GROWUPGROWOLD
HUMAN DEVELOPMENT, BIRTH TO DEATH

Moffitt & Caspi
Genes
Environment
Health
Behavior

Concept Paper Form

Provisional Paper Title: Is Residential Neighborhood Greenery in Childhood and/or Adulthood Protective against Poor Mental Health in Adulthood?
Proposing Author: Amber L. Pearson
Author's Email: apearson @ msu.edu
P.I. Sponsor: Aaron Reuben & Terrie Moffitt (if the proposing author is a student or colleague of an original PI)
Today's Date: 7/8/2024

Please describe your proposal in 2-3 pages with sufficient detail for helpful review.
Laboratory and experimental research suggest that, like nearly all species, humans process visual and auditory cues in their surrounding environment as either threatening or non-threatening, influencing their behavior, sympathetic and parasympathetic nervous activity, and perceived stress or recovery from stress. [1-4] Potentially harmful cues include signs of disorder (e.g., vacant lots)[5-7], busy and noisy roads,[8] and a lack of safe spaces for pursuing goals (e.g., parks).[9] Potentially beneficial cues include signs of care and intentionality (e.g., well-maintained gardens), and green, vegetated spaces. These latter aspects of the built environment are believed to promote mental health and wellbeing.

Residential neighborhood greenness, for example, has repeatedly been associated with better mental health. Residential greenery has been found to predict lower levels of internalizing and externalizing problems among children (after adjustment for age, sex, maternal education, and neighborhood poverty),[10] and positive mood[11] in adults. Two theories offer potential mechanistic explanation for these found associations.[13] 1) Attention Restoration Theory posits that urban environments require "direct" attention (alertness) and therefore deplete cognitive resources.[14] In contrast, natural environments require "indirect attention," which is less effortful and allows direct attention resources to recover. 2) Stress Recovery Theory posits that safe natural environments are less threatening and therefore less arousing, leading to relaxation that allows for recovery from stress.[15] There is considerable mental health evidence for both theories, including the often-cited experimental evidence that adults asked to walk through or view parks experience downregulation in arousal signals (e.g., cortisol, blood pressure) while the opposite is true for those asked to walk through or view urban environments.

The potential positive role of greenspaces for mental health across the lifecourse is a quickly growing area of global research.[25] But this evidence base suffers currently from a lack of good, prospective, longitudinal studies that can approach causal inference and attempt to take into account socioeconomic confounding and selection effects.

Only one study that we are aware of has followed individuals retrospectively across decades to examine later life mental health measures. This study was a large-scale epidemiologic study in Denmark that reported lower risk for a range of adult psychiatric disorders among children raised (before age 10) in neighborhoods with more greenery.[25] Children from the least green neighborhoods were 55% more likely to experience mental disorder than children from the most green neighborhoods. However, this study only followed up until age 28.

While compelling, the Danish study has yet to be replicated, and there is a clear need for further longitudinal evidence into midlife. The proposed study will address existing gaps in the literature on neighborhood greenspace and mental health by turning to the New Zealand population to attempt to replicate reports from Denmark.

In a population-representative longitudinal birth cohort (the Dunedin Study), we will ask whether living in greener neighborhoods is predictive of better mental health in adulthood, accounting for a wide range of known risk factors for poor mental health that could be confounding the nature-health association, including poverty, a family history of poor mental health, and childhood mental health. We will also separately evaluate greenness in childhood versus in adulthood. Follow-up tests in the cohort study will also assess whether greenery-mental health associations are moderated, at least in part, by disadvantage.

Attempts will be made to broaden the analyses to the full NZ population using parallel tests in the NZ-IDI.

Data analysis methods:

Using the longitudinal Dunedin Study's high-resolution information on mental health in adulthood: p-factor and subfactors (primary) and individual DSM 5 diagnoses (secondary), we will ask whether midlife mental health follows neighborhood greenness gradients.

To calculate neighborhood greenness, we will use atmospherically corrected surface reflectance (SR) data obtained by the Landsat 4, 5 TM sensor, Landsat 7 ETM+ sensor, and Landsat 8 OLI/TIRS sensors. This SR image collection has a spatial resolution of 30-meter and a temporal resolution of 16-day. Following the approach established by Engemann et al., we selectively chose images during the vegetation growth season in New Zealand and Australia, typically spanning from December to the following February, to capture the most robust greenness pattern throughout the year. To mitigate the influence of cloud cover, we developed a JavaScript (JS)-based function to identify and mask out cloudy pixels in the Landsat images using the information stored in the Quality Assessment (QA_PIXEL) band. These bands contain satellite image quality statistics, including cloud mask information for the scene, and is presented as a bit-packed layer. Specifically, the 3rd index of this band serves as a cloud flag, with a value of 1 indicating high cloud confidence. Leveraging the JS-function, we generated a collection of cloud-free SR datasets during the plant peak growth stage. Then we followed equation (1) to create the Normalized Difference Vegetation Index (NDVI) image,

$$NDVI = \frac{R\ nir - R\ red}{R\ nir + R\ red} \quad (1)$$

where R_{nir} represents the SR of near-infrared band, and R_{red} presents the SR of red band. NDVI always ranges from -1 to 1 with higher values indicating a higher level of vegetation health and density.

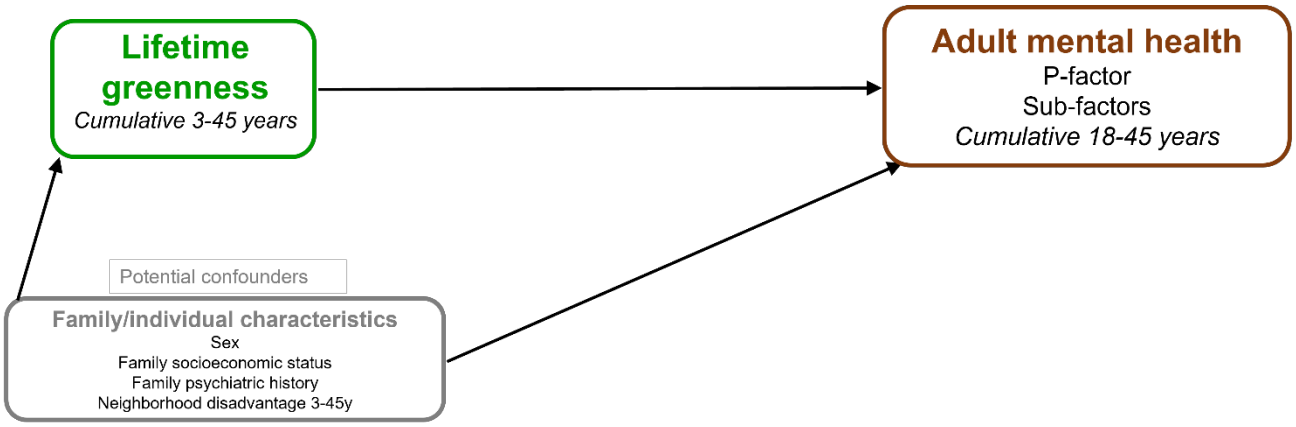
To obtain the typical peak greenness pattern for a particular year, we will create a mean NDVI image by averaging all the NDVI images taken during the peak season. Subsequently, we will apply a mean filter to loop through the entire NDVI mean image using window sizes parameters employed by Engemann et al., e.g., 7*7 pixels and 31*31 pixels. This process will allow us to acquire the averaged neighborhood greenness within a 210*210 m and a 930*930 m square around study members' home locations. Last, we will extract the NDVI values whenever residential home address data is present. Our exposures of interest will be NDVI: 1) cumulative lifetime age 3-45 years, 2) cumulative early childhood (age 3-11 years), and 3) cumulative adulthood (age 18-45 years). Depending on address missingness differences across waves, we may alter the childhood age range slightly to maximize data availability.

Analyses will produce descriptive statistics on neighborhood greenness and mental health. Regression modeling will then involve two stages.

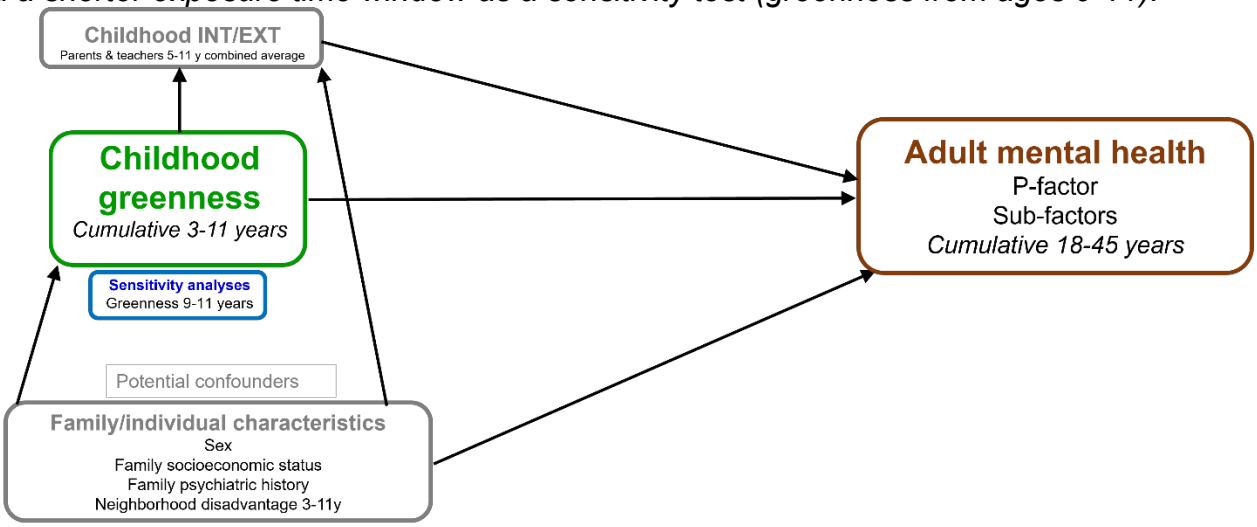
We will fit three main models. Models will employ an additive approach whereby initial models include only the exposure and outcome of interest, then covariates are added. Our primary outcomes of interest are p-factor and subfactors. If robust main effects with the p-factor are found, sensitivity tests will investigate disorder diagnoses to match the methods of Engelman et al (2019).

Model 1:

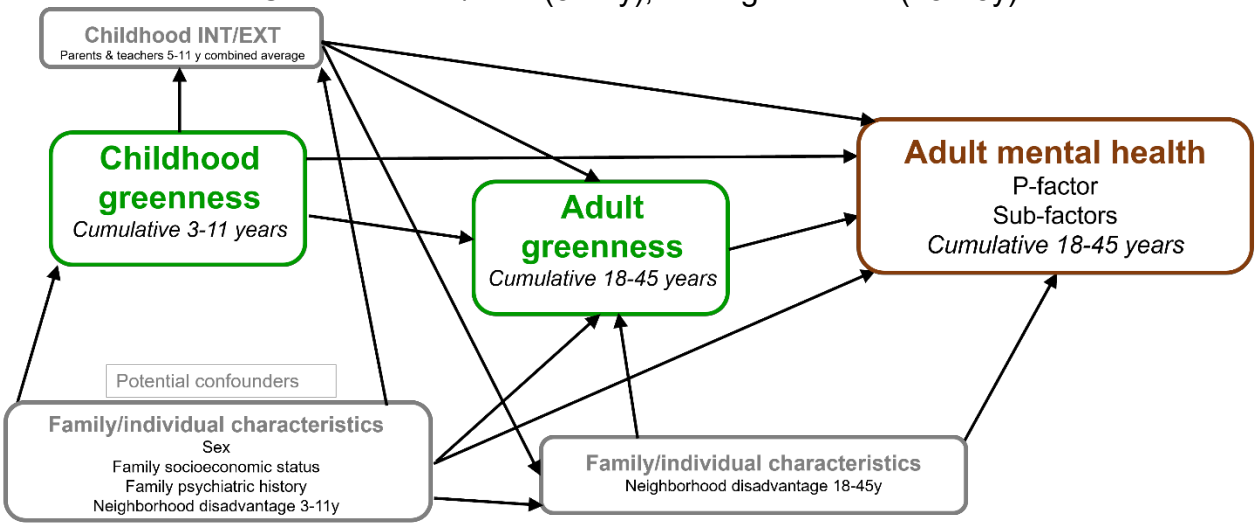
Dependent variable: P-factor (18-45y) and sub-factors
Independent variable of interest: Lifetime greenness (3-45y)
Potential confounders: sex, family socioeconomic status, family psychiatric history, and neighborhood disadvantage (3-45y).



Model 2:
Dependent variable: P-factor (18-45y) and sub-factors
Independent variable of interest: Childhood greenness (3-11y)
Potential confounders: sex, family socioeconomic status, family psychiatric history, and neighborhood disadvantage (3-11y).
Potential mediator: Childhood INT/EXT (5-11y)
Sensitivity analysis: To match Engemann et al., childhood greenness will also be evaluated via a shorter exposure time window as a sensitivity test (greenness from ages 9-11).

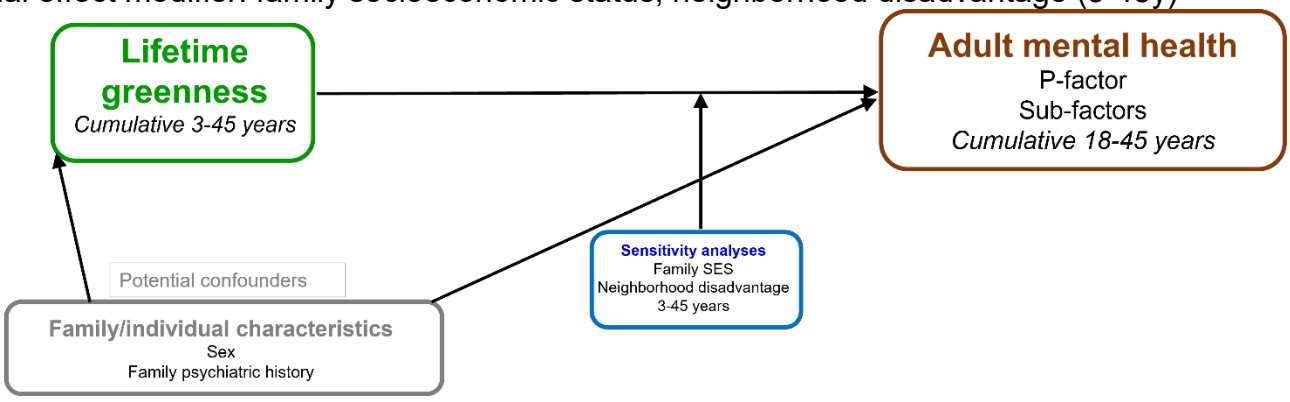


Model 3:
Dependent variable: P-factor (18-45y) and sub-factors
Independent variables of interest: Childhood greenness (3-11y), adult greenness (18-45y)
Potential confounders: sex, family socioeconomic status, family psychiatric history, and neighborhood disadvantage (3-45y).
Potential mediators: Childhood INT/EXT (5-11y), adult greenness (18-45y)



Exploratory model: We will also fit an exploratory model to determine whether SES should be treated as a confounder or an effect modifier.

Exploratory Model A:
Dependent variable: P-factors (18-45y) and sub-factors
Independent variable of interest: Lifetime greenness (3-45y)
Potential confounders: sex, family psychiatric history
Potential effect modifier: family socioeconomic status, neighborhood disadvantage (3-45y)



Variables needed at which ages:

Dunedin Study variables to be used will include:
Exposure variables:

- Neighborhood NDVI for the neighborhood in which Study Members were living at each phase for which residential information is present

Cumulative 18-45y outcome variables:

- p-factor and subfactors by age 45 (continuous variables)
- individual DSM 5 diagnoses by age 45 (count variables)

Additional variables (planned covariates, potential moderators, and effect modifiers):

- Sex
- Childhood family socioeconomic status
- Family psychiatric history
- Childhood INT/EXT
- Cumulative area/neighborhood deprivation (NZDep) (ages 3-11years, 18-45y, 3-45y)

If possible, the NZ-IDI will also be utilized, with NZ-IDI variables analyzed on-site at the NZ Stats data use offices. These variables are excluded from the variable request component of this Dunedin Study-focused concept note.

Significance of the Study (for theory, research methods or clinical practice):
The proposed study will answer novel questions about the potential for early childhood and/or adult cumulative exposure to greenery and mental health in midlife. Such information will expand our capacity to investigate and consider nature-based interventions, opening a potential new avenue in disease prevention and potentially in disparities reduction.

References cited:

1. Nutsford D, Pearson AL, Kingham S, Reitsma F. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. *Health & Place*. 2016;39:70-78. doi:10.1016/j.healthplace.2016.03.002
2. South EC, Kondo MC, Cheney RA, Branas CC. Neighborhood blight, stress, and health: A walking trial of urban greening and ambulatory heart rate. *Am J Public Health*. 2015;105(5):909-913. doi:10.2105/AJPH.2014
3. Koselka EPD, Weidner LC, Minasov A, et al. Walking Green: Developing an Evidence Base for Nature Prescriptions. *International journal of environmental research and public health*. Nov 7 2019;16(22)doi:10.3390/ijerph16224338
4. de Brito JN, Pope ZC, Mitchell NR, et al. The effect of green walking on heart rate variability: A pilot crossover study. *Environ Res*. Mar 18 2020;185:109408. doi:10.1016/j.envres.2020.109408
5. Hill T, Ross C, Angel R. Neighborhood disorder, psychophysiological distress, and health. *Journal of Health and Social Behavior*. 2005;46:170-186.
6. Brunton-Smith I. Untangling the relationship between fear of crime and perceptions of disorder: Evidence from a longitudinal study of young people in England and Wales. *Br J Criminology*. 2011;51:885-899.
7. Johansen R, Neal Z, Gasteyer S. The view from a broken window: How residents make sense of neighbourhood disorder in Flint. *Urban Studies*. 2014;52(16):3054-3069. doi:10.1177/0042098014552768
8. Evans GW, Lercher P, Meis M, Ising H, Kofler WW. Community noise exposure and stress in children *The Journal of the Acoustical Society of America*. 2001;109(1023)doi:10.1121/1.1340642
9. Dzhambov AM, Markevych I, Hartig T, et al. Multiple pathways link urban green- and bluespace to mental health in young adults. *Environ Res*. Jun 8 2018;166:223-233. doi:10.1016/j.envres.2018.06.004
10. Amoly E, Dadvand P, Forns J, et al. Green and blue spaces and behavioral development in Barcelona schoolchildren: the BREATHE project. *Environ Health Perspect*. Dec 2014;122(12):1351-8. doi:10.1289/ehp.1408215
11. Bardhan M, Zhang K, Browning MHEM, et al. Time in nature is associated with higher levels of positive mood: Evidence from the 2023 NatureDose™ student survey. *Journal of Environmental Psychology*. 2023/09/01/ 2023;90:102083. doi:https://doi.org/10.1016/j.jenvp.2023.102083
12. Rigolon A, Browning MHEM, McAnirlin O, Yoon H. Green Space and Health Equity: A Systematic Review on the Potential of Green Space to Reduce Health Disparities. *International journal of environmental research and public health*. 2021;18(5):2563.
13. Bratman GN, Hamilton JP, Daily GC. The impacts of nature experience on human cognitive function and mental health. *Ann N Y Acad Sci*. 2012;1249(1):118-136. doi:doi:10.1111/j.1749-6632.2011.06400.x
14. Kaplan SA. The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*. 1995;15(3):169-182.
15. Ulrich RS, Simons RF, Losito BD, Fiorito E, Miles MA, Zielson M. Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*. 1991;11:201-230.
16. Zhang R, Wulff H, Duan Y, Wagner P. Associations between the physical environment and park-based physical activity: a systematic review. *Journal of sport and health science*. 2019;8(5):412-421.
17. Maas J, Van Dillen SME, Verheij RA, Groenewegen PP. Social contacts as a possible mechanism behind the relation between green space and health. *Health & place*. 2009;15(2):586-595.
18. Vaeztavakoli A, Lak A, Yigitcanlar T. Blue and green spaces as therapeutic landscapes: health effects of urban water canal areas of Isfahan. *Sustainability*. 2018;10(11):4010.
19. Buxton RT, Pearson AL, Allou C, Fristrup K, Wittemyer G. A synthesis of health benefits of natural sounds and their distribution in national parks. *Proceedings of the National Academy of Sciences*. 2021;118(14):e2013097118.
20. Peacock JL, Anderson HR, Bremner SA, et al. Outdoor air pollution and respiratory health in patients with COPD. *Thorax*. 2011;66(7):591-596. doi:10.1136/thx.2010.155358
21. Kuo M. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Front Psychol*. 2015;6:1093. doi:10.3389/fpsyg.2015.01093
22. Pearson AL, Rzotkiewicz A, Pechal JL, et al. Initial Evidence of the Relationships between the Human Postmortem Microbiome and Neighborhood Blight and Greening Efforts. *Annals of the American Association of Geographers*. 2019;109(3):958-978. doi:10.1080/24694452.2018.1519407
23. Liddicoat C, Sydnor H, Cando-Dumancela C, et al. Naturally-diverse airborne environmental microbial exposures modulate the gut microbiome and may provide anxiolytic benefits in mice. *Sci Total Environ*. Jan 20 2020;701:134684. doi:10.1016/j.scitotenv.2019.134684
24. Pearson AL, Pechal J, Lin Z, Benbow ME, Schmidt C, Mavoa S. Associations detected between

measures of neighborhood environmental conditions and human microbiome diversity. *Science of The Total Environment*. 2020;745:141029. doi:10.1016/j.scitotenv.2020.141029
25. Engemann K, Pedersen CB, Arge L, Tsirogiannis C, Mortensen PB, Svenning JC. Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proc Natl Acad Sci U S A*. Mar 12 2019;116(11):5188-5193. doi:10.1073/pnas.1807504116
26. Donovan GH, Gatziolis D, Longley I, Douwes J. Vegetation diversity protects against childhood asthma: results from a large New Zealand birth cohort. *Nat Plants*. Jun 2018;4(6):358-364. doi:10.1038/s41477-018-0151-8
27. Donovan GH, Michael YL, Gatziolis D, Mannetje A, Douwes J. Association between exposure to the natural environment, rurality, and attention-deficit hyperactivity disorder in children in New Zealand: a linkage study. *Lancet Planet Health*. May 2019;3(5):e226-e234. doi:10.1016/s2542-5196(19)30070-1
28. Donovan GH, Gatziolis D, Douwes J. Relationship between exposure to the natural environment and recovery from hip or knee arthroplasty: a New Zealand retrospective cohort study. *BMJ Open*. 2019;9(9):e029522. doi:10.1136/bmjopen-2019-029522
29. Donovan GH, Gatziolis D, t Mannetje A, Weinkove R, Fyfe C, Douwes J. An empirical test of the biodiversity hypothesis: Exposure to plant diversity is associated with a reduced risk of childhood acute lymphoblastic leukemia. *Science of The Total Environment*. 2021/05/10/ 2021;768:144627. doi:https://doi.org/10.1016/j.scitotenv.2020.144627