

Collado, S., Íñiguez-Rueda, L., and Corraliza, J. A. (2016). Experiencing nature and children's conceptualizations of the natural world. *Child. Geogr.* 14, 716–730. doi: 10.1080/14733285.2016.1190812

Cornell University (2020). *Diversity Dashboards [data visualization]*. Available online at: http://irp.dpb.cornell.edu/university-factbook/diversity (accessed October 18, 2020).

Cox, D. T. C., Shanahan, D. F., Fuller, R. A., Anderson, K., Hancock, S., and Gaston, K. J. (2017). Doses of nearby nature simultaneously associated with multiple health benefits. *Int. J. Environ. Res. Public Health* 14:172. doi: 10.3390/ijerph14020172

Engemann, K., Pedersen, C. B., Arge, L., Tsirogiannis, C., Mortensen, P. B., and Svenning, J. C. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proc. Natl. Acad. Sci. U.S.A.* 116, 5188–5193. doi: 10.1073/pnas.1807504116

Erikson, E. (1962). *Childhood and Society*. New York, NY: W. W. Norton and Co.

Evans, G. W., Otto, S., and Kaiser, F. G. (2018). Childhood origins of young adult environmental behavior. *Psychol. Sci.* 29, 679–687. doi: 10.1177/0956797617741894

Ewert, A., Place, G., and Sibthorp, J. (2005). Early-life outdoor experiences and an individual's environmental attitudes. *Leis. Sci.* 27, 225–239. doi: 10.1080/01490400590930853

Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn, Jr. P. H, Lawler, J. J., et al. (2017). Nature contact and human health: a research agenda. *Environ. Health Perspect.* 125:075001. doi: 10.1289/EHP1663

Grigsby-Toussaint, D. S., Turi, K. N., Krupa, M., Williams, N. J., Pandi-Perumal, S. R., and Jean-Louis, G. (2015). Sleep insufficiency and the natural environment: results from the US Behavioral Risk Factor Surveillance System survey. *Prev. Med.* 78, 78–84. doi: 10.1016/j.ypmed.2015.07.011

Jensen, A. K., and Olsen, S. B. (2019). Childhood nature experiences and adulthood environmental preferences. *Ecol. Econ.* 156, 48–56. doi: 10.1016/j.ecolecon.2018.09.011 doi: 10.1016/j.ecolecon.2018.09.011

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Kellert, S. R. (2002). "Experiencing nature: Affective, cognitive, and evaluative development in children," in *Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations*, eds P. H. Kahn and S. R. Kellert (Cambridge, MA: The MIT Press).

Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol.* 6:1093. doi: 10.3389/fpsyg.2015.01093

Larson, L. R., Green, G. T., and Cordell, H. K. (2011). Children's time outdoors: results and implications of the national kids survey. *J. Park Recreat. Admin.* 29, 1–20.

Lohr, V. I., and Pearson-Mims, C. H. (2005). Children's active and passive interactions with plants influence their attitudes and actions toward trees and gardening as adults. *HortTechnology* 15, 472–476. doi: 10.21273/HORTTECH.15.3.0472

Mah, V. K., and Ford-Jones, E. L. (2012). Spotlight on middle childhood: rejuvenating the 'forgotten years'. *Paediatr. Child Health* 17, 81–83. doi: 10.1093/pch/17.2.81

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., et al. (2017). Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environ. Res.* 158, 301–317. doi: 10.1016/j.envres.2017.06.028

McFarland, A. L., Zajicek, J. M., and Waliczek, T. M. (2014). The relationship between parental attitudes toward nature and the amount of time children spend in outdoor recreation. *J. Leis. Res.* 46, 525–539. doi: 10.1080/00222216.2014.11950341

McLeod, S. A. (2018). Erik Erikson's stages of psychosocial development. *Simply Psychol.*

Meredith, G., Rakow, D., Sachs, N. A., Eldermire, E., Madsen, C., and Shelley, S. (2020). Minimum time dose in nature to positively impact the mental health of college-aged students, and how to measure it: a scoping review. *Front. Psychol.* 10:2942. doi: 10.3389/fpsyg.2019.02942

Oliphant, E. L., Hughey, S. M., Stowe, E. W., Kaczynski, A. T., Schipperijn, J., and Hipp, J. A. (2019). ParkIndex: using key informant interviews to inform the development of a new park access evaluation tool. *J. Park Recreat. Admin.* 37, doi: 10.18666/JPRA-2019-8926

Palmer, J. A., Jennifer Suggate, J., Bajd, B., and Tsaliki, E. (1998). Significant influences on the development of adults' environmental awareness in the UK, Slovenia and Greece. *Environ. Educ. Res.* 4, 429–444. doi: 10.1080/1350462980040407

Piaget, J. (1962). The stages of the intellectual development of the child. *Bull. Menn. Clin.* 26, 120–128.

Pol, E., and Castrechini, A. (2013). Disrupción en la educación para la sostenibilidad? Disruption in education for sustainability?. *Rev. Latinoamer. Psicol.* 45, 335–349. doi: 10.14349/rlp.v45i3.1477

Powell, L. M., Slater, S., and Chaloupka, F. J. (2004). The relationship between community physical activity settings and race, ethnicity, and socioeconomic status. *Open Minds J.* 1, 135–144.

Prabhakararao, S. (2016). Overuse of social media affects the mental health of adolescents and early youth. *Int. J. Ind. Psychiatry* 3, 14–19.

Rigolon, A., and Flohr, T. (2014). Access to parks for youth as an environmental justice issue: access inequalities and possible solutions. *Buildings* 4, 69–94. doi: 10.3390/buildings4020069

Roe, J., and Aspinall, P. (2011). The restorative benefits of walking in urban and rural settings in adults with good and poor mental health. *Health Place* 17, 103–113. doi: 10.1016/j.healthplace.2010.09.003

Rosa, C. D., and Collado, S. (2019). Experiences in nature and environmental attitudes and behaviors: setting the ground for future research. *Front. Psychol.* 10:763. doi: 10.3389/fpsyg.2019.00763

Rosa, C. D., Profice, D. C., and Collado, S. (2018). Nature experiences and adults' self-reported pro-environmental behaviors: the role of connectedness to nature and childhood nature experiences. *Front. Psychol.* 9:1055. doi: 10.3389/fpsyg.2018.01055

Saldaña, J. (2013). *The coding manual for qualitative researchers*, 2nd Edn. New York, NY: SAGE.

Schoeppe, S., Vandelanotte, C., Bere, E., Lien, N., Verloigne, M., Kovács, E., et al. (2017). The influence of parental modelling on children's physical activity and screen time: does it differ by gender? *Eur. J. Public Health* 27, 152–157. doi: 10.1093/eurpub/ckw182

Sebba, R. (1991). The landscapes of childhood: the reflection of childhood's environment in adult memories and in children's attitudes. *Environ. Behav.* 23, 395–422. doi: 10.1177/0013916591234001

Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., and Fuller, R. A. (2014). Socio-economic inequalities in access to nature on public and private lands: a case study from Brisbane, Australia. *Land. Urban Plan.* 130, 14–23. doi: 10.1016/j.landurbplan.2014.06.005

Soga, M., Gaston, K. J., Koyanagi, T. F., Kurisu, K., and Hanaki, K. (2016). Urban residents' perceptions of neighbourhood nature: does the extinction of experience matter? *Biol. Conserv.* 203, 143–150. doi: 10.1016/j.biocon.2016.09.020

Starling, P. E. (2011). *An Investigation of Unstructured Play in Nature and Its Effect on Children's Self-Efficacy*. Pennsylvania: University of Pennsylvania. Doctoral dissertation.

Stevenson, K. T., Peterson, M. N., Carrier, S. J., Strand, R. L., Bondell, H. D., Kirby-Hathaway, T., et al. (2014). Role of significant life experiences in building environmental knowledge and behavior among middle school students. *J. Environ. Educ.* 45, 163–177. doi: 10.1080/00958964.2014.901935

Strife, S., and Downey, L. (2009). Childhood development and access to nature: a new direction for environmental inequality research. *Organ. Environ.* 22, 99–122. doi: 10.1177/1086026609333340

Szagun, G., and Mesenholl, E. (1993). Environmental ethics: an empirical study of West German adolescents. *J. Environ. Educ.* 25, 37–44. doi: 10.1080/00958964.1993.9941943

Tillmann, S., Tobin, D., Avison, W., and Gilliland, J. (2018). Mental health benefits of interactions with nature in children and teenagers: a systematic review. *J. Epidemiol. Commun. Health* 72, 958–966. doi: 10.1136/jech-2018-210436

Twenge, J. M. (2014). *Generation me: Why today's Young Americans are More Confident, Assertive, Entitled - and More Miserable than Ever Before*. New York, NY: Atria Paperbacks.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

Weeland, J., Moens, M. A., Beute, F., Assink, M., Staaks, J. P. C., and Overbeek, G. (2019). A dose of nature: two three-level meta-analyses of the beneficial effects of exposure to nature on children's self-regulation. *J. Environ. Psychol.* 65:101326. doi: 10.1016/j.jenvp.2019.101326

Weidner, G., Kohlmann, C. W., Dotzauer, E., and Burns, L. R. (1996). The effects of academic stress on health behaviors in young adults. *Anxiety Stress Coping* 9, 123–133. doi: 10.1080/10615809608249396

Wells, N. M., and Evans, G. W. (2003). Nearby nature: a buffer of life stress among rural children. *Environ. Behav.* 35, 311–330. doi: 10.1177/0013916503035003001

Wells, N. M., and Lekies, K. S. (2006). Nature and the life course: pathways from childhood nature experiences to adult environmentalism. *Child. Youth Environ* 16, 1–24.

Whitburn, J., Linklater, W., and Abrahamse, W. (2020). Meta-analysis of human connection to nature and proenvironmental behavior. *Conserv. Biol.* 34, 180–193. doi: 10.1111/cobi.13381

Winerman, L. (2017). By the numbers: stress on campus. *Monit. Psychol.* 48:88.

Wolf, T. M., and Kissling, G. E. (1984). Changes in life-style characteristics, health, and mood of freshman medical students. *J. Med. Educ.* 59, 806–814. doi: 10.1097/00001888-198410000-00005

Zuo, A., Wheeler, S. A., and Edwards, J. (2016). Understanding and encouraging greater nature engagement in Australia: results from a national survey. *J. Environ. Plan. Manag.* 59, 1107–1125. doi: 10.1080/09640568.2015.1054926

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 11 November 2020
doi: 10.3389/fpsyg.2020.531840

The Self and Its Nature: A Psychopathological Perspective on the Risk-Reducing Effects of Environmental Green Space for Psychosis

*Sjoerd J. H. Ebisch**

Department of Neuroscience, Imaging and Clinical Sciences, Institute of Advanced Biomedical Technologies (ITAB), G. d'Annunzio University of Chieti-Pescara, Chieti, Italy

OPEN ACCESS

Edited by:
Giuseppina Spano, University of Bari Aldo Moro, Italy

Reviewed by:
Annalisa Theodorou, Roma Tre University, Italy
Simon Bell, University of Edinburgh, United Kingdom

***Correspondence:**
Sjoerd J. H. Ebisch
s.ebisch@unich.it

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *01 February 2020*
Accepted: *21 October 2020*
Published: *11 November 2020*

Citation:
Ebisch SJH (2020) The Self and Its Nature: A Psychopathological Perspective on the Risk-Reducing Effects of Environmental Green Space for Psychosis. Front. Psychol. 11:531840. doi: 10.3389/fpsyg.2020.531840

Epidemiological studies have shown that environmental green space contributes to the reduction of psychosis incidence in the population. Clarifying the psychological and neurofunctional mechanisms underlying the risk-decreasing effects of green surroundings could help optimize preventive environmental interventions. This perspective article specifically aims to open a new window on the link between environmental green space and psychosis by considering its core psychopathological features. Psychotic disorders, such as schizophrenia, are essentially characterized by self-disturbances. The psychological structure of the self has been described as a multidimensional phenomenon that emerges from the reciprocal interaction with the environment through intrinsic and extrinsic self-processes. The intrinsic self refers to the experience of mental activity and environmental information as inherently related to one's own person, which involves self-referential processing, self-reflection, memory, interoception, and emotional evaluation. The extrinsic self refers to sensorimotor interactions with the environment and the sense of agency, that is, the experience of being the source of one's own actions and the multisensory consequences thereof. In psychosis, anomalous self-processing has been related to a functional fragmentation of intrinsic and extrinsic self-processes and related brain networks. Moreover, evidence from cognitive neuroscience suggests that green space could have beneficial effects on self-related processing. Based on the literature, it could be hypothesized that self-processing is involved in mediating the beneficial effects of green space for psychosis. Considering the multidimensionality of the self, it is proposed that urban green space design aimed at improving mental health ideally impacts the complexity of self-facets and thus restores the individual's self.

Keywords: intrinsic self, extrinsic self, environment, green space, natural surroundings, psychosis, schizophrenia, urban

INTRODUCTION

Psychotic disorders are severe mental illnesses that involve a "loss of vital contact with reality" (Minkowski, 1927; Parnas and Henriksen, 2014). The most studied and pervasive psychotic disorder is likely schizophrenia, but psychotic episodes can happen in various psychiatric, neurological, and neurodevelopmental conditions and can also be induced by the use of medications or psychoactive drugs. Socioeconomically, psychosis has been associated with premature mortality, morbidity, financial and social burdens, and poor outcomes (Rössler et al., 2005; van Os and Linscott, 2012; Fazel et al., 2014). Psychoses, particularly schizophrenia, place large demands on public healthcare and its budgets (Rössler et al., 2005).

The high heritability of psychosis indicates the existence of genetic risk factors (Smigielski et al., 2020), although genetic components cannot fully explain the development of psychosis (van Os et al., 2010; Pries et al., 2018; Torrey and Yolken, 2019). The risk of developing a psychosis during one's life is also determined by biological, psychological, and social factors (McGrath et al., 2004; van Os et al., 2010; Fusar-Poli et al., 2017). This knowledge provides important information for intervention programs aimed at detecting high-risk individuals and preventing them from becoming psychotic (Ruhrmann et al., 2010; van Os et al., 2017). However, the implementation of large-scale intervention strategies is still limited. In addition to therapeutic interventions (McGorry et al., 2009; Fusar-Poli et al., 2019), other possibilities for preventive intervention have been implied. Epidemiological studies suggest that environmental factors are involved in the development of psychosis as well (van Os et al., 2010; Dragt et al., 2011; Fusar-Poli et al., 2017). Moreover, longitudinal studies suggest that the modulation of psychosis incidence through environmental factors likely involves causal relationships that cannot be explained by other mediating epidemiological variables (van Os et al., 2010).

Some of these factors may be attractive targets for global risk-reducing environmental interventions (Sussman and Hollander, 2014). Among the various environmental factors that have been related to psychosis risk, urbanicity has been consistently associated with an elevated risk of psychosis as compared to living in rural environments (Lewis et al., 1992; Pedersen and Mortensen, 2001; Sundquist et al., 2004; van Os et al., 2004; Newbury et al., 2016; see for reviews, Krabbendam and van Os, 2005; Kelly et al., 2010). Given that the majority of the world population currently lives in urban areas and continues to increase, this is an issue of concern for mental healthcare (United Nations, Department of Economic and Social Affairs, Population Division, 2014). One notable difference between urban and rural environments that has recently received increasing attention in the scientific literature concerning environmental effects on mental health is the quantity and kind of natural or green space (Verheij et al., 2008), which could be hypothesized as constituting a risk-modulating factor for psychosis. In the present article, I will specifically examine the utilization potential of green space to reduce the incidence of psychosis, although it should be emphasized that the diminished availability of green space is by no means the only characteristic of urban environments and that psychosis incidence in the population is likely modulated by a complexity of interacting nvironmental and genetic factors (Tsuang, 2000; Schmitt et al., 2014).

In particular, this perspective article aims at developing a new hypothesis regarding the psychological and neuronal mechanisms that could explain the risk-decreasing effects of natural surroundings for psychosis. For the purpose of focus, an investigation of how the effects of green space on psychosis incidence can be embedded in the full complexity of genetic and environmental factors and events remains beyond the scope of the present article, although, this will be a mandatory topic for ensuing dialog. A better understanding of the underlying risk-reducing mechanisms of concrete environmental features could help in optimally exploiting these features in urban design. Given the fact that structural and direct investigations in compromising mental disorders like psychosis are still sparse, one approach to exploring these mechanisms would be to link the core psychopathological features of psychosis to green space effects.

GREEN SPACE EXPOSURE IS RELATED TO REDUCED PSYCHOSIS RISK

Natural environments usually refer to surroundings that include green space (essentially typified by the presence of vegetation) but also can include blue space (water bodies), which could be developed with or without human intervention (Völker and Kistemann, 2011; Bratman et al., 2012; Smith et al., 2017). The definition of green space, as used in studies that investigate its psychological effects through experience, covers a broad range of environments, from pristine nature to human cultivated gardens, and more specifically includes urban greens, forests/woodlands, countryside/farmland, and the wilderness (Bratman et al., 2012). Urban green space, in turn, can be characterized by the more formal or informal design of gardens and parks (Twedt et al., 2016). The efficiency of green space exposure in modulating health and well-being has been studied more generally in terms of the presence of green space in people's living environments and also more specifically in terms of visual exposure (e.g., window views and virtual environments) and physically spending time in or interacting with green space (Bratman et al., 2012).

The beneficial effects of natural surroundings on daily life have been shown for physical and mental health, social well-being, academic and job performance, and happiness (Hartig, 1993; Maas et al., 2009; Bratman et al., 2012; White et al., 2013; Hartig et al., 2014; Cohen-Cline et al., 2015; James et al., 2015; van den Berg et al., 2015; Sarkar et al., 2018). Although the nature of such effects remains to be clarified, natural surroundings, as compared to urban areas, are generally thought to decrease air and noise pollution, improve social cohesion and stress regulation, facilitate the restoration of attention and fatigue, improve the mood, and reduce depressive symptoms (Kaplan and Kaplan, 1989; Ulrich et al., 1991; Berman et al., 2008; Bratman et al., 2012; Markevych et al., 2017;

Twohig-Bennett and Jones, 2018). A recent study highlighted the relevance of environmental interventions by showing that individuals frequenting urban environments with few green resources and an increased risk for mental illness are particularly receptive of the presence of urban green space (Tost et al., 2019). Some further evidence suggests that being exposed to real green and blue space induces psychophysiological and behavioral responses that can be differentiated from those induced by the same environments when reproduced by visual media (Huang, 2009; Huang et al., 2019). Similarly, a recent meta-analysis showed that real natural settings benefit mood to a greater degree than simulated settings (Browning et al., 2020).

To date, the relationship between the presence of residential natural spaces and a lower risk for psychosis has been investigated by few studies. Boers et al. (2018) showed that psychotic patients had a significantly lower amounts of available green space (agricultural areas, natural areas, and artificially installed greenery) but not blue space near their residence, while controlling for age, gender, urbanicity, and socioeconomic status. The same study did not find any significant relationship between green space and the length of stay in a psychiatric ward as a measure of illness severity. However, because no other measures of illness severity were included, further studies may need to consider more direct measures as well, including illness impact and symptomatology. A nation-wide, population-based study including more than 900,000 people showed that a decreased presence of green space near one's residence during childhood (calculated as the normalized difference vegetation index, NDVI, based on remote sensing satellite images) was associated with higher incidence rate ratios for many psychiatric disorders, including schizophrenia and related psychotic disorders (Engemann et al., 2019a). A dose-response relationship over time was also observed in this study, and the lowest levels of green space were associated with up to a 55% higher risk of psychiatric disorders. Additionally, when adjusting for urbanization, parents' socioeconomic status, family history, parental age, and municipal socioeconomic factors, these effects remained significant for most disorders. Another nation-wide population-based study by the same group focusing on schizophrenia further showed a dose-response relationship between the amount of residential green space present during childhood (NDVI), but not green space heterogeneity, and the risk of developing schizophrenia later in life (Engemann et al., 2018). Also, in this case, the results remained stable after adjustment for urbanization, age, sex, and socioeconomic status. Finally, in a series of follow-up studies, Engemann et al. (2019b) more specifically associated agricultural areas and near-natural green and blue space with lower schizophrenia rates as compared to urban areas, whereas vegetation density (NVDI) was negatively associated with schizophrenia rates in a dose-response manner independently for urban and agricultural areas. Moreover, based on hazard ratios, additive effects on schizophrenia risk were found for childhood green space exposure (NVDI close to residence based on remote sensing satellite images) and genetic liability, while an interaction between these factors could not be detected (Engemann et al., 2020). Taken together, these epidemiological results suggest that the presence of and access to natural surroundings in rural and urban areas may reflect a modulatory environmental factor that contributes to the prevention of psychosis and that green space effects may be disentangled from urbanicity and genetic effects.

DISRUPTED SELF-PROCESSING IS A CORE FEATURE OF PSYCHOSIS

One of the questions that is derived from these studies is "What are the critical aspects of psychosis that might be influenced by green space?" From a historical, psychopathological perspective, schizophrenia and related psychotic disorders have been described as self-disorders (Raballo et al., 2011). Building on these early insights, more recently, psychosis has been characterized as a complexity of self-disturbances that is generally described by an exaggerated self-consciousness and a disrupted sense of owning one's personal perceptions and thoughts (Sass and Parnas, 2003; Nelson et al., 2014). Because self-disturbances are often reported as subclinical phenomena that have already occurred prior to the onset of psychosis, remain stable after the attenuation of frank psychotic symptoms, and are highly predictive of conversion to psychosis, self-disturbances are commonly considered to reflect the core features of psychosis (Schultze-Lutter, 2009; Nelson et al., 2012). These properties of self-disturbances make them interesting targets for preventive intervention programs. Indeed, as reviewed above, green space may positively act on the mechanisms underlying psychosis onset during childhood.

To develop a more concrete understanding of the exact nature of self-disturbances in psychosis, it is useful to take a closer look at the psychological structure of the self-concept. The self and its disturbance have been increasingly portrayed from multiple perspectives in psychology and cognitive neuroscience. A major distinction is that between intrinsic and extrinsic self-processes (Gallagher, 2000; Vanhaudenhuyse et al., 2011), which can be traced to the self-aspects of the "Me," as the conscious person who is known by himself or herself (e.g., "this is me"), and the "I," who experiences and interacts with the environment (e.g., "I did that"), as described by James (1890). Specifically, intrinsic self-processing refers to the perception of information as belonging to oneself or as personally relevant, which allows self-reflection and experiencing a sense of identity (Damasio, 1999; Northoff and Bermpohl, 2004; van der Meer et al., 2010). This is mainly an internally directed process that integrates stimuli and thoughts with inner information from memory, personal narrative, and interoception and is related to emotional evaluation through the link with transient bodily states (Northoff and Panksepp, 2008; van der Meer et al., 2010; Qin and Northoff, 2011). In contrast, extrinsic self-processing regards the experience of oneself as the source of one's own actions and their consequences, that is, the perception of oneself as an entity with a sense of agency (Gallagher, 2000; Haggard, 2017). It can be conceived of as an externally directed process based on the experience of one's

intentional control over the environment through action (Jeannerod, 2003; Gallese and Sinigaglia, 2010). Action-related processes that could be involved include multisensory integration, self-monitoring, and sensorimotor predictions (Blanke, 2012). For instance, the integration of predicted somatosensory, motor, visual, and proprioceptive perceptions with the actual multisensory action consequences is crucial for a coherent self-experience during intentional behavior (Frith et al., 2000; van Kemenade et al., 2019).

This literature suggests that the self is composed of distinguishable but complementary processes. Such processes have been associated with largely distinct brain networks (Vanhaudenhuyse et al., 2011). However, in order to permit self-awareness, the networks involved in intrinsic and extrinsic self-processing (e.g., default mode, sensorimotor, attention, and executive networks) likely interact (Molnar-Szakacs and Uddin, 2013), possibly with an additional modulatory role for the salience network in the insula (Menon and Uddin, 2010). Indeed, recent empirical findings from neuroimaging (Di Plinio et al., 2020) suggest that intrinsic and extrinsic self-processes constitute a multidimensional phenomenon that emerges from a bidirectional interaction between an internal self and its external environment, where such interactions could be facilitated by efficient information exchange and integration across intrinsic and extrinsic self-networks in the brain.

Considering psychosis from this perspective, it can be proposed that anomalous intrinsic and extrinsic self-processes, as well as their functional imbalance, could explain self-disturbances. In particular, it has been proposed that the experience of a disrupted sense of self in its reciprocal interaction with the environment in psychosis could be explained by the fragmented functioning of intrinsic and extrinsic self-networks (Ebisch and Aleman, 2016). Furthermore, a biopsychological neural model has been proposed to describe how psychotic symptoms can be explained *via* a disequilibrium of network states and interference between network activities due to impaired auto-excitation and collateral inhibition (Looijestijn et al., 2015). As a consequence, at the phenomenological level, the distinction between internally and externally generated information may blur, leading to impaired self-recognition, depersonalization, and the tendency to experience one's thoughts, internal speech, or actions as belonging to an external agent or force, rather than oneself (Kircher and Leube, 2003; Nelson et al., 2009; Waters et al., 2012). Because whether and how the beneficial effects of natural surroundings on psychosis can be related to these self-disturbances remain poorly understood, attempts to clarify this issue would require examining the way in which environmental factors associated with natural spaces affect the cognitive and neural mechanisms underlying self-related processing.

CAN GREEN SPACE IMPROVE SELF-PROCESSING?

To address this particular question in more detail, a literature search was performed for articles empirically investigating the relationship between green space and self-processing. PubMed and Google Scholar were screened for peer-reviewed articles published from January 1990 to June 2020, using the terms "self" AND "nature experience" OR "nature exposure" OR "green space" OR "natural space." Similar searches were performed for studies considering self-disturbances, using the terms "psychosis" OR "schizophrenia" AND "self" AND "nature experience" OR "nature exposure" OR "green space" OR "natural space." Articles that resulted from these searches and relevant references cited in those articles were reviewed, and this selection was further completed by searches in the author's personal files, where articles published in English were included. The literature search results showed that this specific issue received limited attention. After close inspection of the articles' content, seven empirical studies were found to be relevant to the present perspective article (i.e., Hunter et al., 2010; Lederbogen et al., 2011; Margalit and Ben-Ari, 2014; Bratman et al., 2015; Hayhurst et al., 2015; Fuller et al., 2017; O'Brien and Lomas, 2017), which are discussed below.

A recent systematic review (Mygind et al., 2019) concluded that there is conditional evidence in children and adolescents for a beneficial effect on the part of diversified nature experiences on self-efficacy, a concept closely related to the sense of agency, though this was based on studies with a note regarding the risk of biased results (mountain and lake activities in O'Brien and Lomas, 2017; wilderness therapy intervention in Margalit and Ben-Ari, 2014; outdoor residential experiences in countryside with woodland in Fuller et al., 2017; and developmental sail voyage experiences in Hayhurst et al., 2015, as well as in Hunter et al., 2010). Similarly positive effects were reported for self-esteem, resilience, and academic and cognitive performance, whereas evidence regarding self-concept, problem solving, and mood were inconclusive (see Mygind et al., 2019). In addition, some cognitive neuroscience studies began to provide relevant insights into the cognitive and neural mechanisms underlying the association between green space and self-processing. In a cross-sectional, functional magnetic resonance imaging (fMRI) study involving non-clinical, healthy individuals, Lederbogen et al. (2011) dissociated the impact of urban upbringing and city living on brain activity when participants were exposed to social evaluative stress. Their results showed that current city living was linked to increased amygdala activity, whereas urban upbringing affected the perigenual anterior cingulate cortex. In another fMRI study, Bratman et al. (2015) investigated the link between nature experiences (a 90-min walk in green space consisting of grassland with scattered trees, shrubs, and fauna, as well as views of hills and a bay, vs. an urban walk in a busy city thoroughfare) and rumination in a sample of non-clinical, healthy participants. Relevantly, rumination can be considered a dysfunctional self-process defined as a maladaptive pattern of self-referential thought and self-relational emotions. Behaviorally, the results showed that the nature experiences, as compared to the urban experiences, led to decreased rumination. Neuro-functionally, nature experiences, as compared to urban experiences, led to decreased neural activity (cerebral blood flow) in the

subgenual prefrontal cortex and perigenual anterior cingulate cortex during rumination.

Notably, both fMRI studies (Lederbogen et al., 2011; Bratman et al., 2015) linked the ventromedial frontal cortex, specifically, the perigenual anterior cingulate cortex, to urbanicity or green experiences. Of interest, the perigenual anterior cingulate cortex has been identified as a crucial brain structure for many self-related processes that comprise self-continuity, self-consciousness, self-reflection, self-regulation, and self-other similarity (van der Meer et al., 2010; Northoff, 2017; Scalabrini et al., 2019). The perigenual anterior cingulate cortex is located in the default mode network, which is characterized by high levels of activity when individuals are involved in free thought, such as mind-wandering (Northoff et al., 2010). Moreover, the perigenual anterior cingulate cortex is a key node within a network that integrates information from the memory and interoception and is affected by its interactions with the anterior insula, medial temporal regions, and posterior cingulate cortex (Northoff and Panksepp, 2008). Regarding its involvement in psychosis, fMRI experiments applying explicit tasks of self-evaluation reported deficient intrinsic self-processing in the perigenual anterior cingulate cortex and adjacent ventromedial prefrontal cortices in patients with schizophrenia as compared to healthy controls (Modinos et al., 2011; Kühn and Gallinat, 2013; van der Meer et al., 2013; Tan et al., 2015).

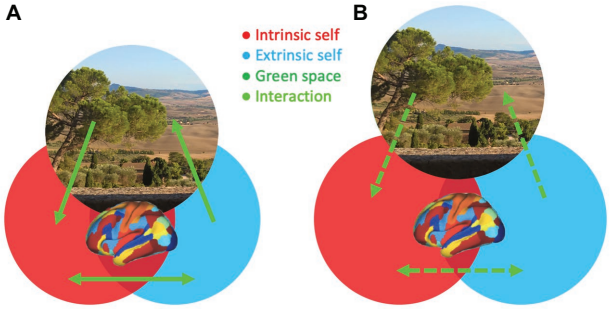


FIGURE 1 | A hypothetical model illustrating the modulation of the integrity of self-related processing, which is impaired in psychosis, through brain network interactions by green space. The experience of natural surroundings (green space area) in one's living environment (**A**; increased interactions and overlap between green space and self-aspects) or being distantiated from natural surroundings during daily life (**B**; decreased interactions and overlap between green space and self-aspects) is associated with more or less integration of intrinsic (red; internally directed) and extrinsic (blue; externally directed) self-aspects, respectively. The green space photo depicts a view on Val d'Orcia in Tuscany, Italy, an UNESCO World Heritage landscape developed in the 14th and 15th centuries to idealize a well-balanced dialog between humans and nature.

DISCUSSION

The evidence reviewed above begins to provide new insights into the mechanisms that may explain how green space exposure can reduce psychosis risk. On the one hand, epidemiological studies consistently show that green space exposure decreases the incidence of psychosis, whereas urbanicity is associated with an increased risk for psychosis. On the other hand, cognitive and neuroscience findings preliminarily suggest that exposure to and experiences of green space, as well as blue space, could have beneficial effects on self-related processing. Based on these findings, it is proposed that self-processing and related brain network interactions may constitute a relevant mechanism that mediates between green space exposure and psychosis risk (**Figure 1**).

Because this hypothesis has received very little or no attention in published empirical investigations using clinical samples and specific reports of positive and null results regarding the link between green space and psychosis-related self-disturbances are lacking, novel studies are encouraged to directly and systematically investigate how the environmental planning of green space could comprehensively facilitate intrinsic and extrinsic self-experiences in non-clinical samples, as well as in psychotic disorders or high-risk populations. The literature reviewed in this article provides concrete perspectives for further investigation. For example, psychological and neuroscientific studies with high levels of control over experimental conditions and modulating factors should reproduce the epidemiological findings. Moreover, definite issues for future studies of the health benefits of green space include the modulating effects of particular types and features of green space and the kind of interactions individuals have with green space on intrinsic/extrinsic self-processing and psychosis risk.

Further limitations of the present review must be mentioned. Because it focuses specifically on the risk-reducing effects of green space for psychosis, it is important to remember that the onset of psychosis depends on a multiplicity of factors and events. The lack of green space exposure is one out of many characteristics of urbanicity that contribute to psychosis risk, in addition to other physical, social, familiar, occupational, and relationship variables (van Os et al., 2010; Brown, 2011; Schmitt et al., 2014). Green space is a piece of an intricated puzzle of interactions between numerous environmental variables, as well as genetic factors, that explains the variance in psychosis onset. It will be crucial for future studies to increase our understanding of how the effects of green space can be embedded in this full complexity of factors, both to explain and prevent psychosis onset (Tsuang, 2000; Howes et al., 2004; Meyer-Lindenberg and Tost, 2012). Finally, in this article, the effect of green space on psychosis prevention is examined in the context of self-disturbances, which are the core features of psychosis and sensitive predictors of its onset, while the relationships with positive symptoms, social impairments, and reduced insight into illness are not considered. It would be relevant to expand this investigating by including these domains too.

In conclusion, self-awareness is a continuous, integrative phenomenon that emerges from a stream of sensory perceptions, actions, bodily states, memories, motivations, thoughts, and imaginations. These processes support a coherent sense of self with a past (autobiographical memories), a present (actual experiences), and a future (prospective thoughts). Green space may be an environment with auspicious qualities that can

modulate mental and bodily self-experiences over time and space on various scales, transforming itself continuously as it evolves and changes over time, while at the same time remaining a familiar environment (Kuo, 2015; Northoff and Huang, 2017). It is therefore hypothesized that green space potentially reduces psychosis risk by offering a dynamic environment that within a complex architecture of environmental and genetic factors, supports a stable, multidimensional self-experience over time. Enhancing our knowledge about the exact relationships between green space experiences and multidimensional self-processing would help in environmental planning, especially in urban areas, to optimize the positive impact of green space on mental health and illness prevention.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work, being responsible for reviewing the literature, developing the concept, and writing the manuscript, and has approved it for publication.

FUNDING

This work was supported by the "Departments of Excellence 2018–2022" initiative of the Italian Ministry of Education, University and Research for the Department of Neuroscience, Imaging and Clinical Sciences (DNISC) of the University of Chieti-Pescara.

REFERENCES

Berman, M. G., Jonides, J., and Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychol. Sci.* 19, 1207–1212. doi: 10.1111/j.1467-9280.2008.02225.x

Blanke, O. (2012). Multisensory brain mechanisms of bodily self-consciousness. *Nat. Rev. Neurosci.* 13, 556–571. doi: 10.1038/nrn3292

Boers, S., Hagoort, K., Scheepers, F., and Helbich, M. (2018). Does residential green and blue space promote recovery in psychotic disorders? A cross-sectional study in the province of Utrecht, the Netherlands. *Int. J. Environ. Res. Public Health* 15:2195. doi: 10.3390/ijerph15102195

Bratman, G. N., Hamilton, J. P., and Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Ann. N. Y. Acad. Sci.* 1249, 118–136. doi: 10.1111/j.1749-6632.2011.06400.x

Bratman, G. N., Hamilton, J. P., Hahn, K. S., Daily, G. C., and Gross, J. J. (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proc. Natl. Acad. Sci. U. S. A.* 112, 8567–8572. doi: 10.1073/pnas.1510459112

Brown, A. S. (2011). The environment and susceptibility to schizophrenia. *Prog. Neurobiol.* 93, 23–58. doi: 10.1016/j.pneurobio.2010.09.003

Browning, M. H., Shipley, N., McAnirlin, O., Becker, D., Yu, C. P., Hartig, T., et al. (2020). An actual natural setting improves mood better than its virtual counterpart: a meta-analysis of experimental data. *Front. Psychol.* 11:2200. doi: 10.3389/fpsyg.2020.02200

Cohen-Cline, H., Turkheimer, E., and Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *J. Epidemiol. Community Health* 69, 523–529. doi: 10.1136/jech-2014-204667

Damasio, A. R. (1999). *The feeling of what happens: Body and emotion in the making of consciousness*. New York: Houghton Mifflin Harcourt.

Di Plinio, S., Perrucci, M. G., Aleman, A., and Ebisch, S. J. (2020). I am me: brain systems integrate and segregate to establish a multidimensional sense of self. *Neuroimage* 205:116284. doi: 10.1016/j.neuroimage.2019.116284

Dragt, S., Nieman, D. H., Veltman, D., Becker, H. E., van de Fliert, R., de Haan, L., et al. (2011). Environmental factors and social adjustment as predictors of a first psychosis in subjects at ultra high risk. *Schizophr. Res.* 125, 69–76. doi: 10.1016/j.schres.2010.09.007

Ebisch, S. J., and Aleman, A. (2016). The fragmented self: imbalance between intrinsic and extrinsic self-networks in psychotic disorders. *Lancet Psychiatry* 3, 784–790. doi: 10.1016/S2215-0366(16)00045-6

Engemann, K., Pedersen, C. B., Arge, L., Tsirogiannis, C., Mortensen, P. B., and Svenning, J. C. (2018). Childhood exposure to green space – a novel risk-decreasing mechanism for schizophrenia? *Schizophr. Res.* 199, 142–148. doi: 10.1016/j.schres.2018.03.026

Engemann, K., Pedersen, C. B., Arge, L., Tsirogiannis, C., Mortensen, P. B., and Svenning, J. C. (2019a). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proc. Natl. Acad. Sci. U. S. A.* 116, 5188–5193. doi: 10.1073/pnas.1807504116

Engemann, K., Svenning, J. C., Arge, L., Brandt, J., Geels, C., Mortensen, P. B., et al. (2019b). Natural surroundings in childhood are associated with lower schizophrenia rates. Schizophr. Res. doi: 10.1016/j.schres.2019.10.012 (in press).

Engemann, K., Pedersen, C. B., Agerbo, E., Arge, L., Børglum, A. D., Erikstrup, C., et al. (2020). Association between childhood green space, genetic liability, and the incidence of Schizophrenia. *Schizophr. Bull.* doi: 10.1093/schbul/sbaa058 [Epub ahead of print]

Fazel, S., Wolf, A., Palm, C., and Lichtenstein, P. (2014). Violent crime, suicide, and premature mortality in patients with schizophrenia and related disorders: a 38-year total population study in Sweden. *Lancet Psychiatry* 1, 44–54. doi: 10.1016/S2215-0366(14)70223-8

Frith, C. D., Blakemore, S. J., and Wolpert, D. M. (2000). Explaining the symptoms of schizophrenia: abnormalities in the awareness of action. *Brain Res. Brain Res. Rev.* 31, 357–363. doi: 10.1016/s0165-0173(99)00052-1

Fuller, C., Powell, D., and Fox, S. (2017). Making gains: the impact of outdoor residential experiences on students' examination grades and self-efficacy. *Educ. Rev.* 69, 232–247. doi: 10.1080/00131911.2016.1199538

Fusar-Poli, P., Davies, C., Solmi, M., Brondino, N., De Micheli, A., Kotlicka-Antczak, M., et al. (2019). Preventive treatments for psychosis: umbrella review (just the evidence). *Front. Psychol.* 10:764. doi: 10.3389/fpsyt.2019.00764

Fusar-Poli, P., Tantardini, M., De Simone, S., Ramella-Cravaro, V., Oliver, D., Kingdon, J., et al. (2017). Deconstructing vulnerability for psychosis: meta-analysis of environmental risk factors for psychosis in subjects at ultra high-risk. *Eur. Psychiatry* 40, 65–75. doi: 10.1016/j.eurpsy.2016.09.003

Gallagher, S. (2000). Philosophical conceptions of the self: implications for cognitive science. *Trends Cogn. Sci.* 4, 14–21. doi: 10.1016/S1364-6613(99)01417-5

Gallese, V., and Sinigaglia, C. (2010). The bodily self as power for action. *Neuropsychologia* 48, 746–755. doi: 10.1016/j.neuropsychologia.2009.09.038

Haggard, P. (2017). Sense of agency in the human brain. *Nat. Rev. Neurosci.* 18, 196–207. doi: 10.1038/nrn.2017.14

Hartig, T. (1993). Nature experience in transactional perspective. *Landsc. Urban Plan.* 25, 17–36. doi: 10.1016/0169-2046(93)90120-3

Hartig, T., Mitchell, R., de Vries, S., and Frumkin, H. (2014). Nature and health. *Annu. Rev. Public Health* 35, 207–228. doi: 10.1146/annurev-publhealth-032013-182443

Hayhurst, J., Hunter, J. A., Kafka, S., and Boyes, M. (2015). Enhancing resilience in youth through a 10-day developmental voyage. *J. Adventure Educ. Outdoor Learn.* 15, 40–52. doi: 10.1080/14729679.2013.843143

Howes, O. D., McDonald, C., Cannon, M., Arseneault, L., Boydell, J., and Murray, R. M. (2004). Pathways to schizophrenia: the impact of environmental factors. *Int. J. Neuropsychopharmacol.* 7, S7–S13. doi: 10.1017/S1461145704004122

Huang, S. C. L. (2009). The validity of visual surrogates for representing waterscapes. *Landsc. Res.* 34, 323–335. doi: 10.1080/01426390902867984

Huang, S. C. L., Chiang, N. C., Kuo, N. F., and Chen, Y. J. (2019). An exploratory approach for using EEG to examine person-environment interaction. *Landsc. Res.* 44, 702–715. doi: 10.1080/01426397.2018.1548586

Hunter, J. A., Kafka, S., Hayhurst, J., Clark, H., Dickerson, D., Harold, G., et al. (2010). Increased self-efficacy following a ten-day developmental voyage. *J. Child Adolesc. Ment. Health* 22, 63–65. doi: 10.2989/17280583.2010.496943

James, W. (1890). *Principles of psychology. Vol. 2*. New York: Henry Holt and Company, 283–324.

James, P., Banay, R. F., Hart, J. E., and Laden, F. (2015). A review of the health benefits of greenness. *Curr. Epidemiol. Rep.* 2, 131–142. doi: 10.1007/s40471-015-0043-7

Jeannerod, M. (2003). The mechanism of self-recognition in humans. *Behav. Brain Res.* 142, 1–15. doi: 10.1016/s0166-4328(02)00384-4

Kaplan, R., and Kaplan, S. (1989). *The experience of nature: A psychological perspective*. New York: Cambridge University Press Archive.

Kelly, B. D., O'Callaghan, E., Waddington, J. L., Feeney, L., Browne, S., Scully, P. J., et al. (2010). Schizophrenia and the city: a review of literature and prospective study of psychosis and urbanicity in Ireland. *Schizophr. Res.* 116, 75–89. doi: 10.1016/j.schres.2009.10.015

Kircher, T. T., and Leube, D. T. (2003). Self-consciousness, self-agency, and schizophrenia. *Conscious. Cogn.* 12, 656–669. doi: 10.1016/s1053-8100(03)00071-0

Krabbendam, L., and van Os, J. (2005). Schizophrenia and urbanicity: a major environmental influence—conditional on genetic risk. *Schizophr. Bull.* 31, 795–799. doi: 10.1093/schbul/sbi060

Kühn, S., and Gallinat, J. (2013). Resting-state brain activity in schizophrenia and major depression: a quantitative meta-analysis. *Schizophr. Bull.* 39, 358–365. doi: 10.1093/schbul/sbr151

Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front. Psychol.* 6:1093. doi: 10.3389/fpsyg.2015.01093

Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., et al. (2011). City living and urban upbringing affect neural social stress processing in humans. *Nature* 474, 498–501. doi: 10.1038/nature10190

Lewis, G., David, A., Andréassson, S., and Allebeck, P. (1992). Schizophrenia and city life. *Lancet* 340, 137–140. doi: 10.1016/0140-6736(92)93213-7

Looijestijn, J., Blom, J. D., Aleman, A., Hoek, H. W., and Goekoop, R. (2015). An integrated network model of psychotic symptoms. *Neurosci. Biobehav. Rev.* 59, 238–250. doi: 10.1016/j.neubiorev.2015.09.016

Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., and Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *J. Epidemiol. Community Health* 63, 967–973. doi: 10.1136/jech.2008.079038

Margalit, D., and Ben-Ari, A. (2014). The effect of wilderness therapy on adolescents' cognitive autonomy and self-efficacy: results of a non-randomized trial. *Child Youth Care Forum* 43, 181–194. doi: 10.1007/s10566-013-9234-x

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., et al. (2017). Exploring pathways linking greenspace to health: theoretical and methodological guidance. *Environ. Res.* 158, 301–317. doi: 10.1016/j.envres.2017.06.028

McGorry, P. D., Nelson, B., Amminger, G. P., Bechdolf, A., Francey, S. M., Berger, G., et al. (2009). Intervention in individuals at ultra-high risk for psychosis: a review and future directions. *J. Clin. Psychiatry* 70, 1206–1212. doi: 10.4088/JCP.08r04472

McGrath, J., Saha, S., Welham, J., El Saadi, O., MacCauley, C., and Chant, D. (2004). A systematic review of the incidence of schizophrenia: the distribution of rates and the influence of sex, urbanicity, migrant status and methodology. *BMC Med.* 2:13. doi: 10.1186/1741-7015-2-13

Menon, V., and Uddin, L. Q. (2010). Saliency, switching, attention and control: a network model of insula function. *Brain Struct. Funct.* 214, 655–667. doi: 10.1007/s00429-010-0262-0

Meyer-Lindenberg, A., and Tost, H. (2012). Neural mechanisms of social risk for psychiatric disorders. *Nat. Neurosci.* 15, 663–668. doi: 10.1038/nn.3083

Minkowski, E. (1927). "La schizophrénie" in *Psychopathologie des schizoïdes et des schizophrénes*. ed. Payot (Paris).

Modinos, G., Renken, R., Ormel, J., and Aleman, A. (2011). Self-reflection and the psychosis-prone brain: an fMRI study. *Neuropsychology* 25, 295–305. doi: 10.1037/a0021747

Molnar-Szakacs, I., and Uddin, L. Q. (2013). Self-processing and the default mode network: interactions with the mirror neuron system. *Front. Hum. Neurosci.* 7:571. doi: 10.3389/fnhum.2013.00571

Mygind, L., Kjeldsted, E., Hartmeyer, R., Mygind, E., Bølling, M., and Bentsen, P. (2019). Mental, physical and social health benefits of immersive nature-experience for children and adolescents: a systematic review and quality assessment of the evidence. *Health Place* 58:102136. doi: 10.1016/j.healthplace.2019.05.014

Nelson, B., Fornito, A., Harrison, B. J., Yücel, M., Sass, L. A., Yung, A. R., et al. (2009). A disturbed sense of self in the psychosis prodrome: linking phenomenology and neurobiology. *Neurosci. Biobehav. Rev.* 33, 807–817. doi: 10.1016/j.neubiorev.2009.01.002

Nelson, B., Parnas, J., and Sass, L. A. (2014). Disturbance of minimal self (ipseity) in schizophrenia: clarification and current status. *Schizophr. Bull.* 40, 479–482. doi: 10.1093/schbul/sbu034

Nelson, B., Thompson, A., and Yung, A. R. (2012). Basic self-disturbance predicts psychosis onset in the ultra high risk for psychosis "prodromal" population. *Schizophr. Bull.* 38, 1277–1287. doi: 10.1093/schbul/sbs007

Newbury, J., Arseneault, L., Caspi, A., Moffitt, T. E., Odgers, C. L., and Fisher, H. L. (2016). Why are children in urban neighborhoods at increased risk for psychotic symptoms? Findings from a UK longitudinal cohort study. *Schizophr. Bull.* 42, 1372–1383. doi: 10.1093/schbul/sbw052

Northoff, G. (2017). Personal identity and cortical midline structure (CMS): do temporal features of CMS neural activity transform into "self-continuity"? *Psychol. Inq.* 28, 122–131. doi: 10.1080/1047840X.2017.1337396

Northoff, G., and Bermpohl, F. (2004). Cortical midline structures and the self. *Trends Cogn. Sci.* 8, 102–107. doi: 10.1016/j.tics.2004.01.004

Northoff, G., and Huang, Z. (2017). How do the brain's time and space mediate consciousness and its different dimensions? Temporo-spatial theory of consciousness (TTC). *Neursci. Biobehav. Rev.* 80, 630–645. doi: 10.1016/j.neubiorev.2017.07.013

Northoff, G., and Panksepp, J. (2008). The trans-species concept of self and the subcortical–cortical midline system. *Trends Cogn. Sci.* 12, 259–264. doi: 10.1016/j.tics.2008.04.007

Northoff, G., Qin, P., and Nakao, T. (2010). Rest-stimulus interaction in the brain: a review. *Trends Neurosci.* 33, 277–284. doi: 10.1016/j.tins.2010.02.006

O'Brien, K., and Lomas, T. (2017). Developing a growth mindset through outdoor personal development: can an intervention underpinned by psychology increase the impact of an outdoor learning course for young people? *J. Adventure Educ. Outdoor Learn.* 17, 133–147. doi: 10.1080/14729679.2016.1232199

Parnas, J., and Henriksen, M. G. (2014). Disordered self in the schizophrenia spectrum: a clinical and research perspective. *Harv. Rev. Psychiatry* 22, 251–265. doi: 10.1097/HRP.0000000000000040

Pedersen, C. B., and Mortensen, P. B. (2001). Evidence of a dose-response relationship between urbanicity during upbringing and schizophrenia risk. *Arch. Gen. Psychiatry* 58, 1039–1046. doi: 10.1001/archpsyc.58.11.1039

Pries, L. K., Guloksuz, S., Ten Have, M., de Graaf, R., van Dorsselaer, S., Gunther, N., et al. (2018). Evidence that environmental and familial risks for psychosis additively impact a multidimensional subthreshold psychosis syndrome. *Schizophr. Bull.* 44, 710–719. doi: 10.1093/schbul/sby051

Qin, P., and Northoff, G. (2011). How is our self related to midline regions and the default-mode network? *Neuroimage* 57, 1221–1233. doi: 10.1016/j.neuroimage.2011.05.028

Raballo, A., Sæbye, D., and Parnas, J. (2011). Looking at the schizophrenia spectrum through the prism of self-disorders: an empirical study. *Schizophr. Bull.* 37, 344–351. doi: 10.1093/schbul/sbp056

Rössler, W., Salize, H. J., van Os, J., and Riecher-Rössler, A. (2005). Size of burden of schizophrenia and psychotic disorders. *Eur. Neuropsychopharmacol.* 15, 399–409. doi: 10.1016/j.euroneuro.2005.04.009

Ruhrmann, S., Schultze-Lutter, F., Salokangas, R. K., Heinimaa, M., Linszen, D., Dingemans, P., et al. (2010). Prediction of psychosis in adolescents and young adults at high risk: results from the prospective European prediction of psychosis study. *Arch. Gen. Psychiatry* 67, 241–251. doi: 10.1001/archgenpsychiatry.2009.206

Sarkar, C., Webster, C., and Gallacher, J. (2018). Residential greenness and prevalence of major depressive disorders: a cross-sectional, observational, associational study of 94 879 adult UK biobank participants. *Lancet Planet. Health* 2, e162–e173. doi: 10.1016/S2542-5196(18)30051-2

Sass, L. A., and Parnas, J. (2003). Schizophrenia, consciousness, and the self. *Schizophr. Bull.* 29, 427–444. doi: 10.1093/oxfordjournals.schbul.a007017

Scalabrini, A., Ebisch, S. J., Huang, Z., Di Plinio, S., Perrucci, M. G., Romani, G. L., et al. (2019). Spontaneous brain activity predicts task-evoked activity during animate versus inanimate touch. *Cereb. Cortex* 29, 4628–4645. doi: 10.1093/cercor/bhy340

Schmitt, A., Malchow, B., Hasan, A., and Fallkai, P. (2014). The impact of environmental factors in severe psychiatric disorders. *Front. Neurosci.* 8:19. doi: 10.3389/fnins.2014.00019

Schultze-Lutter, F. (2009). Subjective symptoms of schizophrenia in research and the clinic: the basic symptom concept. *Schizophr. Bull.* 35, 5–8. doi: 10.1093/schbul/sbn139

Smigielski, L., Jagannath, V., Rössler, W., Walitza, S., and Grünblatt, E. (2020). Epigenetic mechanisms in schizophrenia and other psychotic disorders: a systematic review of empirical human findings. *Mol. Psychiatry* 25, 1718–1748. doi: 10.1038/s41380-019-0601-3

Smith, G., Cirach, M., Swart, W., Dėdelė, A., Gidlow, C., van Kempen, E., et al. (2017). Characterisation of the natural environment: quantitative indicators across Europe. *Int. J. Health Geogr.* 16:16. doi: 10.1186/s12942-017-0090-z

Sundquist, K., Frank, G., and Sundquist, J. A. N. (2004). Urbanisation and incidence of psychosis and depression: follow-up study of 4.4 million women and men in Sweden. *Br. J. Psychiatry* 184, 293–298. doi: 10.1192/bjp.184.4.293

Sussman, A., and Hollander, J. B. (2014). *Cognitive architecture: Designing for how we respond to the built environment*. New York: Routledge.

Tan, S., Zhao, Y., Fan, F., Zou, Y., Jin, Z., Zen, Y., et al. (2015). Brain correlates of self-evaluation deficits in schizophrenia: a combined functional and structural MRI study. *PLoS One* 10:e0138737. doi: 10.1371/journal.pone.0138737

Torrey, E. F., and Yolken, R. H. (2019). Schizophrenia as a pseudogenetic disease: a call for more gene-environmental studies. *Psychiatry Res.* 278, 146–150. doi: 10.1016/j.psychres.2019.06.006

Tost, H., Reichert, M., Braun, U., Reinhard, I., Peters, R., Lautenbach, S., et al. (2019). Neural correlates of individual differences in affective benefit of real-life urban green space exposure. *Nat. Neurosci.* 22, 1389–1393. doi: 10.1038/s41593-019-0451-y

Tsuang, M. (2000). Schizophrenia: genes and environment. *Biol. Psychiatry* 47, 210–220. doi: 10.1016/S0006-3223(99)00289-9

Twedt, E., Rainey, R. M., and Proffitt, D. R. (2016). Designed natural spaces: informal gardens are perceived to be more restorative than formal gardens. *Front. Psychol.* 7:88. doi: 10.3389/fpsyg.2016.00088

Twohig-Bennett, C., and Jones, A. (2018). The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. *Environ. Res.* 166, 628–637. doi: 10.1016/j.envres.2018.06.030

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

United Nations, Department of Economic and Social Affairs, Population Division (2014). World urbanization prospects: The 2014 revision, highlights (ST/ESA/SER.A/352). Available at: https://esa.un.org/unpd/wup/Publications/Files/WUP2014-Highlights.pdf (Accessed January 30, 2020).

van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., and Maas, J. (2015). Health benefits of green spaces in the living environment: a systematic review of epidemiological studies. *Urban For. Urban Green.* 14, 806–816. doi: 10.1016/j.ufug.2015.07.008

van der Meer, L., Costafreda, S., Aleman, A., and David, A. S. (2010). Self-reflection and the brain: a theoretical review and meta-analysis of neuroimaging studies with implications for schizophrenia. *Neursci. Biobehav. Rev.* 34, 935–946. doi: 10.1016/j.neubiorev.2009.12.004

van der Meer, L., de Vos, A. E., Stiekema, A. P., Pijnenborg, G. H., van Tol, M. J., Nolen, W. A., et al. (2013). Insight in schizophrenia: involvement of self-reflection networks? *Schizophr. Bull.* 39, 1288–1295. doi: 10.1093/schbul/sbs122

Vanhaudenhuyse, A., Demertzi, A., Schabus, M., Noirhomme, Q., Bredart, S., Boly, M., et al. (2011). Two distinct neuronal networks mediate the awareness of environment and of self. *J. Cogn. Neurosci.* 23, 570–578. doi: 10.1162/jocn.2010.21488

van Kemenade, B. M., Arikan, B. E., Podranski, K., Steinsträter, O., Kircher, T., and Straube, B. (2019). Distinct roles for the cerebellum, angular gyrus, and middle temporal gyrus in action–feedback monitoring. *Cereb. Cortex* 29, 1520–1531. doi: 10.1093/cercor/bhy048

van Os, J., Kenis, G., and Rutten, B. (2010). The environment and schizophrenia. *Nature* 468, 203–212. doi: 10.1038/nature09563

van Os, J., and Linscott, R. J. (2012). Introduction: the extended psychosis phenotype—relationship with schizophrenia and with ultrahigh risk status for psychosis. *Schizophr. Bull.* 38, 227–230. doi: 10.1093/schbul/sbr188

van Os, J., Pedersen, C. B., and Mortensen, P. B. (2004). Confirmation of synergy between urbanicity and familial liability in the causation of psychosis. *Am. J. Psychiatry* 161, 2312–2314. doi: 10.1176/appi.ajp.161.12.2312

van Os, J., Reininghaus, U., and Meyer-Lindenberg, A. (2017). The search for environmental mechanisms underlying the expression of psychosis: introduction. *Schizophr. Bull.* 43, 283–286. doi: 10.1093/schbul/sbw178

Verheij, R. A., Maas, J., and Groenewegen, P. P. (2008). Urban—rural health differences and the availability of green space. *Eur. Urban Reg. Stud.* 15, 307–316. doi: 10.1177/0969776408095107

Völker, S., and Kistemann, T. (2011). The impact of blue space on human health and well-being–salutogenetic health effects of inland surface waters: a review. *Int. J. Hyg. Environ. Health* 214, 449–460. doi: 10.1016/j.ijheh.2011.05.001

Waters, F., Woodward, T., Allen, P., Aleman, A., and Sommer, I. (2012). Self-recognition deficits in schizophrenia patients with auditory hallucinations: a meta-analysis of the literature. *Schizophr. Bull.* 38, 741–750. doi: 10.1093/schbul/sbq144

White, M. P., Alcock, I., Wheeler, B. W., and Depledge, M. H. (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychol. Sci.* 24, 920–928. doi: 10.1177/0956797612464659

Conflict of Interest: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

PERSPECTIVE
published: 26 November 2020
doi: 10.3389/fpsyg.2020.597935

Adverse Childhood Experiences: The Protective and Therapeutic Potential of Nature

*Anna K. Touloumakos[1,2,3] and Alexia Barrable[4]**

[1] Department of Psychology, Panteion University, Athens, Greece, [2] Centre on Skills, Knowledge and Organisational Performance, Department of Education, University of Oxford, Oxford, United Kingdom, [3] Department of Education Sciences, Hellenic Open University, Patras, Greece, [4] School of Education and Social Work, University of Dundee, Dundee, United Kingdom

Adverse childhood experiences (ACEs) are prevalent in many western populations. Large studies have put the likelihood of having at least one ACE above 50% of the general population. ACEs and the associated experience of chronic stress, moreover, have been consistently linked with a variety of negative physical and psychological health outcomes across the lifespan from behavioral problems and cognitive difficulties early on, to greater chance of suffering from a mental health disorder and engaging in self destructing behaviors. The literature puts forward several protective factors, such as mother-child relations, parental health, and community engagement. In this perspective paper we put forward the potential of regular nature engagement as a possible additional protective factor. Nature's therapeutic potential has been well documented, for many psychopathologies and mental health difficulties. Yet studies looking at the protective and therapeutic potential of nature with people with ACEs are remarkably limited in numbers. In this perspective piece we conduct a search of the literature to find previous applications of nature as a protective or therapeutic intervention for people with ACEs. We highlight the gap in the current literature, and put forward various mechanisms of action that justify a closer exploration of this area in further research.

Keywords: adverse childhood experiences, trauma, psychopathology, nature, nature-based therapies, nature-based interventions, protective factors

OPEN ACCESS

Edited by:
Giuseppina Spano, University of Bari Aldo Moro, Italy

Reviewed by:
Blanca Silvia Fraijo-Sing, University of Sonora, Mexico
Simon Bell, University of Edinburgh, United Kingdom

****Correspondence:***
Alexia Barrable
a.barrable@dundee.ac.uk

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *22 August 2020*
Accepted: *03 November 2020*
Published: *26 November 2020*

Citation:
Touloumakos AK and Barrable A (2020) Adverse Childhood Experiences: The Protective and Therapeutic Potential of Nature. Front. Psychol. 11:597935. doi: 10.3389/fpsyg.2020.597935

INTRODUCTION

The term adverse and traumatic experiences was first used in the adverse childhood experiences (ACE) study conducted in the Kaiser Permanente Centers for Disease Control and Prevention back in the 1990s. ACEs include family abuse (physical, sexual, emotional), neglect (physical and emotional), and family dysfunction (domestic violence, substance abuse, mental illness, separation/divorce, imprisonment of family member) (Felitti et al., 1998). The term has been widely used since to refer to these 10 experiences, although additional adverse experiences have been acknowledged in the literature, such as for example economic adversity (see McLaughlin et al., 2012). ACEs have been acknowledged as an important public health issue: a recent large-scale United States study suggests that as many as the 61.55% of the participants report at least one ACE and 24.64% of the participants report three or more ACEs (Merrick et al., 2018). The unfavorable and pervasive impact of ACEs across the lifespan on physiological and psychobiological variables has been well documented (indicatively, Ford, 2005). Fortunately, the evidence also highlights protective factors for those at-risk or having

experienced ACEs, namely safe and nurturing relationships (Crouch et al., 2019) mother-partner relationship, family finances, parent health and wellness, community and neighborhood, and parent child relations (Walsh et al., 2020). Such factors can moderate the adverse effect of ACEs on mental and physical health and are an important factor when looking at promoting health and wellbeing across populations (Hughes et al., 2018).

In this perspective piece, we argue for the protective and therapeutic potential of nature in relation to ACEs. We first present a summary of possible negative effects of ACEs on development and well-being (see also, Purvis et al., 2013). We then highlight through two different literature searches that evidence on the therapeutic and protective potential of nature with ACEs is limited. Finally we present several mechanisms of action through which nature exposure and engagement could act as a significant protective factor with individuals having or at risk of ACEs.

Physiological Impact of ACEs

Berens et al. (2017) provide a comprehensive overview of disruptions documented among people with ACEs along five physiological axes that link to various impairments. For example, disruptions in brain structure and activity link to executive functioning and emotion regulation impairments; hypothalamic pituitary adrenal (HPA) hyper and hypo activity, and autonomic functioning, link similarly to cardiovascular disease, metabolic dysregulation, and psychopathology.

Ford (2009) explains how neurophysiological changes occur in the brain that experiences adversity (Berens et al., 2017 brain structure and activity axis). In particular, the stress response system of the brain is mobilized under stress conditions – perceived or real threat– to keep all body systems in balance; it does so via the autonomic nervous system. As a result, areas of the brain such as the brainstem and the amygdala within the limbic system are activated to ensure *survival*. Prolonged adversity means irreversible changes in the neurochemical systems too (Perry, 1994). Ultimately disruptions are noted in the neuroendocrine and the immune systems (Oral et al., 2016), for example, the overload of cortisol following activation of the HPA at first, that is then followed by lack of cortisol.

Psychological Impact of ACEs

The foundations of the neuroanatomical structure of the brain can be located in the genome, however, the experiences have a determining role in the patterns of learning and cognition - and the handling of all new information (Streeck-Fischer and van der Kolk, 2000, p. 908). At the emotional and behavioral sphere, the intermediation of the caregiver is key to emotional development. When caregivers are responsive and empathetic, and experiences positive, emotions (in this instance mostly positive) are experienced first on a physical level; then become verbal and mental (Kooiman et al. (2004). When caregivers are abusive and neglectful or environments emotionally deprived (in ACEs conditions), problems are noted in the area of regulation, spanning to severe forms of affect psychopathology (see for example, Kessler et al., 2010). PTSD is among the most common sequelae from early onset interpersonal trauma (Cloitre et al., 2005) although a linear and straightforward link between the two is questioned (Ehring and Quack, 2010). Forms of major anxiety and have been associated with early onset adversities (Spinhoven et al., 2010). Emotion dysregulation -and depression-in addition provide a pathway from exposure to trauma (emotional abuse especially), to psychopathology in the form of emotional eating (Michopoulos et al., 2015). Similarly, traumatic victimization is associated with oppositional-defiant disorder (after controlling for a host of related variables such as age, gender, family psychopathology, etc.), but this is not the case for exposure to non-victimization trauma (Ford et al., 1999).

In terms of the cognitive functioning difficulties, for example, ADHD and executive functions difficulties have been documented as common problems among children exposed to ACEs and to trauma (for example, Sugarman, 2006). The link, however, between ADHD and trauma seems complicated: the high prevalence of ADHD diagnoses and history of trauma among children, as well as an overlap of symptoms between ADHD and PTSD could be both reasons for misrepresentation of trauma pathology (Conway et al., 2011; Szymanski et al., 2011). Problems in executive functions have also been reported too. While not always so severe to lead to diagnoses of specific disorders, when comparing children with history of trauma to matched controls (see, Bücker et al., 2012) the former perform significantly worse in cognitive areas such as attention, immediate verbal recall, and working memory tests.

The Positive Effects of Nature and its Therapeutic Applications

Contact with natural environments has been found to have positive physiological and psychological effects on people. Recent large-scale studies and meta-analyses show a stress reduction effect for people immersed in natural environments (e.g., Razani et al., 2019) as well as positive impacts on mental health (e.g., Kotera et al., 2020) and cognitive functions (Zijlema et al., 2017). Moreover, therapeutic nature interventions and ecotherapy have become more widely used both with children and adults, including in the treatment of depression (e.g., Korpela et al., 2016), anxiety (e.g., Nguyen and Brymer, 2018), and ADHD (Kuo and Faber Taylor, 2004). Ecotherapy, adventure therapy, as well as forest school have been used to support optimal development and growth in areas such as self-esteem, resilience and communication for children and young people (e.g., Ward Thompson et al., 2006 and for a review of nature connection intervention in children see Barrable and Booth, 2020). Nature has also been flagged up as a factor for mitigating stress (Ward Thompson et al., 2016) as well as a protective factor for emotional wellbeing (Huynh et al., 2013).

Given the possible overlap between the impact that natural environments have on human physiology and psychology, and the effects of ACEs, we reviewed the literature conducting two separate searches, one for relevant empirical studies that acknowledge nature's therapeutic potential in relation to ACEs and one for studies that acknowledge nature's protective potential.

SEARCH AND RESULTS

Inclusion criteria:

1. English language original or translated
2. Both empirical and conceptual articles
3. Published in peer-reviewed journals

We did not include any chronological criteria.

Search 1: The Therapeutic Potential of Nature in People With ACEs

Search strategy: Major research search engines used, included Scopus, Web of Science and Google Scholar were searched between February and August 2020. The strategy undertaken was:

1. Keywords used included various combinations of the following: "nature," "natural environment," "trauma," "ACEs," "adverse childhood experiences," and "therapy" in the title, abstract, or keywords of the article.
2. Titles and abstracts were then scanned for suitability of inclusion in this review. From the articles that were deemed relevant, the authors used a snowballing approach to look through the citing and cited literature.

Results: Nine papers resulted from the searches on the therapeutic potential of nature for children who had experienced ACEs and/or trauma (see **Table 1**). Two of them offered reviews (Harper, 2017; Summers and Vivian, 2018). Of the remaining seven papers, five directly focused on children or presented at least a case on children and/or youth (Berger and Lahad, 2010; Burgon, 2013; Razani et al., 2019; Berger, 2020; Birch et al., 2020), while five looked at the effects of a nature-based intervention (psychological, educational, or both) on adversity (Berger and Lahad, 2010; Burgon, 2013; Hurly and Walker, 2019; Razani et al., 2019; Birch et al., 2020). Notably, approaches to nature therapy varied much and the same was true for the methodologies employed. Razani et al. (2019) present a group of children screened for ACEs specifically and assessed in different areas (e.g., children's stress or resilience) at different points in time; Hurly and Walker (2019) used semi-structured interviews and photo-elicitation to explore refugees' views on the effects of nature-based leisure on their well-being; and Burgon (2013) used ethnographic methods to approach the experience of young people from hard places in a horsemanship program. There were, furthermore, two papers that sought to present nature therapy (Berger and Tiry, 2012; Berger, 2020).

Search 2. The Protective Potential of Nature

Search strategy: Major research search engines used, including Scopus, Web of Science, and Google Scholar were searched between 20 and 30 October 2020. The strategy undertaken was:

1. Keyword search was conducted using combinations the terms "nature," "natural environments," "protective factor," " adverse childhood experiences," or "trauma" in the title, abstract, or keywords of the articles.
2. Titles and abstracts were then scanned for suitability of inclusion in this review. From the articles that were deemed relevant, the authors used a snowballing approach to look through the citing and cited literature.

Results: Of the 22 papers resulting from this search two were selected as substantially meeting the criteria (see **Table 2**). The first presented the positive effects of exposure to 1-day surf training regarded as therapy among youth at risk for intimidation, harassment, discrimination, and bullying-based on identity or status – immigration status, gender-identity/expression, disability, or due to being in foster care or being recipients of the public mental healthcare system (Sarkisian et al., 2020). The second work presented the experience with, and the buffering role of the natural environment among immigrants at risk due to inadequate housing, but also due to "social isolation; language difficulties; underemployment or unemployment; noise pollution; transportation difficulties; and systemic barriers in health, education, and government institutions" (Hordyk et al., 2015, p.76). Results, in both cases show potential.

DISCUSSION

In contrast to the limited evidence on the use of nature specifically with people at-risk or having experienced adversity, ecotherapy, nature engagement, and more specific nature interventions are commonly used therapeutically for –what we regard as– the *effects* of trauma and associated later psychopathology (for the effects see, Felitti et al., 1998, 2019; Burke et al., 2011; Fuller-Thomson et al., 2016; McDonnell and Valentino, 2016; Hughes et al., 2017; van der Kolk, 2017). However, there seems to be a clear gap in research that explores the use of natural engagement in children who are experiencing or have experienced ACEs as a factor that can *mitigate* all or part of the harm or developmental impairment of the child and can act as a protective factor before the harmful impacts of ACEs on development happens. In this sense, in the rest of this perspective paper we wish to bridge this gap by outlining some of the mechanisms of action that may come in useful for practitioners and researchers who are looking to work in this area, a work worth pursuing in our view. As ACEs have notable and varied impact on development, both on the physical and psychological realm, we consider them separately. However, this may be viewed as a false dichotomy, as many of these impacts overlap and are compounded by each other.

Physiological Areas

Engagement and exposure to natural environments including local green spaces mitigate some of changes and stress responses recounted earlier, as indicated in previous work, mainly in adults (e.g., Ward Thompson et al., 2016). Moreover, studies that have looked specifically at cortisol levels have also found greater access to green spaces to be associated with lower cortisol levels: studies from Japan that have compared salivary diurnal cortisol concentrations in adults who have undertaken forest-bathing versus a control group have also found lower concentrations in the forest-bathing group (Park et al., 2007; Park et al., 2010). Research in urban contexts that has looked at hair cortisol

TABLE 1 | Summary of themes of the reviewed papers on nature's therapeutic potential.

Type of adversity (or wellbeing aim)	Main themes of nature connectedness approach	Population	Brief description of paper, and/or method, and/or approach to nature related intervention employed	References
Traumatic experience of second Lebanese War by Israeli children.	• Connecting the story of the recovery of the forest from war with work on developing resiliency, advancing flexibility normalizing bad experience and offering safety. • Dramatic distancing (and use of metaphors like children as trees) where children act out their story of their own coping, fears, and connect with inner strengths. • Did not include data on effectiveness of the program.	Young children (in Jewish, Arab, and Druze kindergarten), in northern Israel.	Psycho-educational program in kindergartens.	Berger and Lahad, 2010.
Mental wellbeing and mental-health difficulties.	• Perceived health and wellbeing benefits of nature and nature elements including gaining different sense(s) of self in engaging with the environment; experiencing a sense of escape- nature is what people are not, nature does not judge, it offers a secure sense of self, so it is inclusive; and sense of connection, relationship and care, with trees, houseplants, wildlife or pets; also a theme that nature does not always help. • Effectiveness was measured by participants perception.	Youth (17–27) of which nine had a lived experience of a mental health difficulty (part of the IWUN-improving wellbeing through urban nature study). From diverse ethnic/racial/backgrounds; from deprived areas.	Research/interviews and art workshops on perceived health and wellbeing benefits of nature.	Birch et al., 2020.
Refugee experience/refugee wellbeing.	• Investigated the impacts of nature-based *leisure* on the well-being of refugees. • Participants reported they welcomed the opportunity to connect with others, to learn new activities, involve their families, and as a distraction from their daily lives. • Participants responses supported that nature-based leisure fostered a sense of belonging and refugees' well-being.	Participants, from three African countries, and Iran (four refugees) in Canada, adults.	Research/semi-structured interviews and photo-elicitation to explore experiences of a 2-day winter camping experience in northern Alberta and how it might foster their well-being.	Hurly and Walker, 2019.
Stress problems/problems in family life; raising awareness of mind-body relationship among students; Israeli children in kindergarten post second Lebanese War.	• Fundamental assumption of Nature Therapy healing can come from reconnection with nature, where people learn to connect with their inner strengths. • It can connect clients to a feeling of inner power and authenticity thus enabling them to develop and express important personal qualities. • Nature therapy bridges elements from Play Therapy, Drama Therapy, narrative approaches, and Gestalt, as well as Ecotherapy, Deep Ecology, Vision Quests, and Adventure and Wilderness Therapies.	Various, adults and groups of Israeli children in kindergarten.	Theoretical paper, drawing from three separate cases to present nature therapy.	Berger, 2020.
Emotional and psychiatric difficulties.	• Links to drama therapy and art therapy. • Exemplification of the how nature's uncontrollable changes can have a therapeutic power. • How the use of nature can help enter both the fantastic and dramatic realities of participants, which in turn empowers participants and can help mitigate defense mechanisms associated with their difficulties.	Adults.	Application of Nature Therapy, draining from cases to exemplify nature therapy.	Berger and Tiry, 2012.

(Continued)

TABLE 1 | Continued

Type of adversity (or wellbeing aim)	Main themes of nature connectedness approach	Population	Brief description of paper, and/or method, and/or approach to nature related intervention employed	References
Children with adversities.	• Three months following a park prescription for nature exposure, each additional park visit per week a child had was associated with a significant improvement in the child's self-reported resilience. • Clinic and park partnerships be considered as a community asset in addressing toxic stress.	Children 7–17 at a safety-net primary care clinic, low-income families.	Research paper/regression self-reported resilience on part visits, also looking at ACEs, stress, assignment to intervention, and age.	Razani et al., 2019.
Young people experiencing psychosocial difficulties (in foster care/residential facility/youth offending team, also diagnoses for some of them with SEN, autistic spectrum and ADHD).	• Use of Equine-Assisted Learning and Equine-Assisted Therapy (EAL/T). • Reported experience as being calm, (which was very profound for the case with ADHD symptoms), more self-aware- (similarities with exercises in the mindfulness-based stress reduction program), being free, in the moment, authentic, and self-regulated. • Being outdoors provided the right place to be this way.	Young people 11–21 (at risk), participating in a Therapeutic Horsemanship program in United Kingdom.	Research paper-ethnographic approach toward the experience in nature with the horses in the Horsemanship program.	Burgon, 2013.
Child and youth case (not otherwise specified).	• Three thematic areas of practice and research emerged from analysis of included publications: (1) wilderness and adventure therapy, (2) therapeutic camping, and (3) adventure education and physical activity.	63 papers with child populations.	Scoping review paper.	Harper, 2017.
Various physical, mental health, and other disorders.	• Flagging out the different evidence from the literature on the positive effects of time spent outdoors and ecotherapy. • Areas of positive effect included: general medical recovery (e.g., heart rate, blood pressure, surgery recovery, cardiopulmonary rehabilitation), pain reduction, mood and stress (e.g., post-traumatic stress, anxiety, self- esteem, addiction, mental well-being), Attention deficit/hyperactivity disorder, dementia, obesity, other disorders (e.g., vitamin D deficiencies, general mental health issues).	Non-specific.	A review of the literature on ecotherapy.	Summers and Vivian, 2018.

TABLE 2 | Summary of themes of the reviewed papers on nature as a protective factor.

Type of risk	Main themes of nature intervention	Population	Brief description of paper, and/or method, and/or approach to nature engagement employed	References
Risk for intimidation, harassment, discrimination, and bullying based on identity or status – immigration status, gender-identity/expression, disability, ethnicity, race, sexual orientation, religion, nationality, or association with a person or group. Youth in foster care and recipients of the public mental healthcare system too.	• One-day surf therapy program (part of the ocean therapy approach). • Use of outdoor water and blue space environments for well-being. • Surfing allows engagement with nature in a symbiotic way, promoting both well-being and self-efficacy. • The 1-day ocean therapy program for youth at-promise includes "(1) an opening talking circle where participants share their experience around a given theme, (2) a surf lesson on land, (3) a surf lesson in the ocean, (4) a second talking circle, (5) a second surf lesson in the ocean, (6) lunch, and (7) a closing talking circle with opportunity to reflect on the theme of the day and other experiences" (p. 6). • 10–12 participants in each session. • The main goal of the program is for participants to be exposed to surfing in an environment that is fun, safe and inclusive.	Youth at-risk (Hispano-Latino primarily, and African American, other ethnicities were only 6% of the group), *N* = 152, ages 6–19.	An observational pre-post-test study, using the Children's Hope Study (as a measure of a construct linking to resilience) was used to evaluate the program outcomes. The program process was evaluated through rating participant's drawings.	Sarkisian et al., 2020.
Risk due to inadequate housing but also due to "social isolation; language difficulties; underemployment or unemployment; noise pollution; transportation difficulties; and systemic barriers in health, education and government institutions" (p. 76).	• The study examined the embodied, everyday practices of immigrant children and families drawing from their experiences with urban greenspaces such as parks, fields, backyards, streetscapes, gardens, forests, and rivers. • Structural factors affect social processes in ways that they can give rise to health problems. Adverse social and material living conditions may lead to physiological and psychological stress responses and correspondingly to an increase propensity to health problems and unhealthy coping behaviors. • Positive effects of exposure and engagement with non-threatening forms of urban green spaces on well-being and health (stress reduction theory, attention restoration theory, theory of biophilia). • How familiar sensory stimuli and practices in nature facilitate remembering and belonging.	Immigrants/newcomers in an area with inadequate housing characteristics due to cost, size, and physical conditions. Seven families, 10 adults and 13 children (7–13) comprised the sample.	Interpretative phenomenological analysis of participants lived experience of outdoors and nature, using drawings, the five senses popcorn questions, namely *"what is the first thing that pops into mind when asked to name one thing you have tasted in nature in Canada? Then, one thing you have smelled?"* etc. (p. 77), and semi-structured interviews with the adults (and the children if they wished to join).	Hordyk et al., 2015.

concentrations (HCC) as an indicator of chronic stress found a positive association between living in areas with greater access to natural environments and lower level of HCC (Gidlow et al., 2016). Few studies have looked at children, but a Norwegian prospective longitudinal study in mainstream education found that children (aged 9–10) who experience more outdoor learning, in this case in a forest environment, had a healthier diurnal cortisol rhythm (Dettweiler et al., 2017). Looking at behavioral measures too, Wells and Evans (2003) suggest that nature can act as a buffer for life stresses in children. Overall, although more evidence is required, we believe there is potential for green spaces to be used in order to mitigate some of the physiological effects of trauma.

Psychological Areas

Natural environments have a positive effect on emotional regulation. A theoretical perspective is given by Richardson (2019) and primarily based on Gilbert's (2014) three circle model – which in essence simplifies the interaction of physiological and affective factors. Using Gilbert's model as a starting point, and drawing upon some of the positive affective and physiological experiences that occur in natural environments (including relaxation, feelings of awe and joy) the author proposes that the balance of sympathetic and parasympathetic nervous system responses (as per Porges, 2007) can in fact lead to improved mood and emotional regulation. Earlier theoretical (Johnsen, 2011) and empirical research (Johnsen and Rydstedt, 2013) from Norway supported this potential for using engagement with natural environments as an avenue toward emotional regulation and better psychological health. A recent empirical study from Australia suggests that access to green schoolyards can have a positive impact on self-regulation for young children (Taylor and Butts-Wilmsmeyer, 2020).

Although not directly aiming at specific major anxiety and depression disorders, there is some preliminary evidence to suggest the positive effect of nature and nature-based therapies in these areas too. Maund et al. (2019) worked with adults diagnosed with anxiety and/or depression and ran a pilot on a 6-week wetland nature intervention that showed significant positive effects. In addition, Evans et al. (2003) working with 337 children reported that nearby nature seemed to moderate the effect of stressful events and children's psychological distress, an effect especially pronounced among children who have experienced high levels of stress. The effect of therapeutic and learning nature-based interventions with children (and adults) with depression, anxiety, but also eating disorders and conduct problems (aggression and defiance) is well-documented in the literature.

Attention Restoration Theory (ART; Kaplan, 1995) puts forward the restorative potential of natural environments, especially in mitigating the effects of stress and directed attention. A systematic review and meta-analysis of the evidence for such a restorative potential, however, has found mixed effects, mostly due to small samples and heterogeneity in tests used and reporting (Ohly et al., 2016). Studies in children, on the other hand, report measurable effects on attention and memory (for example, see Kuo and Faber Taylor, 2004; Ulset et al., 2017). In terms of executive function, studies in both adults (Bourrier et al., 2018) and children (Schutte et al., 2017; Stenfors et al., 2019) have found positive effects of exposure to nature especially as opposed to urban environments. No meta-analytic studies of these exist at the moment, but the effect of exposure to natural environments on human attention, especially in children with pathologies, such as ADHD, merits more research.

CONCLUSION

In summary, in this perspective paper we propose that nature holds therapeutic and protective potential for children who have experienced adversity or are at-risk. The brief review of the existing literature indicated that:

1. Children with adversity do present poor physiological and often psychopathological outcomes across the board;
2. Children and adults at-risk or diagnosed with difficulties, physical, emotional, and/or cognitive can benefit from therapeutic nature-based interventions; and
3. To our knowledge there are not specific interventions for children with ACEs or at-risk.

Given the above, it is our view that the mitigating effect of exposure to natural environments needs to be acknowledged, utilized, and researched. In this sense, regular nature engagement can be acknowledged and evaluated for its possible effect as a protective factor for the development of psychopathologies following exposure to ACEs in children. Based on the evidence on mechanisms of action presented earlier, we propose that it is worth investing in designing nature-based programs and developing evidence-based therapeutic and learning interventions targeted specifically to the population of children with risk of being exposed to ACEs.

The approach proposed here (working *a priori* with children at risk or facing adversity rather than working with the effects from ACEs) is seen as granting the positive effects associated with *early intervention* (indicatively, Hester et al., 2003; Evangelou et al., 2007; Lovett et al., 2017): intervening before the appearance of psychopathologies could potentially counter the effects of ACEs altogether. This is especially important as we know that seven of the eight basic categories of adversities are significantly associated with complex adult psychopathology, and pairwise combinations of specific adversities have additive or multiplicative effect in increasing chances for psychopathology across the lifespan (Putnam et al., 2013). For all these reasons, we would welcome the development of nature-based interventions that focus on the above mechanisms of action, expecting that they would optimize children's chances to escape physical and psychological health challenges in the short-, medium-, and long-term.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

AT was the lead author and conducted the reviews for the manuscripts selected through the searches. AB conducted the literature searches. AT and AB wrote the manuscript collaboratively. Both authors contributed to the article and approved the submitted version.

REFERENCES

Barrable, A., and Booth, D. (2020). Increasing Nature connection in children: a mini review of interventions. *Front. Psychol.* 11:492. doi: 10.3389/fpsyg.2020.00492

Berens, A. E., Jensen, S. K., and Nelson, C. A. (2017). Biological embedding of childhood adversity: from physiological mechanisms to clinical implications. *BMC Med.* 15:135. doi: 10.1186/s12916-017-0895-4

Berger, R. (2020). Nature therapy: incorporating nature into arts therapy. *J. Humanist. Psychol.* 60, 244–257. doi: 10.1177/0022167817696828

Berger, R., and Lahad, M. (2010). A safe place: ways in which nature, play and creativity can help children cope with stress and crisis–establishing the kindergarten as a safe haven where children can develop resiliency. *Early Child Dev. Care* 180, 889–900. doi: 10.1080/03004430802525013

Berger, R., and Tiry, M. (2012). The enchanting forest and the healing sand—nature therapy with people coping with psychiatric difficulties. *Arts Psychother.* 39, 412–416. doi: 10.1016/j.aip.2012.03.009

Birch, J., Rishbeth, C., and Payne, S. R. (2020). Nature doesn't judge you–how urban nature supports young people's mental health and wellbeing in a diverse UK city. *Health Place* 62:102296. doi: 10.1016/j.healthplace.2020.102296

Bourrier, S. C., Berman, M. G., and Enns, J. T. (2018). Cognitive strategies and natural environments interact in influencing executive function. *Front. Psychol.* 9:1248. doi: 10.3389/fpsyg.2018.01248

Bücker, J., Kapczinski, F., Post, R., Ceresér, K. M., Szobot, C., Yatham, L. N., et al. (2012). Cognitive impairment in school-aged children with early trauma. *Compr. Psychiatry* 53, 758–764. doi: 10.1016/j.comppsych.2011.12.006

Burgon, H. L. (2013). Horses, mindfulness and the natural environment: observations from aqualitative study with at-risk young people participating in therapeutic horsemanship. *Int. J. Psychosoc. Rehabil.* 17, 51–67.

Burke, N. J., Hellman, J. L., Scott, B. G., Weems, C. F., and Carrion, V. G. (2011). The impact of adverse childhood experiences on an urban pediatric population. *Child Abuse Negl.* 35, 408–413. doi: 10.1016/j.chiabu.2011.02.006

Cloitre, M., Miranda, R., Stovall-McClough, K. C., and Han, H. (2005). Beyond PTSD: emotion regulation and interpersonal problems as predictors of functional impairment in survivors of childhood abuse. *Behav. Ther.* 36, 119–124. doi: 10.1016/s0005-7894(05)80060-7

Conway, F., Oster, M., and Szymanski, K. (2011). ADHD and complex trauma: a descriptive study of hospitalized children in an urban psychiatric hospital. *J. Infant Child Adolesc. Psychother.* 10, 60–72. doi: 10.1080/15289168.2011.575707

Crouch, E., Radcliff, E., Strompolis, M., and Srivastav, A. (2019). Safe, stable, and nurtured: protective factors against poor physical and mental health outcomes following exposure to adverse childhood experiences (ACEs). *J. Child Adolesc. Trauma* 12, 165–173. doi: 10.1007/s40653-018-0217-9

Dettweiler, U., Becker, C., Auestad, B. H., Simon, P., and Kirsch, P. (2017). Stress in school. Some empirical hints on the circadian cortisol rhythm of children in outdoor and indoor classes. *Int. J. Environ. Res. Public Health* 14:475. doi: 10.3390/ijerph14050475

Ehring, T., and Quack, D. (2010). Emotion regulation difficulties in trauma survivors: the role of trauma type and PTSD symptom severity. *Behav. Ther.* 41, 587–598. doi: 10.1016/j.beth.2010.04.004

Evangelou, M., Brooks, G., and Smith, S. (2007). The birth to school study: evidence on the effectiveness of PEEP, an early intervention for children at risk of educational under-achievement. *Oxf. Rev. Educ.* 33, 581–609. doi: 10.1080/03054980701476477

Evans, G. W., Wells, N. M., and Moch, A. (2003). Housing and mental health: a review of the evidence and a methodological and conceptual critique. *J. Soc. Issues* 59, 475–500.

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., et al. (1998). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: the adverse childhood experiences (ACE) study. *Am. J. Prev. Med.* 14, 245–258. doi: 10.1016/s0749-3797(98)00017-8

Felitti, V. J., Anda, R. F., Nordenberg, D., Williamson, D. F., Spitz, A. M., Edwards, V., et al. (2019). Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults: the adverse childhood experiences (ACE) study. *Am. J. Prev. Med.* 56, 774–786. doi: 10.1016/j.amepre.2019.04.001

Ford, J. D. (2005). Treatment implications of altered neurobiology, affect regulation and information processing following child maltreatment. *Psychiatr. Ann.* 35, 410–419. doi: 10.3928/00485713-20050501-07

Ford, J. D. (2009). "Neurobiological and developmental research," in *Treating Complex Traumatic Stress Disorders: An Evidence-Based Guide*, eds C. A. Courtois and J. D. Ford (New York, NY: Guilford Press), 31–58.

Ford, J. D., Racusin, R., Daviss, W. B., Ellis, C. G., Thomas, J., Rogers, K., et al. (1999). Trauma exposure among children with oppositional defiant disorder and attention deficit–hyperactivity disorder. *J. Consult. Clin. Psychol.* 67, 786–789. doi: 10.1037/0022-006X.67.5.786

Fuller-Thomson, E., Baird, S. L., Dhrodia, R., and Brennenstuhl, S. (2016). The association between adverse childhood experiences (ACEs) and suicide attempts in a population-based study. *Child Care Health Dev.* 42, 725–734. doi: 10.1111/cch.12351

Gidlow, C. J., Randall, J., Gillman, J., Smith, G. R., and Jones, M. V. (2016). Natural environments and chronic stress measured by hair cortisol. *Landsc. Urban Plan.* 148, 61–67. doi: 10.1016/j.landurbplan.2015.12.009

Gilbert, P. (2014). The origins and nature of compassion focused therapy. *Br. J. Clin. Psychol.* 53, 6–41. doi: 10.1111/bjc.12043

Harper, N. J. (2017). Wilderness therapy, therapeutic camping and adventure education in child and youth care literature: a scoping review. *Child. Youth Serv. Rev.* 83, 68–79. doi: 10.1016/j.childyouth.2017.10.030

Hester, P. P., Baltodano, H. M., Gable, R. A., Tonelson, S. W., and Hendrickson, J. M. (2003). Early intervention with children at risk of emotional/behavioral disorders: a critical examination of research methodology and practices. *Educ. Treat. Child.* 26, 362–381.

Hordyk, S. R., Hanley, J., and Richard, É. (2015). "Nature is there; its free": urban greenspace and the social determinants of health of immigrant families. *Health Place* 34, 74–82.

Hughes, K., Bellis, M. A., Hardcastle, K. A., Sethi, D., Butchart, A., Mikton, C., et al. (2017). The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. *Lancet Public Health* 2, e356–e366.

Hughes, K., Ford, K., Davies, A. R., Homolova, L., and Bellis, M. A. (2018). *Sources of Resilience and their Moderating Relationships with Harms from Adverse Childhood Experiences*. Cardiff: Public Health Wales.

Hurly, J., and Walker, G. J. (2019). "When you see nature, nature give you something inside": the role of nature-based leisure in fostering refugee well-being in Canada. *Leis. Sci.* 41, 260–277. doi: 10.1080/01490400.2017.1325799

Huynh, Q., Craig, W., Janssen, I., and Pickett, W. (2013). Exposure to public natural space as a protective factor for emotional well-being among young people in Canada. *BMC Public Health* 13:407. doi: 10.1186/1471-2458-13-407

Johnsen, S. Å. K. (2011). The use of nature for emotion regulation: toward a conceptual framework. *Ecopsychology* 3, 175–185. doi: 10.1089/eco.2011.0006

Johnsen, S. Å. K., and Rydstedt, L. W. (2013). Active use of the natural environment for emotion regulation. *Eur. J. Psychol.* 9, 798–819. doi: 10.5964/ejop.v9i4.633

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Kessler, R. C., McLaughlin, K. A., Green, J. G., Gruber, M. J., Sampson, N. A., Zaslavsky, A. M., et al. (2010). Childhood adversities and adult psychopathology in the WHO world mental health surveys. *Br. J. Psychiatry* 197, 378–385. doi: 10.1192/bjp.bp.110.080499

Kooiman, C. G., van Rees Vellinga, S., Spinhoven, P., Draijer, N., Trijsburg, R. W., and Rooijmans, H. G. (2004). Childhood adversities as risk factors for

alexithymia and other aspects of affect dysregulation in adulthood. *Psychother. Psychosom.* 73, 107–116. doi: 10.1159/000075542

Korpela, K. M., Stengård, E., and Jussila, P. (2016). Nature walks as a part of therapeutic intervention for depression. *Ecopsychology* 8, 8–15. doi: 10.1089/eco.2015.0070

Kotera, Y., Richardson, M., and Sheffield, D. (2020). Effects of Shinrin-Yoku (forest bathing) and nature therapy on mental health: a systematic review and meta-analysis. *Int. J. Ment. Health Addict.* 1–25.

Kuo, F. E., and Faber Taylor, A. (2004). A potential natural treatment for attention-deficit/hyperactivity disorder: evidence from a national study. *Am. J. Public Health* 94, 1580–1586. doi: 10.2105/ajph.94.9.1580

Lovett, M. W., Frijters, J. C., Wolf, M., Steinbach, K. A., Sevcik, R. A., and Morris, R. D. (2017). Early intervention for children at risk for reading disabilities: the impact of grade at intervention and individual differences on intervention outcomes. *J. Educ. Psychol.* 109, 889–914. doi: 10.1037/edu0000181

Maund, P. R., Irvine, K. N., Reeves, J., Strong, E., Cromie, R., Dallimer, M., et al. (2019). Wetlands for wellbeing: piloting a nature-based health intervention for the management of anxiety and depression. *Int. J. Environ. Res. Public Health* 16:4413. doi: 10.3390/ijerph16224413

McDonnell, C. G., and Valentino, K. (2016). Intergenerational effects of childhood trauma: evaluating pathways among maternal ACEs, perinatal depressive symptoms, and infant outcomes. *Child Maltreat.* 21, 317–326. doi: 10.1177/1077559516659556

McLaughlin, K. A., Green, J. G., Gruber, M. J., Sampson, N. A., Zaslavsky, A. M., and Kessler, R. C. (2012). Childhood adversities and first onset of psychiatric disorders in a national sample of US adolescents. *Arch. Gen. Psychiatry* 69, 1151–1160. doi: 10.1001/archgenpsychiatry.2011.2277

Merrick, M. T., Ford, D. C., Ports, K. A., and Guinn, A. S. (2018). Prevalence of adverse childhood experiences from the 2011-2014 behavioral risk factor surveillance system in 23 states. *JAMA Pediatrics* 172, 1038–1044. doi: 10.1001/jamapediatrics.2018.2537

Michopoulos, V., Powers, A., Moore, C., Villarreal, S., Ressler, K. J., and Bradley, B. (2015). The mediating role of emotion dysregulation and depression on the relationship between childhood trauma exposure and emotional eating. *Appetite* 91, 129–136. doi: 10.1016/j.appet.2015.03.036

Nguyen, J., and Brymer, E. (2018). Nature-based guided imagery as an intervention for state anxiety. *Front. Psychol.* 9:1858. doi: 10.3389/fpsyg.2018.01858

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., et al. (2016). Attention restoration theory: a systematic review of the attention restoration potential of exposure to natural environments. *J. Toxicol. Environ. Health Part B* 19, 305–343. doi: 10.1080/10937404.2016.1196155

Oral, R., Ramirez, M., Coohey, C., Nakada, S., Walz, A., Kuntz, A., et al. (2016). Adverse childhood experiences and trauma informed care: the future of health care. *Pediatr. Res.* 79, 227–233. doi: 10.1038/pr.2015.197

Park, B. J., Tsunetsugu, Y., Kasetani, T., Hirano, H., Kagawa, T., Sato, M., et al. (2007). Physiological effects of Shinrin-Yoku (taking in the atmosphere of the forest)—using salivary cortisol and cerebral activity as indicators—. *J. Physiol. Anthropol.* 26, 123–128. doi: 10.2114/jpa2.26.123

Park, B. J., Tsunetsugu, Y., Kasetani, T., Kagawa, T., and Miyazaki, Y. (2010). The physiological effects of Shinrin-Yoku (taking in the forest atmosphere or forest bathing): evidence from field experiments in 24 forests across Japan. *Environ. Health Prev. Med.* 15, 18–26. doi: 10.1007/s12199-009-0086-9

Perry, B. D. (1994). "Neurobiological sequelae of childhood trauma: post-traumatic stress disorders in children," in *Catecholamine Function in Post-Traumatic Stress Disorder: Emerging Concepts*, ed. M. M. Murburg (Washington, DC: American Psychiatric Association), 253–276.

Porges, S. W. (2007). The polyvagal perspective. *Biol. Psychol.* 74, 116–143. doi: 10.1016/j.biopsycho.2006.06.009

Purvis, K. B., Cross, D. R., Dansereau, D. F., and Parris, S. R. (2013). Trust-based relational intervention (TBRI): a systemic approach to complex developmental trauma. *Child Youth Serv.* 34, 360–386. doi: 10.1080/0145935X.2013.859906

Putnam, K. T., Harris, W. W., and Putnam, F. W. (2013). Synergistic childhood adversities and complex adult psychopathology. *J. Trauma. Stress* 26, 435–442. doi: 10.1002/jts.21833

Razani, N., Niknam, K., Wells, N. M., Thompson, D., Hills, N. K., Kennedy, G., et al. (2019). Clinic and park partnerships for childhood resilience: a prospective study of park prescriptions. *Health Place* 57, 179–185. doi: 10.1016/j.healthplace.2019.04.008

Richardson, M. (2019). Beyond restoration: considering emotion regulation in natural well-being. *Ecopsychology* 11, 123–129. doi: 10.1089/eco.2019.0012

Sarkisian, G. V., Curtis, C., and Rogers, C. M. (2020). Emerging hope: outcomes of a one-day surf therapy program with youth at-promise. *Glob. J. Commun. Psychol. Pract.* 11, 1–16.

Schutte, A. R., Torquati, J. C., and Beattie, J. L. (2017). Impact of urban nature on executive functioning in early and middle childhood. *Environ. Behav.* 49, 3–30. doi: 10.1177/0013916515603095

Spinhoven, P., Elzinga, B. M., Hovens, J. G., Roelofs, K., Zitman, F. G., van Oppen, P., et al. (2010). The specificity of childhood adversities and negative life events across the life span to anxiety and depressive disorders. *J. Affect. Disord.* 126, 103–112. doi: 10.1016/j.jad.2010.02.132

Stenfors, C. U. D., Van Hedgere, S. C., Schertz, K. E., Meyer, F., Smith, K. E., Norman, G., et al. (2019). Positive effects of nature on cognitive performance across multiple experiments: test order but not affect modulates the cognitive effects. *Front. Psychol.* 10:1413. doi: 10.3389/fpsyg.2019.01413

Streeck-Fischer, A., and van der Kolk, B. A. (2000). Down will come baby, cradle and all: diagnostic and therapeutic implications of chronic trauma on child development. *Aust. N. Z. J. Psychiatry* 34, 903–918. doi: 10.1080/00048670 0265

Sugarman, A. (2006). Attention deficit hyperactivity disorder and trauma. *Int. J. Psychoanal.* 87, 237–241. doi: 10.1516/F2BD-QXEU-NENX-QL3N

Summers, J. K., and Vivian, D. N. (2018). Ecotherapy–A forgotten ecosystem service: a review. *Front. Psychol.* 9:1389. doi: 10.3389/fpsyg.2018.01389

Szymanski, K., Sapanski, L., and Conway, F. (2011). Trauma and ADHD–association or diagnostic confusion? A clinical perspective. *J. Infant Child Adolesc. Psychother.* 10, 51–59. doi: 10.1080/15289168.2011.575704

Taylor, A. F., and Butts-Wilmsmeyer, C. (2020). Self-regulation gains in kindergarten related to frequency of green schoolyard use. *J. Environ. Psychol.* 70:101440. doi: 10.1016/j.jenvp.2020.101440

Ulset, V., Vitaro, F., Brendgen, M., Bekkhus, M., and Borge, A. I. (2017). Time spent outdoors during preschool: links with children's cognitive and behavioral development. *J. Environ. Psychol.* 52, 69–80. doi: 10.1016/j.jenvp.2017.05.007

van der Kolk, B. A. (2017). Developmental trauma disorder: toward a rational diagnosis for children with complex trauma histories. *Psychiatr. Ann.* 35, 401–408. doi: 10.3928/00485713-20050501-06

Walsh, M. C., Joyce, S., Maloney, T., and Vaithianathan, R. (2020). Exploring the protective factors of children and families identified at highest risk of adverse childhood experiences by a predictive risk model: an analysis of the growing up in New Zealand cohort. *Child. Youth Serv. Rev.* 108:104556. doi: 10.1016/j.childyouth.2019.104556

Ward Thompson, C., Aspinall, P., Roe, J., Robertson, L., and Miller, D. (2016). Mitigating stress and supporting health in deprived urban communities: the importance of green space and the social environment. *Int. J. Environ. Res. Public Health* 13:440. doi: 10.3390/ijerph13040440

Ward Thompson, C., Travlou, P., and Roe, J. (2006). *Free-Range Teenagers: The Role of Wild Adventure Space in Young People's Lives: Final Report. OPENspace*. Available online at: http://publications.naturalengland.org.uk/publication/41009 (accessed May 20, 2010).

Wells, N. M., and Evans, G. W. (2003). Nearby nature: a buffer of life stress among rural children. *Environ. Behav.* 35, 311–330. doi: 10.1177/0013916503035003001

Zijlema, W. L., Triguero-Mas, M., Smith, G., Cirach, M., Martinez, D., Dadvand, P., et al. (2017). The relationship between natural outdoor environments and cognitive functioning and its mediators. *Environ. Res.* 155, 268–275. doi: 10.1016/j.envres.2017.02.017

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Psychology

ORIGINAL RESEARCH
published: 11 January 2021
doi: 10.3389/fpsyg.2020.575245

Natural Is Not Always Better: The Varied Effects of a Natural Environment and Exercise on Affect and Cognition

Janet P. Trammell†* and *Shaya C. Aguilar*†

Social Science Department, Seaver College, Pepperdine University, Malibu, CA, United States

The Attention Restoration Theory (ART) has been widely cited to account for beneficial effects of natural environments on affect and attention. However, the effects of environment and exercise are not consistent. In a within-subjects design, participants completed affective and cognitive measures that varied in attentional demands (memory, working memory, and executive function) both before and after exercise in a natural and indoor environment. Contrary to the hypotheses, a natural environment resulted in lower positive affect and no difference in negative affect compared to an indoor environment. A natural environment resulted in the most improvement for cognitive tasks that required moderate attentional demand: Trail Making Test A and Digit Span Forwards. As predicted, exercise resulted in improved affect and improved executive function (Trail Making Test B). There were no interactions between environment and exercise. These results suggest that ART cannot fully explain the influence of environment on affect and cognition.

Keywords: Attention Restoration Theory, affect (emotion, mood, personality), attention, cognition, natural environment, exercise

OPEN ACCESS

Edited by:
Giovanni Sanesi,
University of Bari Aldo Moro, Italy

Reviewed by:
Tjeerd C. Andringa,
University of Groningen, Netherlands
Simon Bell,
University of Edinburgh,
United Kingdom

***Correspondence:**
Janet P. Trammell
janet.trammell@pepperdine.edu

***ORCID:**
Janet P. Trammell
orcid.org/0000-0002-0304-6974
Shaya C. Aguilar
orcid.org/0000-0002-4274-3166

Specialty section:
This article was submitted to Environmental Psychology, a section of the journal Frontiers in Psychology

Received: *22 June 2020*
Accepted: *02 December 2020*
Published: *11 January 2021*

Citation:
Trammell JP and Aguilar SC (2021) Natural Is Not Always Better: The Varied Effects of a Natural Environment and Exercise on Affect and Cognition. Front. Psychol. 11:575245. doi: 10.3389/fpsyg.2020.575245

INTRODUCTION

Nature is more than a physical environment; it is an environment that can both restore and enhance the mind and behavior. It is well established that time spent in natural environments is associated with beneficial outcomes for mental health, such as increases in positive affect and decreases in stress, negative affect, anger, fatigue, and sadness (see Bowler et al., 2010, and McMahan and Estes, 2015, for a review of affective benefits; but see Gascon et al., 2015 for limitations). These natural environments typically contain green and/or blue spaces; green spaces are spacious, lush, serene, and include vegetation such as trees, grass, forests, and parks, whereas blue spaces include all kinds of water such as lakes, rivers, and the ocean (Gascon et al., 2015). People are more likely to be physically active as well as experience feelings of peace and restoration in green and blue spaces (Finlay et al., 2015), with the largest benefit in positive affect resulting from areas that have a combination of both green and blue spaces (White et al., 2010).

In addition to affective benefits, natural environments are also associated with cognitive benefits, particularly in regards to attention. According to Attention Restoration Theory (ART; Kaplan, 1995; Berman et al., 2008; Kaplan and Berman, 2010), natural environments capture attention in an involuntary but undemanding way. This "soft fascination" is in contrast to the direct and focused

attentional demands of most other environments, and results in improved affect as well as allowing attentional resources—particularly those involved in focused directed attention, which is utilized in cognitively demanding tasks—a chance to recover. Stress reduction theory (SRT; Ulrich et al., 1991) posits that rather than soft fascination leading to both attentional restoration and affective benefits, the affective benefits resulting from exposure to natural environments lead to attentional restoration. However, recent data suggests that affective benefits are not the cause for cognitive benefits; rather, the two are more independent (Schertz and Berman, 2019).

Compared to exposure to urban environments, many studies have found attentional improvements as a result of exposure to natural environments. These improvements occur across young and old adults (Gamble et al., 2014), mentally fatigued individuals (Berto, 2005), and children with ADHD (Taylor and Kuo, 2009). Lending further support, two meta-analyses (Ohly et al., 2016; Stevenson et al., 2018) reported that performance on tasks that utilize both directed attention and working memory [Digit Span Forwards (DSF)/Digit Span Backwards (DSB)] and both directed visual attention and executive function [sometimes called cognitive flexibility; Trail Making Test B (TMTB)] is improved as a result of exposure to natural environments. However, these cognitive benefits are less consistent than affective benefits; no consistent improvement was found for Trail Making Test A (TMTA; Ohly et al., 2016), vigilance, impulse control, or processing speed (Stevenson et al., 2018), and an earlier meta-analysis did not find support for improvement in attention after exposure to a natural environment (Bowler et al., 2010).

Why might cognitive benefits be inconsistent? The demands of the task likely matter (Ohly et al., 2016; Stevenson et al., 2018), such that more demanding tasks (DSB, TMTB) are more likely to show benefits of nature-based restoration than less demanding tasks (DSF, TMTA). It is also likely that participants' degree of fatigue or need for restoration influences the amount of restoration experienced (Stevenson et al., 2018). In addition, while ART focuses primarily on attentional restoration, tasks such as Digit Span and Trail Making also rely heavily on other cognitive resources, such as working memory and executive function, the effect of environment on which is less understood.

Importantly, while effects on attention have been extensively investigated, the effect of environment on tasks with low attentional demands, such as long-term memory, has rarely been investigated. In the only experimental investigation to date of the effects of a natural environment (a 10 min walk) on memory, no significant effects of environment were found (Rider and Bodner, 2016); however, actual encoding and recall took place in an indoor environment, not in the natural or urban walk environments. If improvement in performance on tasks such as Digit Span and Trail Making is due purely to attentional restoration, as proposed in ART, then we would not expect to see environmental differences on a memory task. If, however, improvements in performance are due to other factors, such as increased interest and motivation (Joye and Dewitte, 2018), or affective benefits leading to cognitive benefits (SRT; Ulrich et al., 1991), then we should see similar improvements in memory as for tasks with greater attentional demand.

A second consideration is that much of this research has focused on simple exposure to natural environments—such as viewing pictures or videos (e.g., Gamble et al., 2014), or exercising at light intensity by walking (e.g., Gidlow et al., 2016). It is possible that with more activity, such as moderate intensity exercise, the environment would have different effects, particularly as moderate exercise is presumed to physically fatigue individuals regardless of the environment in which it takes place. Additionally, while indoor environments have been somewhat investigated, most comparisons to a natural environment are an urban environment; however, for the majority of adults who work, learn, or otherwise engage in cognitively demanding tasks, they must do so indoors rather than in an outdoor urban environment.

Exercise, of course, has a separate influence on affect and cognition. Similar to natural environments, it is well established that physical exercise, regardless of whether it is an acute episode or long term engagement, has numerous physical and mental health benefits. For instance, exercise has a therapeutic and occasionally protective effect on mood and cognition for those diagnosed with ADHD and autism (Tan et al., 2016), Alzheimer's (Farina et al., 2014), Mild Cognitive Impairment (Öhman et al., 2014), and other conditions. In particular, "green exercise," or exercise in green outdoor spaces, has been shown to have benefits such as increased energy, engagement and revitalization, and decreased depression and tension (for reviews, see Pretty et al., 2007; Coon et al., 2011).

Over the last several decades, cognitive benefits of exercise, in various domains such as attention, memory, learning, speed, processing, and executive function, have been robustly demonstrated across the lifespan in children (Tomporowski et al., 2011), young-to-middle age adults (Hötting et al., 2012; Loprinzi et al., 2018), and older adults (Colcombe and Kramer, 2003). The intensity and duration of exercise are important factors influencing these effects. Acute aerobic exercise of at least 20 min produces stronger effects on cognition than shorter bouts, particularly when cognitive assessments are completed 11–20 min after the cessation of exercise (Chang et al., 2012). Regarding intensity, evidence suggests that moderate intensity leads to larger benefits for cognition than lower intensity (e.g., Naderi et al., 2019), and that exercise of greater intensity may produce longer-lasting benefits (Chang et al., 2012).

Despite these robust and generally consistent findings, however, there are still unanswered questions concerning the interplay between exercise and cognition. First, benefits on cognition are not always consistent; while both Chang et al. (2012) and Lambourne and Tomporowski (2010) find strong meta-analytic support for beneficial effects of acute exercise on long term memory, effects on other cognitive functions, such as working memory and executive function, are less consistent. This may be because effect sizes are typically larger for long term memory effects than for executive function (Lambourne and Tomporowski, 2010). Further, particularly in regards to working memory, the duration and intensity of exercise, and the particular measures used, contribute to the variances in the findings. Second, research has typically focused on exercise conducted in a laboratory, gym, or otherwise generally static, typically indoor

environment. However, a laboratory is not a typical exercise environment; many adults lack access to a fitness facility and thus exercise outdoors by running, cycling, walking, gardening, and hiking, etc. According to ART, there is reason to think that an exercise environment may be an important factor in effects on cognition, with natural environments being more beneficial. Research into the cognitive benefits of "green exercise" has been steadily increasing, albeit with inconsistent results and typically focusing primarily on attentional tasks. One study utilizing running (Bodin and Hartig, 2003) found no attentional benefits for a natural compared to an urban environment, although statistical power was low. Others (Rogerson and Barton, 2015) have found that viewing a nature video during indoor treadmill running resulted in greater improvement on DSB scores than viewing an urban video or no video.

While key assumptions of ART are the ideas that directed attention can be depleted, and that natural environments restore this resource, the conceptualization of "directed attention" is not clearly defined (Ohly et al., 2016; Joye and Dewitte, 2018). The mechanism for improved cognitive performance after exposure to natural environments could be affective benefits leading to increased motivation and persistence on cognitively demanding tasks rather than restoration of a depleted resource (Joye and Dewitte, 2018). In order to more effectively test the attention-restoring claims of ART, Joye and Dewitte (2018) make several recommendations, two of which we will undertake here: (1) including a non-fatigued control group (here, affective and cognitive assessment at the beginning of exposure to each environment) and (2) using within-subjects comparisons to assess identical pre- and post- environment measures. These recommendations help to determine the limits of restoration: when participants are not yet fatigued at the first measurement, will being in a natural environment benefit affect and cognition? Or will any benefits of a natural environment be evident only after participants experience fatigue (induced through the first set of cognitive tests and exercise)?

By testing the effect of environment and exercise on affect and cognition in Experiment 1, and further exploration of the restorative characteristics of the natural environment in Experiment 2, we aim to: (1) more effectively test the attention restoration claims of ART as suggested by Joye and Dewitte (2018) and (2) to provide clarity for the effects of environment and inconsistent effects of exercise on different cognitive tasks varying in attentional demands, such as short term recall and long term recognition memory (little attentional demand), working memory (DSF: moderate attentional demand/DSB: greater attentional demand), and executive function (TMTA: moderate attentional demand; TMTB: greater attentional demand). Accordingly, we compared affect and the cognitive performance of adults both before and after both an outdoor trail run in a natural environment and an indoor treadmill run in a laboratory environment. If ART theory is supported, affect and tasks involving attention (DSF/DSB, TMTA/TMTB) would be improved in the natural environment condition compared to the indoor condition, with the largest benefits in the tests that require the greatest attentional demands, and no benefit expected for memory. If instead other factors, such as interest, motivation, or stress reduction are driving performance differences, then all cognitive measures should show improvement in the natural environment compared to the indoor environment, regardless of attentional demands. Further, if ART theory is supported, we expect an interaction, such that non-fatigued participants at the beginning of exposure to the environment should not differ in affective and cognitive measures as a function of their environment, but that post-exercise restoration would be greater in the natural environment, leading to lower negative affect, greater positive affect, and improved cognitive performance. In regards to exercise, we hypothesized that affect and long term memory would improve after exercise, and that working memory and executive function may differ (e.g., Lambourne and Tomporowski, 2010; Chang et al., 2012).

MATERIALS AND METHODS

Participants

Twenty-eight (13 men, 15 women) regular runners (defined as running at least 1 time per week for at least 6 months) between the ages of 18 and 50 (M = 26.96, SD = 10.16) were recruited from the University and local population to participate in this 2 (Environment: Natural vs Indoor) X 2 (Exercise: Pre vs Post) within-subjects design. Participants with physical (injury), mental (cognitive impairment), or pharmacological (stimulant medications) indicators were excluded from participation.

Materials and Measures

Exercise Environment

The natural environment was the main hiking and running trail in Solstice Canyon, located in the Santa Monica Mountains National Recreation Area. At the parking area near the trailhead, a shaded pavilion with picnic tables served as the location for completing all pre- and post-exercise measures. The trail (see section "**Appendix**") was a wide dirt and gravel-packed path with a gradual slope that followed a stream through trees, a canyon, and historical ruins. At the end of the main trail, a waterfall cascaded into the stream. Participants were instructed to remain on the main trail at all times and to turn around after either slightly more than halfway through the 20 min time period (10 min and 20 s to account for the uphill on the way to the waterfall and downhill on the return) or after reaching the waterfall. If they returned to the beginning of the trailhead before the 20 min was completed, participants were to run the beginning part of the trail again as needed to make their run end at the trailhead at approximately 20 min.

The indoor location consisted of a research laboratory room on the campus of Pepperdine University. The room was divided with a treadmill (Nordic Track T 6.5S) behind a partial wall and table and chairs to complete all affective and cognitive measures on the other side of the wall. To approximate the trail run, participants were instructed to increase to a gradual incline in the first 10 min, and to decrease the incline back to zero during the last 10 min.

Exercise Materials

All participants were fitted with a Garmin Fenix 5 Plus watch before each run. A beep sounded to alert the participant to turn around and return to the trailhead after 10 min and 20 s in the natural environment condition. Further, as a precaution in the unlikely event that participants disregarded instructions to remain on the main trailhead or became lost (none did so), participants were shown how to access the map feature on the watch, which provided an option for GPS assisted routing back to the trailhead. The watch also recorded the total running distance and time, which was used to confirm that participants ran with minimal to no walking (i.e., a pace faster than 13 min per mile) and did not run more than 30 s longer or shorter than the instructed 20 min. For the indoor condition, distance, time, and pace was confirmed through the treadmill display. All participants viewed and verbally indicated understanding the Rating of Perceived Exertion (Borg, 1982), a 15 point (6 = *No Exertion at All*, 20 = *Maximal Exertion)* perceived exertion scale prior to each run.

Affective Measures

Participants completed the Positive and Negative Affect Schedule Short Form (PANAS-SF; Watson et al., 1988). Participants rated how strongly they were currently experiencing 10 positive (e.g., enthusiastic) and 10 negative (e.g., irritable) feelings on a Likert-scale ranging from 1 (*very slightly or not at all*) to 5 (*extremely*). Total scores could range from 10–50. The PANAS-SF has demonstrated acceptable reliability and validity (Watson et al., 1988). Participants answered two additional items, "happy" and "stressed," on the same scale.

Cognitive Measures

In order to reduce practice effects, all participants completed 4 different versions of each cognitive test: pre- and post-exercise in both the indoor and natural environment.

Memory

Participants completed a shortened variant of the Rey Auditory Verbal Learning Task (AVLT; Rey, 1964). The researcher read out loud to participants one of 4 different versions of a 15 item word list. Words were read at a rate of 1 s per word. For short-term recall, immediately after hearing the list, participants reported all of the words they could remember. For long term recognition memory, after a delay of 15 min (during which participants engaged in the two other cognitive tasks, followed by light stretching) the researcher read a list consisting of the previously read 15 words intermixed with 15 new words in random order. After hearing each word, participants indicated which words were on the original list by saying "yes" to old items and "no" to new items. For recognition, the ability to discriminate between "old" and "new" was measured by d' (z of Hit Rate – z of False Alarm rate). Hit rate was calculated by the proportion of old items correctly identified as old, and False Alarm rate was calculated by the proportion of new items incorrectly identified as old. All lists contained nouns that were equated for word frequency; the 4 different versions of the recall list were lists 1–4 and the additional 15 new items added to each recognition test were lists 5–8 from Potter and Keeling (2005).

Working memory

Participants completed DSF and DSB tests. For DSF, participants heard digit sequences and were required to repeat them in order. Sequences were two to nine digits in length (two sequences of each length for a total of 16 sequences) and were presented in increasing length. For DSB, participants heard digit sequences and were required to repeat them in backwards order (i.e., if the sequence was "3, 2" they were to report "2, 3"). There were 14 sequences, consisting of two sequences each of two to eight digits. For both DSF and DSB, after making mistakes on two sequences or upon completion of the final sequence the task was ended. The number of correct sequences was recorded, with a maximum score of 16 (DSF) or 14 (DSB). In addition, the length of the longest sequence (i.e., span length) recalled correctly was recorded. The total number correct and span length were multiplied to create a product score (Kessels et al., 2000). Four different versions of the DSF and DSB were created and administered.

Executive function

Participants completed the Trail Making Test A and B (Bowie and Harvey, 2006). Both parts consisted of 25 circles distributed over a sheet of paper. In TMTA, the circles were numbered 1–25, and the participant drew lines to connect the numbers in ascending order as quickly as possible, without lifting the pen or pencil from the paper. In TMTB, the circles included both numbers (1–13) and letters (A – L); as in TMTA, the participant drew lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). If the participant made an error, the researcher pointed it out immediately and instructed him or her to correct it. The total time to complete the test was measured. In addition to the original A and B (Bowie and Harvey, 2006), 3 additional versions were created by rearranging the numbers and letters in each circle.

Procedure

This research was approved by the Institutional Review Board of Pepperdine University. Interested participants who passed the physical, cognitive, and pharmacological screening completed 2 conditions in random order: a 20-min outdoor trail run (natural environment) and a 20-min treadmill run (indoor environment). Outdoor runs did not take place in hazardous or adverse weather conditions (for example, temperatures above 90 °F/32.2°C or strong winds) or non-daylight hours. Each participant completed their indoor and outdoor runs at approximately the same time of day, 1 week apart.

At Session 1, participants met the researcher at either the natural environment (Solstice Canyon main parking area) or the indoor environment (the research room on the University's campus), depending on which location they were randomly assigned to first. Participants gave informed consent and then completed the first PANAS, happiness, and stress questionnaire followed by the recall portion of the AVLT. Next, participants completed either the Digit Span or Trail Making tests (in random order), followed by light stretching, until 15 min had passed since the completion of the recall test. Then, participants completed the

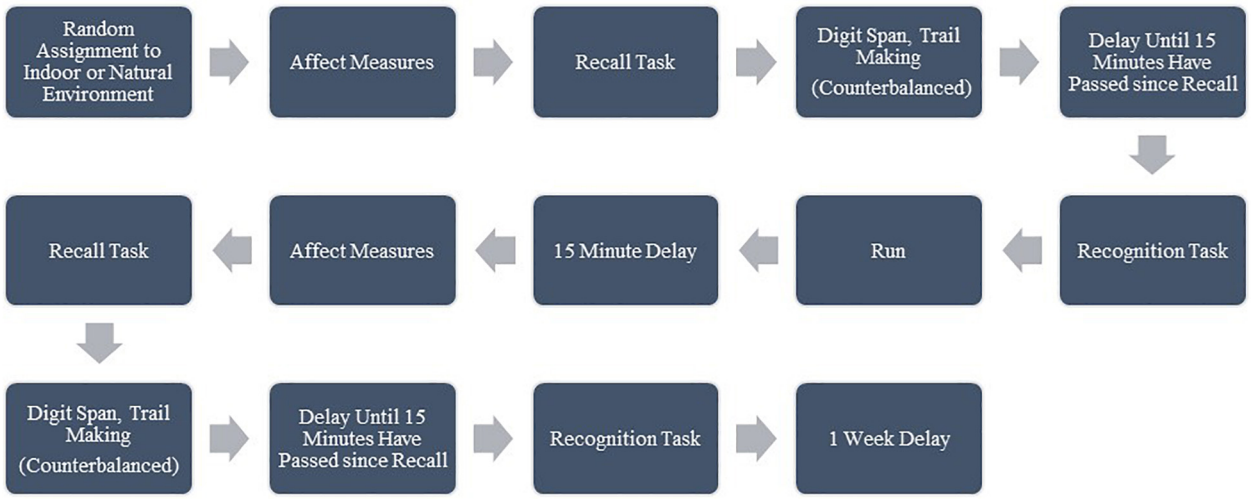


FIGURE 1 | Session 1 procedure; Session 2 followed the same procedure in the alternate environment. Affect Measures included ratings of: happiness, stress, Positive Affect (PA), and Negative Affect (NA). Cognitive measures included a recall and recognition test for word lists, Digit Span Forwards (DSF), Digit Span Backwards (DSB), Trail Making Test A (TMTA), and Trail Making Test (B).

recognition portion of the AVLT. Before their run, participants viewed the perceived exertion scale (Borg, 1982) and received instructions to maintain a moderate to high intensity, or a 14–15. Participants then completed the 20 min run as described above. After the run, participants were offered bottled water and were instructed to engage in light stretching or to alternate walking with sitting for 15 min. Finally, participants completed the second set of affect and cognitive measures, in the same manner as they completed the first set. They were then reminded of the location and time for Session 2 and offered an energy sports snack (such as Clif Blocks, GU Gel, or similar product). Please see **Figure 1** for a representation of the procedure.

At Session 2, 1 week after Session 1, participants followed the same procedure as in Session 1 in the other environment with the two remaining versions of the cognitive tasks. They were then debriefed and thanked with a $50 Amazon gift card for their participation.

RESULTS

With one exception, there were no environment order effects; for the fourth administration (the end of Session 2) of the TMTB, those who had completed their first session indoors (M = 31.22, SD = 9.24) responded faster than those who had completed their first session in the natural environment (M = 45.87, SD = 13.33), F (1, 27) = 11.51, p = 0.002, and η^2 = 0.31. Given the lack of order effects on any other measure, order was not considered as a factor in further analyses. Similarly, there were no significant gender effects or interactions. For all analyses, a 2 (Environment: Indoor, Natural) × 2 (Exercise: Pre, Post) Repeated Measures ANOVA was conducted to determine the effects of environment and exercise on affect and cognition (with the exception of Trail Making, as described below).

Affect

Happiness

There was a significant effect of environment on happiness, F (1, 27) = 5.87, p = 0.02, and η_p^2 = 0.18, such that participants reported more happiness in the indoor environment than in the natural environment, see **Table 1**. There was also a significant main effect of exercise on happiness, F (1, 27) = 5.64, p = 0.03, η_p^2 = 0.17, such that participants were happier after exercise than they were before exercise. The interaction between environment and exercise was not significant, F (1, 27) = 0.04, p = 0.85, η_p^2 = 0.001.

Stress

There was no significant effect of environment on stress, F (1, 27) = 0.08, p = 0.78, and η_p^2 = 0.003. There was a significant main effect of exercise on stress, F (1, 27) = 14.03, p = 0.001, and η_p^2 = 0.34, such that participants were less stressed after exercise than they were before exercise, see **Table 1**. The interaction between environment and exercise was not significant, F (1, 27) = 1.21, p = 0.28, and η_p^2 = 0.04.

PANAS

There was a significant effect of environment on positive affect, F (1, 27) = 15.72, p < 0.001, and η_p^2 = 0.37, such that participants reported higher positive affect in the indoor environment (than in the natural environment. There was also a significant main effect of exercise on positive affect, F (1, 27) = 32.19, p < 0.001, and η_p^2 = 0.54, such that participants reported higher positive affect after exercise than before exercise. The interaction between environment and exercise was not significant, F (1, 27) = 1.55, p = 0.22, and η_p^2 = 0.05, see **Table 1**.

There was no significant effect of environment on negative affect, F (1, 27) = 1.60, p = 0.22, and η_p^2 = 0.06. There was a significant main effect of exercise on negative affect, F (1,

TABLE 1 | Mean (*SD*) affect as a function of location and exercise.

	Happiness	Stress	Positive Affect	Negative Affect
Natural environment	3.50 (0.95)	2.11 (1.12)	30.88 (8.63)	12.73 (3.41)
Pre-Exercise	3.39 (0.96)	2.43 (1.17)	28.43 (7.49)	12.93 (3.63)
Post-Exercise	3.61 (0.96)	1.79 (0.99)	33.32 (9.11)	12.54 (3.22)
Indoor environment	3.77 (0.93)	2.07 (1.08)	34.30 (7.41)	13.30 (4.39)
Pre-Exercise	3.68 (0.90)	2.29 (1.24)	32.43 (6.65)	14.18 (5.25)
Post-Exercise	3.86 (0.97)	1.86 (0.85)	36.18 (7.76)	12.43 (3.17)
Pre-Exercise	3.54 (0.93)	2.36 (1.20)	30.43 (7.30)	13.55 (4.51)
Post-Exercise	3.73 (0.96)	1.82 (0.92)	34.75 (8.51)	12.48 (3.17)
Total	3.63 (0.95)	2.09 (1.10)	32.59 (8.19)	13.02 (3.92)

TABLE 2 | Mean (*SD*) cognitive performance as a function of location and exercise.

	Memory (d')	Digit Span Forwards	Digit Span Backwards	Trail Making A	Trail Making B
Natural environment	1.86 (0.96)	92.45 (26.95)	43.45 (21.83)	19.39 (5.01)	39.86 (15.46)
Pre-Exercise	1.99 (0.94)	92.68 (29.23)	41.46 (21.85)	18.25 (4.99)	52.08 (17.91)
Post-Exercise	1.74 (0.98)	92.21 (24.99)	45.43 (22.03)	20.57 (4.84)	35.93 (12.58)
Indoor environment	1.86 (0.91)	84.98 (30.84)	42.05 (21.73)	21.34 (5.92)	39.49 (11.29)
Pre-Exercise	2.03 (0.81)	89.61 (34.86)	41.39 (18.58)	20.30 (5.70)	45.52 (13.13)
Post-Exercise	1.70 (0.91)	80.36 (26.04)	42.71 (24.82)	22.39 (6.04)	35.61 (8.00)
Pre-Exercise	2.01 (0.87)	91.14 (31.91)	41.43 (20.10)	19.27 (5.41)	47.71 (14.87)
Post-Exercise	1.72 (0.97)	86.29 (25.99)	44.07 (23.29)	21.49 (5.51)	35.77 (10.44)
Total	1.86 (0.93)	88.71 (29.07)	42.75 (21.70)	20.37 (5.55)	39.65 (13.23)

27) = 4.48, $p = 0.04$, $\eta_p^2 = 0.14$, such that participants reported lower negative affect after exercise than before exercise, see **Table 1**. The interaction between environment and exercise was marginally significant, F (1, 27) = 3.34, $p = 0.08$, and $\eta_p^2 = 0.11$, suggesting that negative affect decreased more after exercise in the indoor condition than in the outdoor condition, see **Table 1**.

Cognitive Performance

Memory

There was no significant effect of environment [F (1, 27) = 0.00, $p = 1.00$, and $\eta_p^2 = 0.00$], exercise [F (1, 27) = 1.44, $p = 0.24$, and $\eta_p^2 = 0.05$], or an interaction [F (1, 27) = 2.22, $p = 0.15$, and $\eta_p^2 = 0.08$] on correct recall of the word lists. There was a marginal effect of exercise, F (1, 27) = 3.14, $p = 0.09$, $\eta_p^2 = 0.10$, such that discrimination (d') was higher before exercise than after exercise. There was no significant effect of environment [F (1, 27) = 0.00, $p = 0.99$, $\eta_p^2 = 0.00$) and no interaction [F (1, 27) = 0.14, $p = 0.72$, and $\eta_p^2 = 0.01$), see **Table 2**.

Digit Span

The product score for DSF was computed by multiplying the number correct (which could range from 0–16) by the length of the longest sequence accurately completed (which could range from 2–9), for a total score ranging from 0–144. There was a significant effect of environment, F (1, 27) = 4.12, $p = 0.05$, and $\eta_p^2 = 0.14$, such that participants scored higher in the natural environment than in the indoor environment. There was no significant effect of exercise [F (1, 27) = 2.73, $p = 0.11$, $\eta_p^2 = 0.09$], and no interaction [F (1, 27) = 0.98, $p = 0.33$, and $\eta_p^2 = 0.04$], see **Table 2**.

The product score for DSB was computed by multiplying the number correct (which could range from 0–14) by the length of the longest sequence accurately completed (which could range from 2–8), for a total score ranging from 0–112. There were no significant effects [Environment: F (1, 27) = 0.61, $p = 0.44$, and $\eta_p^2 = 0.02$; Exercise: F (1, 27) = 2.62, $p = 0.12$, and $\eta_p^2 = 0.09$; Interaction: F (1, 27) = 0.83, $p = 0.37$, and $\eta_p^2 = 0.03$), see **Table 2**.

Trail Making

For both A and B, versions 1 and 3 were always completed pre-exercise (counterbalanced for either the indoor or natural environment); similarly, versions 2 and 4 were always completed post-exercise, counterbalanced by environment. Thus, given the confound of version with exercise, it was important to determine if the 4 versions were comparable in difficulty (see Experiment 2). For TMTA, a repeated measures ANOVA revealed significant differences, F (3, 60) = 7.00, $p < 0.001$, and $\eta_p^2 = 0.26$. Post-hoc (LSD) tests revealed that TMTA version 1 ($M = 17.01$, $SE = 0.83$) and version 3 ($M = 17.63$, $SE = 1.04$) did not differ from each other, $p = 0.56$. Likewise, version 2 ($M = 21.11$, $SE = 1.17$), and version 4 ($M = 20.53$, $SE = 0.99$) did not differ from each other, $p = 0.43$. However, versions 1 and 3 differed significantly from versions 2 and 4 ($ps < 0.05$). For TMTB, a repeated measures ANOVA revealed significant differences, F (3, 60) = 2.69, $p = 0.05$, and $\eta_p^2 = 0.19$. Post-hoc (LSD) tests revealed that version 3 ($M = 39.29$, $SE = 2.48$) was significantly more difficult than version 1 ($M = 35.30$, $SE = 1.90$, and $p = 0.05$) and version 4 ($M = 32.72$, $SE = 1.88$, and $p = 0.01$). Versions 1, 2 ($M = 35.67$, $SE = 2.36$), and 4 did not significantly differ from each other, all

*p*s > 0.05. Therefore, TMTB version 3 was excluded from analysis in the present study.

Thus, with the present sample, for TMTA, two *t*-tests were conducted separately to determine the effect of environment: (1) pre-exercise and (2) post-exercise. A paired-sample *t*-test revealed that, pre-exercise, those in the natural environment were marginally faster than those in the indoor environment, t (27) = 1.85, p = 0.08, Cohen's d = 0.38. Similarly, post-exercise, those in the natural environment were marginally faster than those in the indoor environment, t (26) = 1.82, p = 0.08, Cohen's d = 0.40, see **Table 2**.

With the present sample, time to complete TMTB (Versions 1, 2, and 4) was analyzed with the factors of environment and exercise in a normal identity generalized estimating equation. There was a main effect of exercise such that participants completed the task faster after exercise than before exercise, Wald $\chi 2$ (1, 83) = 20.16, $p < 0.001$, *QICC* = 11499.16. There was no effect of environment, Wald $\chi 2$ (1, 83) = 1.03, p = 0.31, *QICC* = 11499.16, and no interaction, Wald $\chi 2$ (1, 83) = 0.87, p = 0.35, *QICC* = 11499.16, see **Table 2**.

DISCUSSION

In contrast to the hypothesis, participants indicated greater happiness and positive affect in the indoor environment than in the natural environment. These results are in direct contrast to prior research (Bowler et al., 2010; McMahan and Estes, 2015), although other studies (Butryn and Furst, 2003; Kerr et al., 2006) have found no difference in mood as a result of running in an urban or natural environment. One possibility for the surprising difference in happiness and positive affect is that the natural environment location was not, in fact, restorative and may have even been perceived as dangerous. If this were the case, we would also expect stress and negative affect scores to differ across environments, but they were generally quite low and did not differ. This may indicate that there was not a great need for restoration in the first place, as participants were not currently undergoing stress or negative emotional experiences. However, the natural environment did result in improvement on cognitive tests requiring moderate amounts of attentional resources, indicating that there was room for at least some restoration to take place.

Solstice Canyon was deliberately chosen for its general popularity as an outdoor location, for its lack of crime, for the fact that it contains both green and blue elements, the ease of running on a hard-packed trail, and its general convenience to the University campus. Nevertheless, while natural environments are generally seen as restorative, such restoration is not universal. For instance, environments containing higher visibility (high prospect) and fewer hiding places (low refuge) are perceived as being more restorative, less dangerous, and result in higher attentiveness scores than low prospect, high refuge environments (Gatersleben and Andrews, 2013). In addition, for environments that are perceived as dangerous, being in nature with company (but not solitude) leads to restoration; solitude increased restoration only when danger was controlled for Staats and Hartig (2004). These findings demonstrate that the level of restoration from nature depends on the participants' level of attention and fear, particularly for those who are alone, as was the case in this experiment. To examine the possibility that participants experienced fear, we compared the means from the PANAS item: the extent to which participants were currently feeling "Afraid." The results showed no effect of environment, F (1, 27) = 0.00, p = 1.00, and η_p^2 = 0.00. Answers to an individual PANAS question (which are not typically examined in isolation), however, likely do not capture the full extent to which Solstice Canyon may have been perceived as fearful or dangerous, and do not touch at all on the perceived restoration of this environment. Thus, Experiment 2 explored the perceived restoration, fear, and danger of Solstice Canyon.

In regards to cognition, the effect of a natural environment was somewhat beneficial. There was no effect of environment on short or long term memory, but one working memory measure (DSF) and one measure of executive function (TMTA) were improved when in the natural environment compared to the indoor environment. It is worth noting that, contrary to Ohly et al. (2016), the versions requiring moderate attentional resources showed improvement from a natural environment, whereas versions requiring greater attentional resources (DSB, TMTB) showed no effect of environment. No cognitive measures showed worse performance for the natural environment compared to the indoor environment. These results, therefore, show partial support for ART, in that memory (which requires little attentional resources) was not affected by the environment, but tasks that require moderate attention (DSF, TMTA) showed improvements in a natural environment consistent with attentional restoration. This supports Stevenson et al.'s (2018) meta-analytic finding of disparate evidence for an attentional restoration mechanism. Two findings, however, suggest that factors other than attentional restoration may be at play. First, there was no effect of environment for the tasks with the greatest attentional demands, DSB and TMTB. Second, there were no significant interactions between environment and exercise, such that those in the natural environment did not show a larger restoration in affective or cognitive measures from pre to post exercise than those in the indoor environment. In the one marginal interaction, negative affect decreased more after exercise in the indoor environment than in the natural environment. While restoration cannot fully explain these results, neither can interest or motivation, as affective and cognitive effects of environment were not consistent across tasks, and neither can stress reduction, as stress was not affected by environment.

As hypothesized, exercise, regardless of environment, increased happiness and positive affect, and decreased stress and negative affect. In contrast to the hypothesis, exercise did not improve memory scores, and in fact resulted in marginally lower scores. This is surprising, given that long-term memory benefits are one of the more consistently supported effects of exercise (Lambourne and Tomporowski, 2010; Chang et al., 2012). Given the lack of consistency in regards to the effects of exercise on working memory, it is not surprising that exercise did not result in differences on DSF or DSB. When it could be assessed (TMTB), exercise did improve executive function. These

results lend further clarity to the literature regarding differing effects of exercise on different cognitive tasks.

Overall, it appears that a natural environment has some beneficial effects on working memory and executive function tasks that require moderate amounts of attention, and no effects on tasks that require little attention. However, given the possibility that the natural environment location may not have been restorative, further investigation into this environment is needed before drawing definitive conclusions.

EXPERIMENT 2

The purpose of Experiment 2 was to clarify the results from Experiment 1 in two ways. First, to compare the difficulty of the 4 different TMTA and 4 different TMTB versions, participants completed all 4 TMTA and all 4 TMTB versions from Experiment 1 in random order and in one sitting.

Second, in order to draw conclusions about the restorative effects of the natural environment used in Experiment 1, we measured the perceived restoration, perceived danger, and attentiveness to the natural location used in Experiment 1.

METHOD

Participants

Twenty-seven participants (17 women, 7 men; *M* age = 19.46, *SD* = 1.18) who did not participate in Experiment 1 were recruited.

Materials

Participants completed an 11-item version of the Perceived Restorativeness Scale (PRS; Pasini et al., 2015), which was developed as a shorter version of the original PRS (Hartig et al., 1996). This 11-item scale measures the perceived restorative quality of natural environments with 4 groupings: Being Away (e.g., "Places like this are a refuge from nuisances"), Fascination ("e.g., In places like this my attention is drawn to many interesting things"), Coherence (e.g., "There is a clear order in the physical arrangement of places like this"), and Scope (e.g., "That place is large enough to allow exploration in many directions"). Each item was measured on a scale of 1 (*Strongly Agree)* to 7 (*Strongly Disagree)*.

Four questions (adapted from Gatersleben and Andrews, 2013) measured perceived danger ("I think I could come to harm during a walk through this place"), perceived fear ("I would be uneasy taking a walk through this place"), attentiveness ("I felt attentive to this place"), and behavior ("I would like to take a walk through this place"). Each item was measured on a scale of 1 (*Strongly Disagree)* to 7 (*Strongly Agree)*.

Procedure

After giving informed consent, each participant completed the 4 TMTA and 4 TMTB in random order. All participants took the test in the same location (an indoor laboratory on the University's campus) and did not exercise prior to the experiment. Next, participants viewed a slideshow that contained 32 images from Solstice Canyon Trail displayed for 6 seconds each; these images contained scenes that were either of the trail itself or of scenes that were easily visible from the trail. After viewing the slideshow, participants answered demographic questions and completed the PRS, danger, fear, attentiveness, and behavior items regarding the trail.

RESULTS

The data from 3 participants was discarded as excessive errors in the Trail Making portion of the task indicated they were not attending to the task. Trail Making results are described in Experiment 1.

To determine if the natural environment location was indeed restorative, the responses on the 11 PRS items were averaged (Hartig et al., 1996) and indicated that participants somewhat agreed that Solstice was restorative (*M* = 3.09, *SD* = 1.07). The mean was also separately calculated for the 3 Fascination items (*M* = 2.81, *SD* = 1.44), 3 Being Away items (*M* = 3.08, *SD* = 1.44), 3 Coherence items (*M* = 3.68, *SD* = 1.28), and 2 Scope (*M* = 2.67, *SD* = 1.52) items.

To examine the hypothesis that Solstice Canyon could induce fear, the mean was calculated for the two fear questions. The results suggested that participants disagreed that they would be uneasy about the location (*M* = 5.87, *SD* = 1.08) and somewhat disagreed that they could come to potential harm *(M* = 4.54, *SD* = 1.47). Further, participants agreed that they would like to take a walk through this place (*M* = 2.58, *SD* = 1.44). Lastly, participants somewhat agreed that they felt attentive to the location, (*M* = 2.96, *SD* = 1.00).

GENERAL DISCUSSION

The results indicated that Solstice did not induce fear and was not perceived as dangerous, that participants would like to walk there, and were attentive. Further, Solstice was perceived as somewhat restorative. Thus, the lack of greater positive affect and happiness for the natural environment was not due to fear, danger, inattention to the environment, or a lack of restoration. However, the lack of strong restorative scores on the PRS may explain why the expected affective benefits of the natural environment did not manifest, and perhaps why the cognitive benefits only manifested for tasks requiring only moderate amounts of attention—DSF and TMTA. If the environment was only somewhat restorative, it is possible that direct attention was only partially restored. Thus, tasks that require moderate amounts of attention may show the benefits of a small restoration, but tasks that require greater amounts of attention (DSB, TMTB) would not show significant improvement. One limitation to this interpretation, however, is that participants in Experiment 2, unlike Experiment 1, simply viewed the natural environment (consistent with Gatersleben and Andrews, 2013), rather than being present in the natural environment like in Experiment 1.

But why was the natural environment not more strongly restorative? An intriguing possibility is that while the natural

environment contained all of the restorative elements, such as green and blue spaces, and low fear and danger, these types of natural environments are more commonly experienced by these participants, reducing its effect and the need for restoration. The University is located in Malibu, California, a location known not only for its highly urbanized landscape near Los Angeles, but also for its beautiful beaches and ocean views, rugged Santa Monica Mountains, and natural beauty with plentiful access to natural space. Compared to many other urban environments, green spaces are relatively accessible and numerous. If such experiences are frequent for most participants, then perhaps a natural environment would not be as strongly restorative or have as strong affective benefits. Further, the results from this participant population, who have relatively easy and frequent access to natural environments, may not generalize to populations for whom natural environments are far less accessible and/or safe. Future research should consider the inclusion of a sample with greater diversity in access to nature.

This possibility is consistent with hedonic adaptation, wherein the emotional effects of a stimulus become weakened with repeated experience of that stimulus (Frederick and Loewenstein, 1999). Researchers have suggested that this adaptation and subsequent weakening of affective reactions is due to a reduction in attention to that stimulus; novel, self-relevant stimuli that once captured attention no longer do so (Wilson and Gilbert, 2008). However, our results indicated that participants in Experiment 2 were attentive to the environment. This "variety is the spice of life" explanation is not consistent with research showing that more time spent in nature is linked to greater positive affect [an effect partially accounted for by the quality of the nature experience (i.e., fascination; Sato and Connor, 2013)] and that increased exposure or availability of natural environments is related to many benefits, such as better mental health (Alcock et al., 2014), less stress, depression, and anxiety (Thompson et al., 2012; Beyer et al., 2014), and greater occupational well-being (Hyvönen et al., 2018). Future research should investigate the possibility that with repeated exposure, each individual exposure results in smaller *immediate* affective benefits due to hedonic adaptation, but that greater cumulative exposure results in larger long-term affective benefits. Even if the effect of environment on affect is smaller for those who experience natural environments regularly, our results show that such environments can still benefit cognition. Future studies should investigate the possibility that our findings of increased performance on DSF and TMTA would be more robust for those who are unused to natural environments, perhaps extending to DSB and TMTB.

An additional possibility is that there may have been an incongruency between the natural environment and experiment expectations. In other words, participants may have expected and been intrinsically motivated for exploration and relaxation in a natural environment, but were instead met with a prescribed running route and with cognitively demanding tasks. Specifically, participants lacked agency and autonomy to choose how they spent their time in the natural environment (e.g., Ryan and Deci, 2000; Andringa et al., 2013) and were asked to perform tasks that were incongruent with the environment. Such incongruency could explain lower positive affect and happiness. Conversely, the indoor environment likely fostered a higher congruency between expectations and demands; many of the participants were students or professors of the University where the indoor environment was located and likely associated that location with more prescribed and cognitively demanding tasks.

The environments also differ in ways other than simple exposure to nature. In Experiment 1, the indoor location, despite being a more impoverished and controlled environment, approximates situations (e.g., an office, school) where the type of cognitive tests used in this and similar research are likely to be relevant. The natural environment, however, is richer and less controlled. In Experiment 2, the natural environment was viewed from a more controlled laboratory setting. Future research into the effects of natural environments should take into account and further explore how laboratory environments differ from natural environments, and how these differences may contribute to different motivations and behaviors.

In accordance with our first aim, using a within-subjects design and non-fatigued control groups, we found some support for ART, with tasks that required moderate attentional resources showing the greatest benefit of a natural environment, and tasks showing little attentional demand (memory) showing no difference. However, the lack of improvement in tasks requiring the most amount of direct attention, and the lack of an interaction with exercise, suggests that ART cannot fully explain cognitive performance in natural and indoor environments. With the pre-exercise measures serving as a non-fatigued control for both environments, post-exercise (fatigued) benefits for executive function in both environments suggest that either attentional restoration (stemming purely from the environment) is not the explanation for improved post-exercise performance, or that participants were not in fact suffering from depleted direct attentional resources in the first place.

Regarding our second aim, the effects of exercise were generally, with the exception of memory, consistent with our hypotheses—improved affect, no effect on working memory, and some benefit to executive function. While the picture is becoming clearer regarding exercise effects on working memory and executive function, further research is still needed to tease out the factors that might lead to benefits in some circumstances with some tasks, and no such benefits in others. In conclusion, exercise and environment both appear to improve cognitive performance across different tasks, while affective benefits may depend on other factors, such as how regularly one experiences natural environments. These findings lend further support to the need to provide and maintain accessible restorative natural environments. However, while understanding the environment is critical to understanding affective and cognitive behavior, it is important to remember that natural environments are not always universally beneficial.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of Pepperdine University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JT developed the research idea, methodology, conducted all data analyses, and wrote the initial draft of the manuscript. SA was an active contributor to methodology, collected all data, and provided substantial and meaningful contributions to interpretation of results and writing of the manuscript. Both authors contributed to the article and approved the submitted version.

FUNDING

This research was funded by internal grants from Pepperdine University.

REFERENCES

Alcock, I., White, M. P., Wheeler, B. W., Fleming, L. E., and Depledge, M. H. (2014). Longitudinal effects on mental health of moving to greener and less green urban areas. *Environ. Sci. Technol.* 48, 1247–1255. doi: 10.1021/es403688w

Andringa, T. C., van den Bosch, K. A. M., and Vlaskamp, C. (2013). Learning autonomy in two or three steps: linking open-ended development, authority, and agency to motivation. *Front. Psychol.* 4:766. doi: 10.3389/fpsyg.2013.00766

Berman, M. G., Jonides, J., and Kaplan, S. (2008). The cognitive benefits of interacting with Nature. *Psychol. Sci.* 19, 1207–1212. doi: 10.1111/j.1467-9280.2008.02225.x

Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *J. Environ. Psychol.* 25, 249–259. doi: 10.1016/j.jenvp.2005.07.001

Beyer, K. M., Kaltenbach, A., Szabo, A., Bogar, S., Nieto, F. J., and Malecki, K. M. (2014). Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin. *Int. J. Environ. Res. Public Health* 11, 3453–3472. doi: 10.3390/ijerph110303453

Bodin, M., and Hartig, T. (2003). Does the outdoor environment matter for psychological restoration gained through running? *Psychol. Sport Exer.* 4, 141–153. doi: 10.1016/S1469-0292(01)00038-3

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Med. Sci. Sports Exer.* 14, 377–381. doi: 10.1249/00005768-198205000-00012

Bowie, C. R., and Harvey, P. D. (2006). Administration and interpretation of the Trail Making Test. *Nat. Protoc.* 1, 2277–2281. doi: 10.1038/nprot.2006.390

Bowler, D. E., Buyung-Ali, L. M., Knight, T. M., and Pullin, A. S. (2010). A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health* 10:456. doi: 10.1186/1471-2458-10-456

Butryn, T. M., and Furst, D. M. (2003). The effects of park and urban settings on the moods and cognitive strategies of female runners. *J. Sport Behav.* 26, 335–355.

Chang, Y. K., Labban, J. D., Gapin, J. I., and Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Res.* 1453, 87–101. doi: 10.1016/j.brainres.2012.02.068

Colcombe, S., and Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: a meta-analytic study. *Psychol. Sci.* 14, 125–130.

Coon, J. T., Boddy, K., Stein, K., Whear, R., Barton, J., and Depledge, M. H. (2011). Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environ. Sci. Technol.* 45, 1761–1772. doi: 10.1021/es102947

Farina, N., Rusted, J., and Tabet, N. (2014). The effect of exercise interventions on cognitive outcome in Alzheimer's disease: a systematic review. *Int. Psychogeriatr.* 26, 9–18. doi: 10.1017/S1041610213001385

Finlay, J., Franke, T., MacKay, H., and Sims-Gould, J. (2015). Therapeutic landscapes and wellbeing in later life: impacts of blue and green spaces for older adults. *Health Place* 34, 97–106. doi: 10.1016/j.healthplace.2015.05.001

Frederick, S., and Loewenstein, G. (1999). "Hedonic adaptation," in *Well-Being: The Foundations of Hedonic Psychology*, eds D. Kahneman, E. Diener, and N. Schwarz (New York, NY: Russell Sage Foundation), 302–329.

Gamble, K. R., Howard, J. H. Jr., and Howard, D. V. (2014). Not just scenery: Viewing nature pictures improves executive attention in older adults. *Exp. Aging Res.* 40, 513–530. doi: 10.1080/0361073X.2014.956618

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., et al. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. *Int. J. Environ. Res. Public Health* 12, 4354–4379. doi: 10.3390/ijerph120404354

Gatersleben, B., and Andrews, M. (2013). When walking in nature is not restorative–The role of prospect and refuge. *Health Place* 20, 91–101. doi: 10.1016/j.healthplace.2013.01.001

Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., et al. (2016). Where to put your best foot forward: psycho-physiological responses to walking in natural and urban environments. *J. Environ. Psychol.* 45, 22–29. doi: 10.1016/j.jenvp.2015.11.003

Hartig, T., Korpela, K. M., Evans, G. W., and Gärling, T. (1996). "Validation of a measure of perceived environmental restorativeness," in *Göteborg Psychological Reports*, Vol. 26, (Göteborg: Göteborg University), 1–64.

Hötting, K., Schauenburg, G., and Röder, B. (2012). Long-term effects of physical exercise on verbal learning and memory in middle-aged adults: results of a one-year follow-up study. *Brain Sci.* 2, 332–346. doi: 10.3390/brainsci2030332

Hyvönen, K., Törnroos, K., Salonen, K., Korpela, K., Feldt, T., and Kinnunen, U. (2018). Profiles of nature exposure and outdoor activities associated with occupational well-being among employees. *Front. Psychol.* 9:754. doi: 10.3389/fpsyg.2018.00754

Joye, Y., and Dewitte, S. (2018). Nature's broken path to restoration. A critical look at attention restoration theory. *J. Environ. Psychol.* 59, 1–8. doi: 10.1016/j.jenvp.2018.08.006

Kaplan, S. (1995). The restorative benefits of nature: toward an integrative framework. *J. Environ. Psychol.* 15, 169–182. doi: 10.1016/0272-4944(95)90001-2

Kaplan, S., and Berman, M. G. (2010). Directed attention as a common resource for executive functioning and self-regulation. *Perspect. Psychol. Sci.* 5, 43–57. doi: 10.1177/1745691609356784

Kerr, J. H., Fujiyama, H., Sugano, A., Okamura, T., Chang, M., and Onouha, F. (2006). Psychological responses to exercising in laboratory and natural environments. *Psychol. Sport Exer.* 7, 345–359. doi: 10.1016/j.psychsport.2005.09.002

Kessels, R. P. C., van Zandvoort, M. J. E., Postma, A., Kappelle, L. J., and De Haan, E. H. F. (2000). The corsi block-tapping task: standardization and normative data. *Appl. Neuropsychol.* 7, 252–258. doi: 10.1207/S15324826AN0704_8

Lambourne, K., and Tomporowski, P. (2010). The effect of exercise-induced arousal on cognitive task performance: a meta-regression analysis. *Brain Res.* 1341, 12–24. doi: 10.1016/j.brainres.2010.03.091

Loprinzi, P. D., Frith, E., Edwards, M. K., Sng, E., and Ashpole, N. (2018). The effects of exercise on memory function among young to middle-aged adults: systematic review and recommendations for future research. *Am. J. Health Promot.* 32, 691–704. doi: 10.1177/0890117117737409

McMahan, E. A., and Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: a meta-analysis. *J. Posit. Psychol.* 10, 507–519. doi: 10.1080/17439760.2014.994224

Naderi, A., Shaabani, F., Esmaeili, A., Salman, Z., Borella, E., and Degens, H. (2019). Effects of low and moderate acute resistance exercise on executive function in community-living older adults. *Sport Exer. Perform. Psychol.* 8, 106–122. doi: 10.1037/spy0000135

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., et al. (2016). Attention restoration theory: a systematic review of the attention restoration potential of exposure to natural environments. *J. Toxicol. Environ. Health Part B* 19, 305–343. doi: 10.1080/10937404.2016.1196155

Öhman, H., Savikko, N., Strandberg, T. E., and Pitkälä, K. H. (2014). Effect of physical exercise on cognitive performance in older adults with mild cognitive impairment or dementia: a systematic review. *Dement. Geriatr. Cogn. Disord.* 38, 347–365. doi: 10.1159/000365388

Pasini, M., Berto, R., Brondino, M., Hall, R., and Ortner, C. (2015). How to measure the restorative quality of environments: The PRS-11. *Proc. Soc. Behav. Sci.* 159, 293–297. doi: 10.1016/j.sbspro.2014.12.375

Potter, D., and Keeling, D. (2005). Effects of moderate exercise and circadian rhythms on human memory. *J. Sport Exerc. Psychol.* 27, 117–125. doi: 10.1123/jsep.27.1.117

Pretty, J., Peacock, J., Hine, R., Sellens, M., South, N., and Griffin, M. (2007). Green exercise in the UK countryside: effects on health and psychological well-being, and implications for policy and planning. *J. Environ. Plan. Manag.* 50, 211–231. doi: 10.1080/09640560601156466

Rey, A. (1964). *L'examen Clinique en Psychologie*. Paris: Presses universitaires de France.

Rider, N. D., and Bodner, G. E. (2016). Does taking a walk in nature enhance long-term memory? *Ecopsychology* 8, 27–34. doi: 10.1089/eco.2015.0042

Rogerson, M., and Barton, J. (2015). Effects of the visual exercise environments on cognitive directed attention, energy expenditure and perceived exertion. *Int. J. Environ. Res. Public Health* 12, 7321–7336. doi: 10.3390/ijerph120707321

Ryan, R. M., and Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemp. Educ. Psychol.* 25, 54–67. doi: 10.1006/ceps.1999.1020

Sato, I., and Connor, T. S. (2013). The quality of time in nature: how fascination explains and enhances the relationship between nature experiences and daily affect. *Ecopsychology* 5, 197–204. doi: 10.1089/eco.2013.0026

Schertz, K. E., and Berman, M. G. (2019). Understanding nature and its cognitive benefits. *Curr. Direct. Psychol. Sci.* 28, 496–502. doi: 10.1177/0963721419854100

Staats, H., and Hartig, T. (2004). Alone or with a friend: a social context for psychological restoration and environmental preferences. *J. Environ. Psychol.* 24, 199–211. doi: 10.1016/j.jenvp.2003.12.005

Stevenson, M. P., Schilhab, T., and Bentsen, P. (2018). Attention restoration theory II: a systematic review to clarify attention processes affected by exposure to natural environments. *J. Toxicol. Environ. Health Part B* 21, 227–268. doi: 10.1080/10937404.2018.1505571

Tan, B. W., Pooley, J. A., and Speelman, C. P. (2016). A meta-analytic review of the efficacy of physical exercise interventions on cognition in individuals with autism spectrum disorder and ADHD. *J. Autism Dev. Disord.* 46, 3126–3143. doi: 10.1007/s10803-016-2854-x

Taylor, A. F., and Kuo, F. E. (2009). Children with attention deficits concentrate better after a walk in the park. *J. Attent. Disord.* 12, 402–409. doi: 10.1177/1087054708323000

Thompson, C. W., Roe, J., Aspinall, P., Mitchell, R., Clow, A., and Miller, D. (2012). More green space is linked to less stress in deprived communities: evidence from salivary cortisol patterns. *Landsc. Urban Plan.* 105, 221–229. doi: 10.1016/j.landurbplan.2011.12.015

Tomporowski, P. D., Lambourne, K., and Okumura, M. S. (2011). Physical activity interventions and children's mental function: an introduction and overview. *Prevent. Med.* 52, S3–S9. doi: 10.1016/j.ypmed.2011.01.028

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., and Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *J. Environ. Psychol.* 11, 201–230. doi: 10.1016/S0272-4944(05)80184-7

Watson, D., Clark, L. A., and Tellegan, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *J. Pers. Soc. Psychol.* 54, 106. doi: 10.1037/0022-3514.54.6.1063

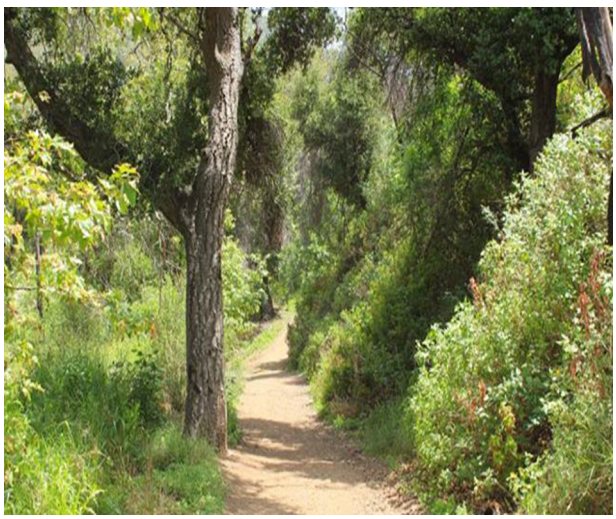
White, M., Smith, A., Humphyres, K., Pahl, S., Snelling, D., and Depledge, M. (2010). Blue space: the importance of water for preference, affect, and restorativeness ratings of natural and built scenes. *J. Environ. Psychol.* 30, 482–493. doi: 10.1016/j.jenvp.2010.04.004

Wilson, T. D., and Gilbert, D. T. (2008). Explaining away: a model of affective adaptation. *Perspect. Psychol. Sci.* 3, 370–386. doi: 10.1111/j.1745-6924.2008.00085.x

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

APPENDIX

Solstice Canyon Trail



Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: frontiersin.org/about/contact

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership