Green Exposure objectively-measured by individual pathway, and Mental Health
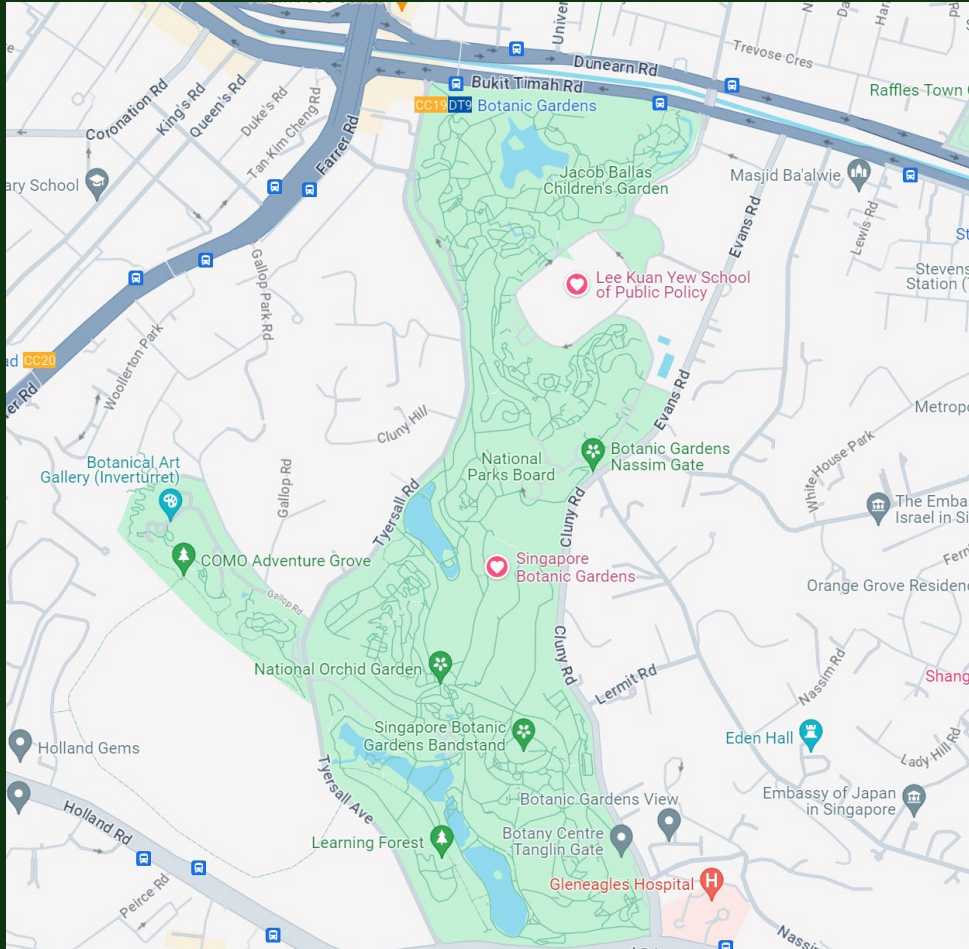
이창준, 이대호, 오하영

Motivation
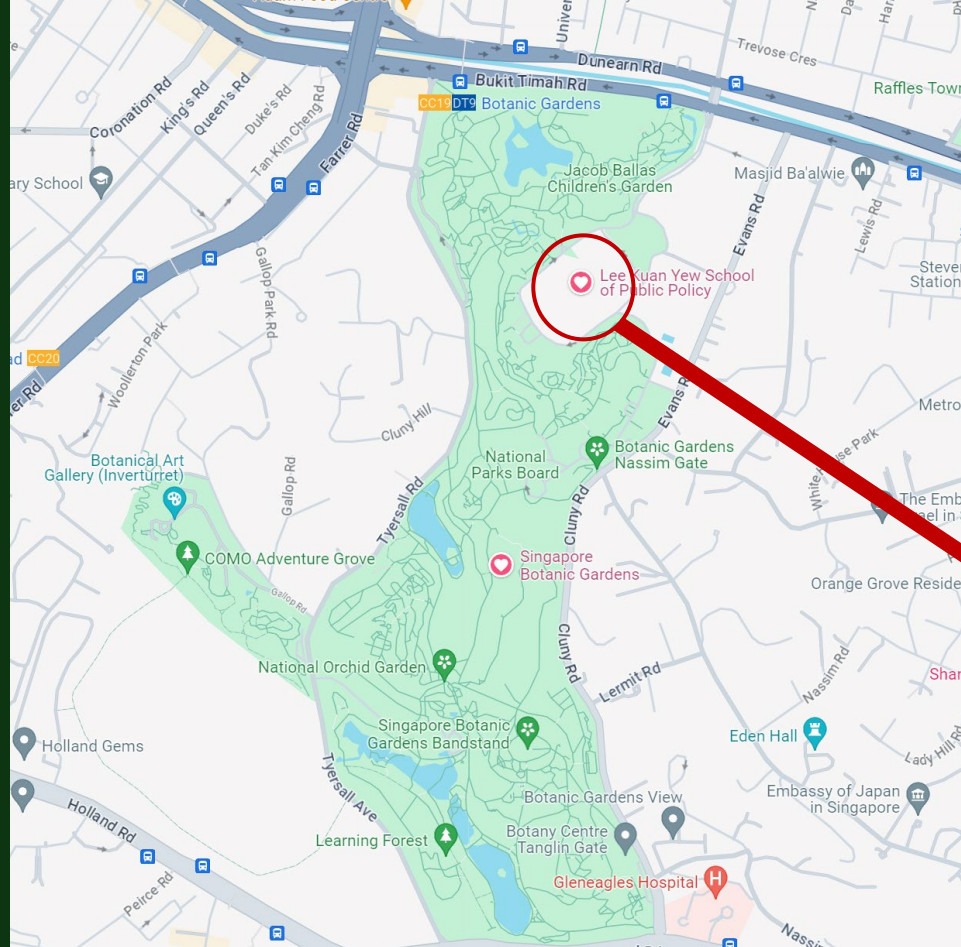
Introduction

Green Space

- **Green spaces**, integral to urban and rural landscapes, play a crucial role in promoting ecological sustainability, enhancing biodiversity, and improving human health and well-being.

- **Academically**, green spaces can be categorized based on their ecological characteristics, functionality, accessibility, and the type of vegetation they contain.

  - Urban Parks
  - Natural Reserves and Protected Areas
  - Community Gardens
  - Green Corridors and Greenways
  - Green Roofs and Walls

Types of Green Spaces

Theoretical Framework

Stress Recovery Theory (SRT) (Ulrich, R.S., 1984)

- SRT posits that natural environments have **restorative effects** on individuals experiencing psychological stress.

- **Mechanisms**:
  Exposure to green spaces can lead to reductions in stress, such as **through promoting positive emotional responses** and **reducing physiological markers of stress**, such as heart rate and cortisol levels.

- The theoretical framework of SRT suggests that natural environments capture our attention in a gently engaging way, a concept known as **'soft fascination'**, allowing cognitive mechanisms responsible for directed attention and vigilance to rest and recover from fatigue. This restorative effect of nature is thought to be automatic, requiring no conscious effort, and leads to improved mood, cognitive functioning, and overall well-being.

Theoretical Framework

Attention Restoration Theory (ART) (Kaplan, 1989; Kaplan, & Kaplan, 1989)

- ART a framework that <u>explains how exposure to nature can improve cognitive functioning and reduce mental fatigue</u>.

- The theory is grounded in the distinction between **two types of attention**: directed attention, which requires effort and is used for tasks requiring focus, and <u>involuntary attention</u>, which is effortless and elicited by inherently interesting or engaging stimuli.

- **Mechanism**:
The Kaplans argue that modern life often places heavy demands on directed attention, leading to cognitive fatigue and diminished capacity to focus. Natural environments, by contrast, are rich in stimuli that **gently capture involuntary attention**—a process the Kaplans refer to as "soft fascination." This allows the cognitive mechanisms responsible for directed attention to rest and recover, similar to how muscles recover after physical exertion.

Empirical Evidence on Green Space and Health

Green Exposure and Physical Health

- **Green Spaces Increase Physical Activity**: Research by Lu et al., (2018) shows greenery significantly boosts the likelihood of walking, enhancing health.

- **Leisure and Entertainment Activities**: Further findings by Lu (2019) and Yang et al., (2021) reveal green exposure promotes various healthful physical activities.

- **Overall Health Benefits**: The encouragement of physical activity in green spaces contributes to improved physical health outcomes.

Empirical Evidence on Green Space and Health

Green Exposure and Physical Health

- **Enhanced Social Interaction:** Studies (Mass et al., 2009; De Vries et al., 2013) highlight green spaces foster social cohesion and reduce feelings of loneliness.

- **Stress and Noise Pollution Reduction:** Green areas are linked to lower stress and noise pollution, contributing to overall well-being (Gidlof-Gunnarsson & Ohrstrom, 2007).

- **Challenges in Measuring Green Space Exposure:** Current methods mainly assess proximity rather than the frequency of green space use, posing challenges in accurately gauging exposure levels.

Empirical Evidence on Green Space and Health

Green Exposure and Mental Health

- **Metrics to Measure Mental Health**: Utilizes General Health Questionnaire (GHQ), subjective wellbeing, depression, stress, psychological distress, happiness, general mood, rumination, self-esteem, cognitive and psychological measures (Callaghan, A., 2021).

- **Green Space Proximity** and **Mental Disorders**: Availability and proximity of green spaces within 3km are significantly correlated with reduced instances of anxiety/mood disorders. A 1% increase in available green space corresponds to a 4% decrease in treatment counts for these disorders (Nutsford, D., 2013).

- **Distance to Nearest Green Space**: Closer proximity (100m reduction) to available green spaces is linked to a 3% reduction in anxiety/mood disorder treatment rates (Nutsford, D., 2013).

- **Urban vs. Slightly Urban Areas**: Findings indicate a positive mental health impact of green spaces in slightly urban areas, with no significant correlation found in highly urban environments (Nutsford, D., 2013).

Empirical Evidence on Green Space and Health
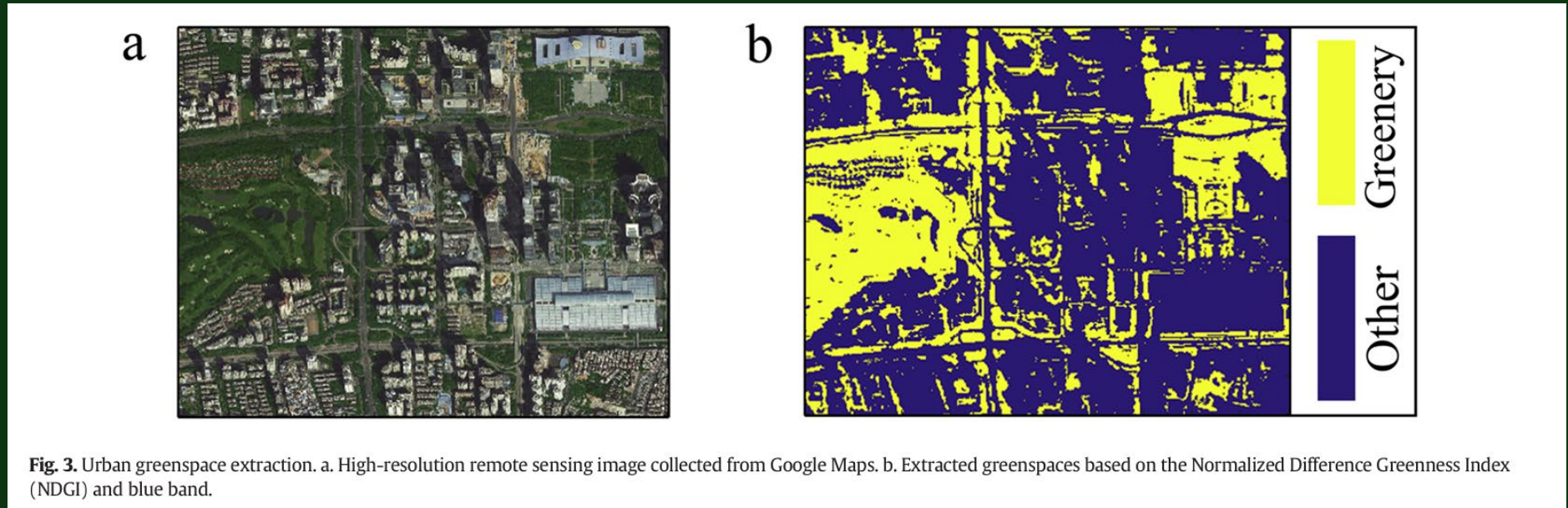
Green Exposure and Mental Health

- **Definition of Green Exercise: Physical Activity → Psychological benefit:** Physical activity in natural environments, incorporating the physical elements of the individual, exercise, and environment. It encompasses psychological and physiological processes (Rogerson, M., 2016).

- **Benefits of Green Exercise:** Immediate improvements in self-esteem (7.7%), stress reduction (18.4%), and mood enhancement (14.2%) after a single session of green exercise. This supports long-term exercise behavior (Rogerson, M., 2016).

- **Impact of Exercise Environment:** Natural environments offer more psychological benefits and improvements in physiological markers like blood pressure and immune function compared to artificial environments, due to their complexity and affordances (Rogerson, M., 2016).

- **Differential Effects by Age and Mental Health Status:** Significant self-esteem improvements in individuals with mental illnesses, with **young** people showing **positive self-esteem** outcomes and **older adults** showing **mood** improvements from exercising in green spaces (Barton, J., 2010).

Research Gap

- Current research predominantly focuses on the effects of proximity to green spaces and green space types on health, **utilizing survey methods**.

- Existing studies utilizing big data analyze green space exposure at a community or regional level, **not accounting for individual exposure**.

- There is a significant research gap in studying the **impact of individual-level green space exposure**, based on **personal movements and trajectories, on health outcomes**.

- This gap highlights the necessity for employing big data analytics to explore the direct correlation between individual interactions with green spaces and their health benefits.

Method

Population Exposure to Urban Greenspace using muti-source big data (Song et al., 2018)

Fig. 3. Urban greenspace extraction. a. High-resolution remote sensing image collected from Google Maps. b. Extracted greenspaces based on the Normalized Difference Greenness Index (NDGI) and blue band.

$$GE = \frac{\sum_{i=1}^{n} G_i}{n}$$

modified the model in Eq. (left) in a **population-weighted manner** (right).

$$GE = \frac{\sum_{i=1}^{n} (P_i \times G_i)}{\sum_{i=1}^{n} P_i}$$

where G_i denotes the green level of the ith individual's surrounding environment, n is the total population within the study area, and GE is the average green exposure of the targeted study area (e.g., the urban area of a city).

where p_i is the relative amount of population in the ith grid, and G_i is the green level of the area around the ith grid. Specifically, we used the green coverage rate to evaluate the green level of a region. GE denotes the green exposure (population-weighted average greenery coverage) of the target study area.
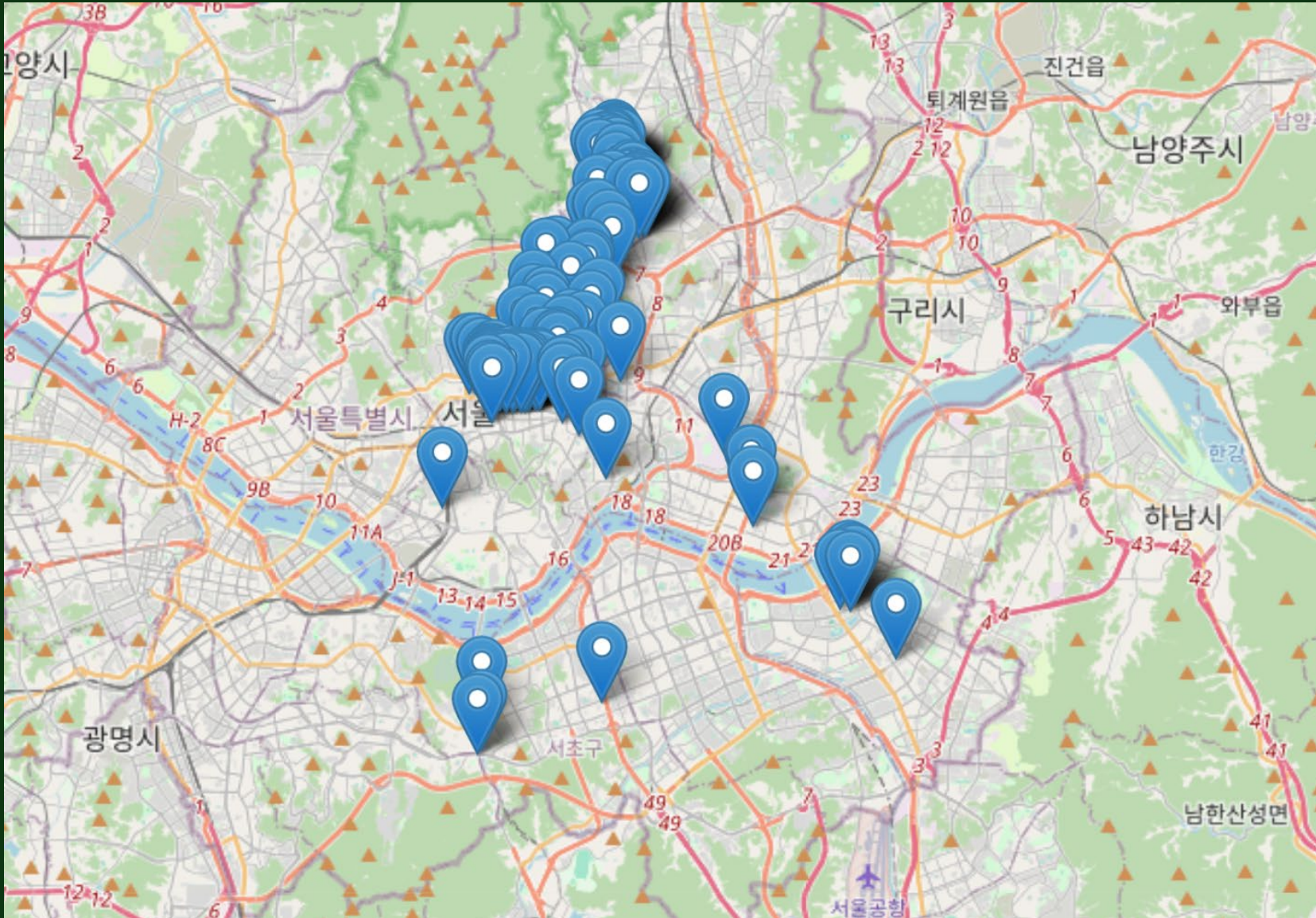
Method: Calculating Individual Daily Exposure to Green Space

Computational Steps:

1) **Data Filtering and Transformation:** The locational data for the specified individual and date are filtered. The longitude (lng) and latitude (lat) are then used to create spatial points.

2) **Buffer Zone Creation:** For each locational point, <u>a circular buffer zone with a radius equal to {200, 400, 600, 800} meters is created</u>. This step expands the area of influence for each point, accounting for green space exposure within the vicinity of the individual's location.

3) **Spatial Intersection:** The method proceeds with a spatial join operation between the buffered locational points and the green spaces dataset. <u>This step identifies intersections, where an individual's buffer zone overlaps with a green space</u>.

4) **Overlap Quantification:** A binary factor variable is generated for each locational point, indicating whether it overlaps (1) or does not overlap (0) with a green space. The individual's daily exposure to green spaces is quantified by summing these binary values, providing a count of the locational points intersecting with green spaces.

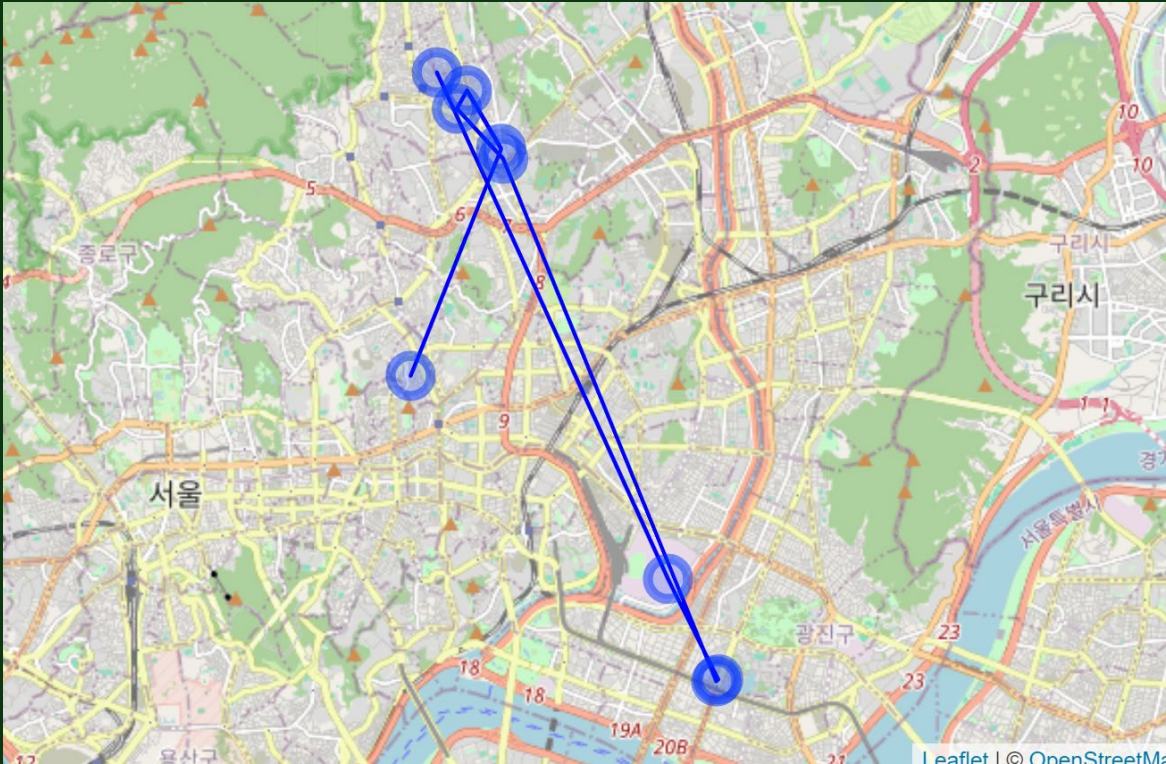$$GE_i = \sum_{t=1}^{n} I[B(P_{i,t}, Radius) \cap G \neq 0] \qquad \text{--- (eq. 1)}$$

Method: Calculating Individual Daily Exposure to Green Space

For instance,

This marks the places where a specific individual stayed for more than 5 minutes.

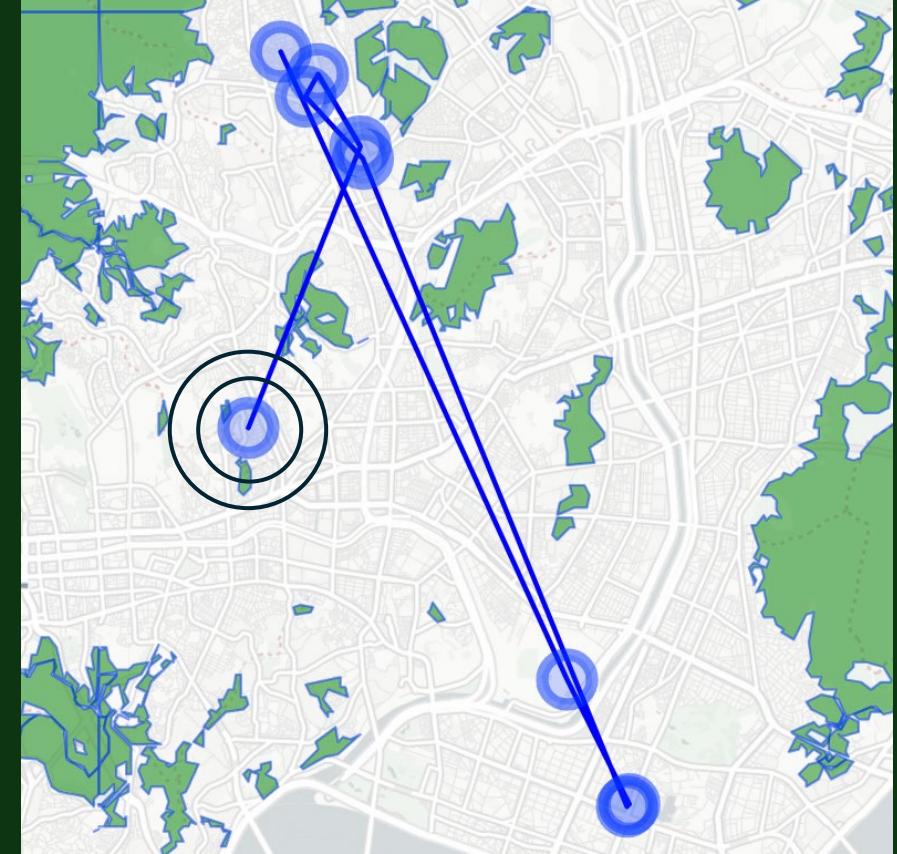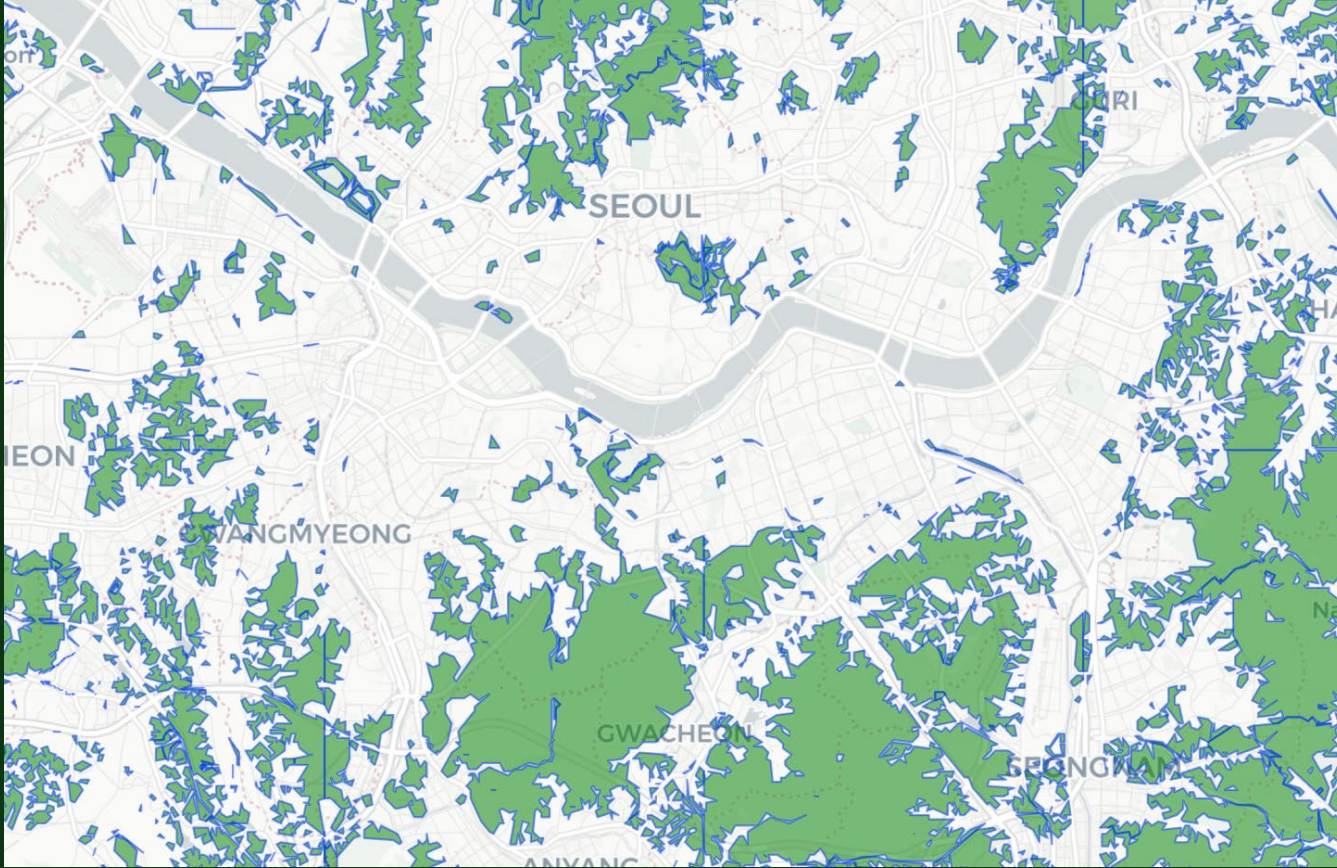# **Method:** Calculating Individual Daily Exposure to Green Space

A continuous display of the daily movements (pathway) of a specific individual

Zoom-in → See how close to Green Space

Method: Calculating Individual Daily Exposure to Green Space

Korea's green space shape file (.shp) is visualized on a white map.

Place the individual's movement line on top of it, draw a buffer zone for the individual's movement line, and check whether it overlaps with the green space.

Method: Calculating Individual Daily Exposure to Green Space

$$GE_i = \sum_{t=1}^{n} I[B(P_{i,t}, R) \cap G \neq 0]$$

where,

- GE_i represents the individual's daily exposure to green spaces.
- I is an indicator function that returns 1 if the buffer zone around point Pi intersects with any green space (G) and 0 otherwise.
- B(Pi, R) denotes the buffer zone created around locational point Pi with radius R ∈ {200, 400, 600, 800 meters}.
- n is the total number of locational points for the individual on the specified day.
- G represents the set of green spaces.

$$GE\_Ratio_i = \frac{GE_i}{n}$$

Green Exposure Ratio (GE_Ratio_i): The ratio of degree of Green Exposure compared to the total number of daily movement

Method: Measuring Physical Health

Physical Discomfort was constructed to encapsulate aspects of physical health, focusing on an individual's physical functionality, self-management skills, ability to perform daily activities, and experiences of pain and discomfort.

- **Physical functionality**: Q9: Athletic ability

- **Self-management skills**: Q10: Self-care

- **Ability to perform daily activities**: Q11: Daily activities

- **Pain and discomfort**: Q12: Pain or discomfort

Method: Measuring Mental Health

Poor Mental Health was developed to assess the multifaceted nature of psychological well-being, focusing specifically on individuals' experiences of stress, their coping skills, and their emotional responses to challenging situations.
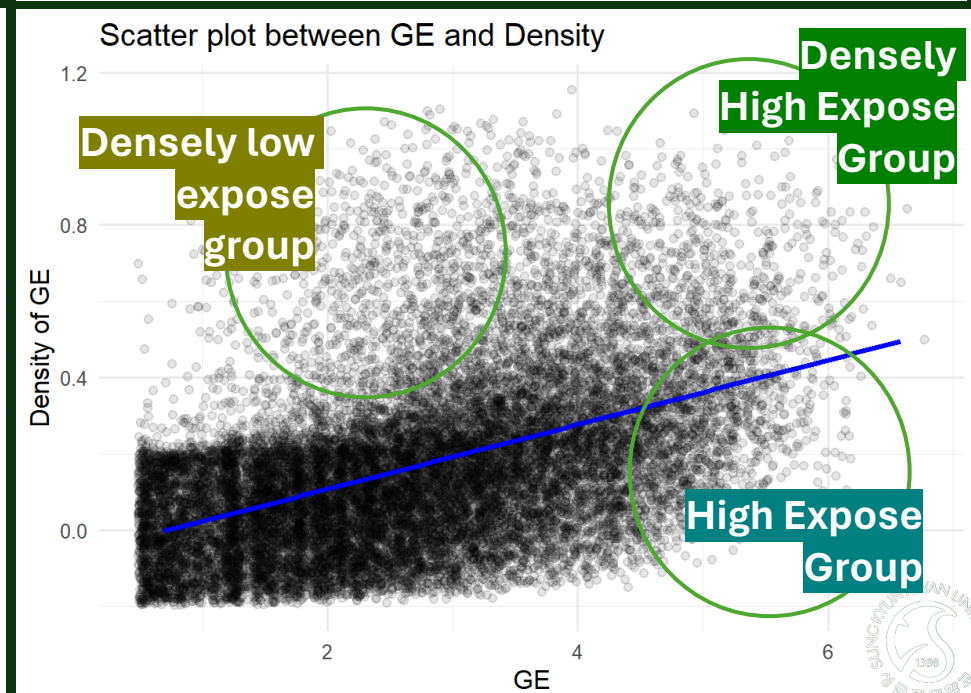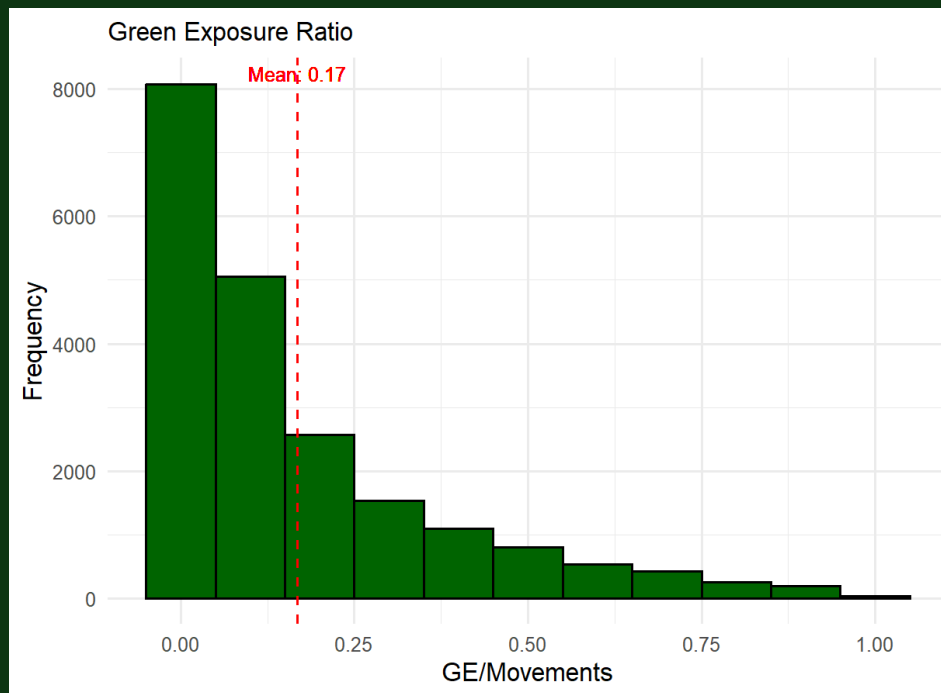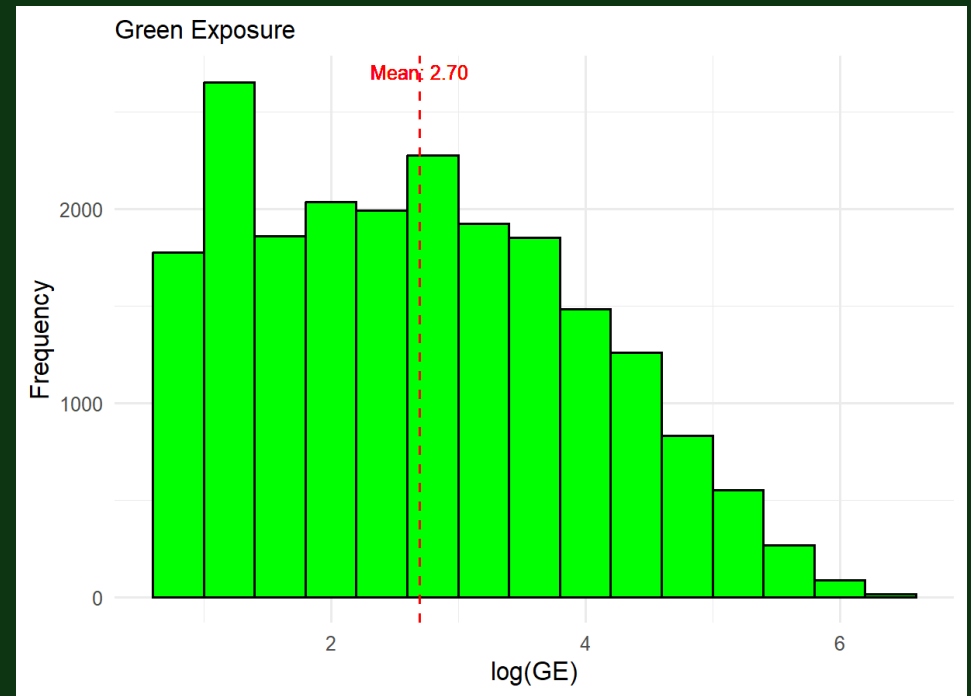
Items for stress coping skills

- Q4: Reaction to something unexpected

- Q5: Feeling of loss of control

- Q6: Stress and nervousness

- Q7: Anger in uncontrollable situations

- Q8: Feeling overwhelmed

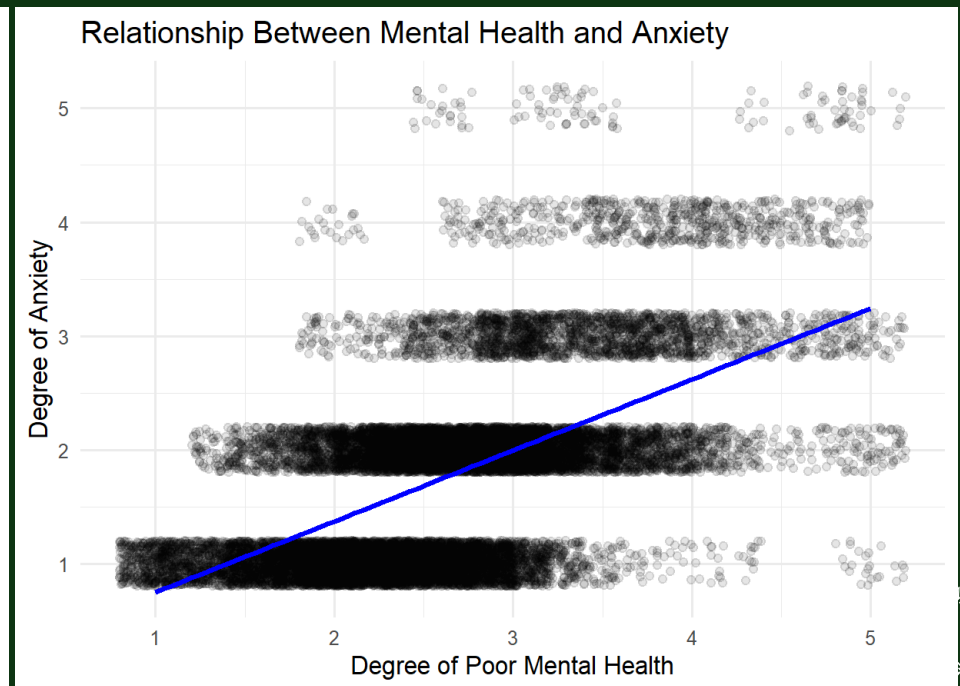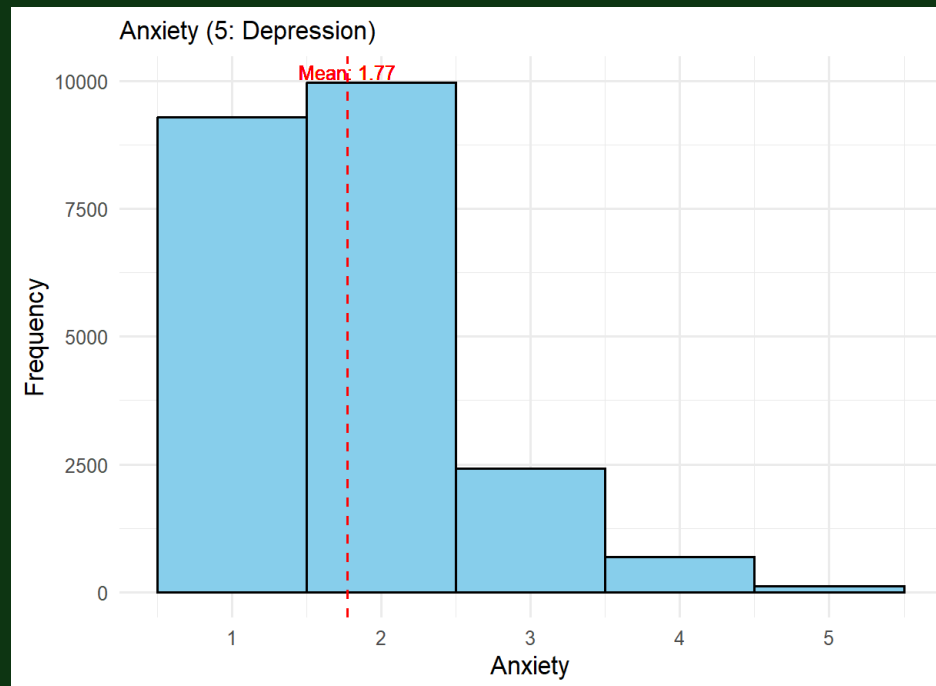**Anxiety or depression** was measured by a single item.

Result

- Histograms of GE and GER

- Relationship btw GE and GER:

  Positive

- Groups can be distinguished

Result

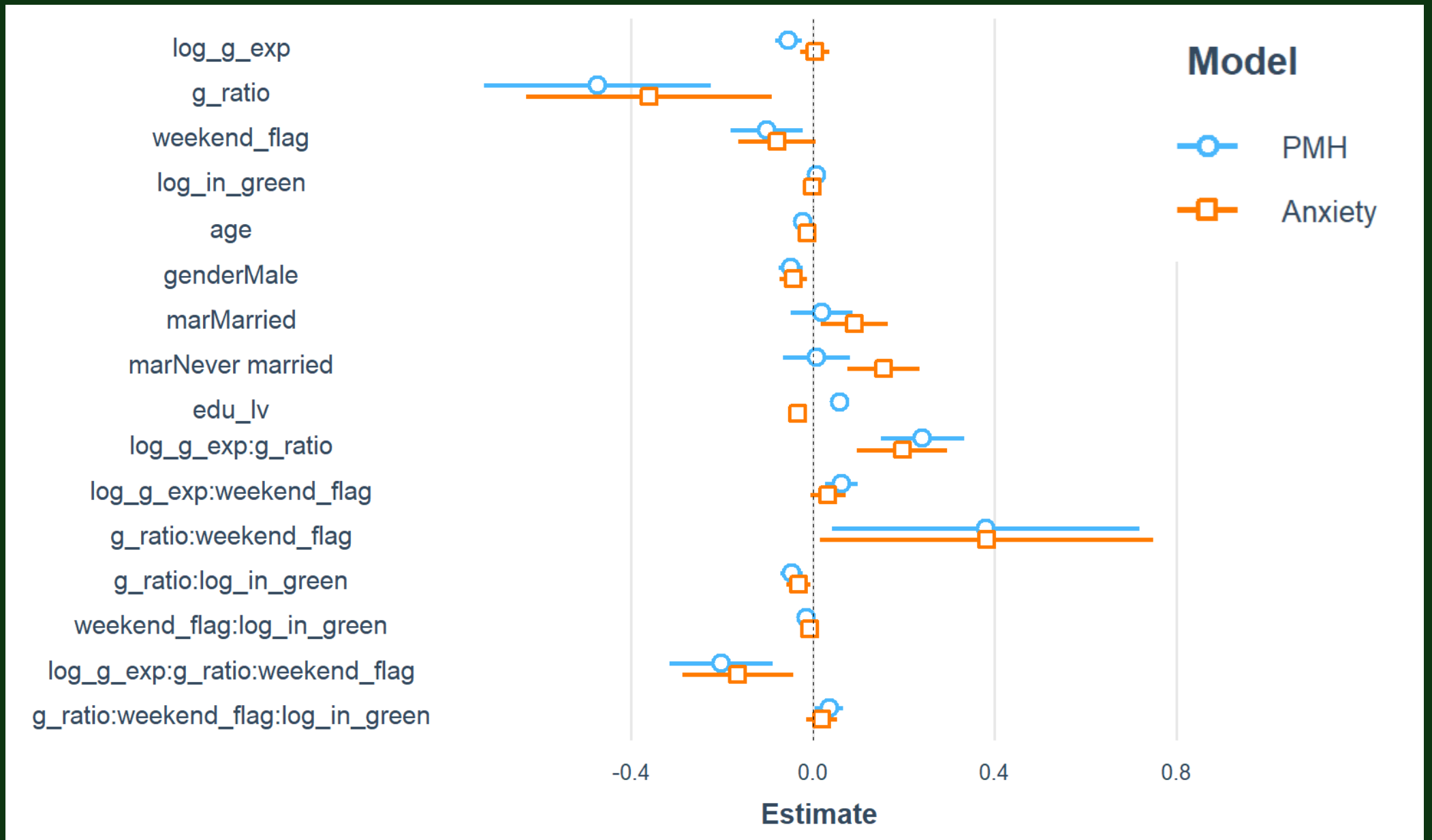- Histograms of PMH and Anxiety

- Relationship btw PMH and Anxiety:

  Positive

Result

	Poor Mental Health		Anxiety (Depression)	
	Coef.	(se)	Coef.	(se)
Main effects				
Green Exposure (log_g_exp)	-0.053 ***	(0.015)	0.005	(0.016)
Urban Park Staying duration (log_in_green)	0.009	(0.005)	-0.001	(0.005)
Exposure Density (g_ratio)	-0.473 ***	(0.127)	-0.360 **	(0.137)
Controls				
age	-0.022 ***	(0.001)	-0.012 ***	(0.001)
Male	-0.048 ***	(0.014)	-0.042 **	(0.015)
Married (ref.: etc)	0.019	(0.035)	0.092 *	(0.038)
Never married	0.008	(0.038)	0.156 ***	(0.041)
Educational attainment	0.059 ***	(0.007)	-0.033 ***	(0.007)
Weekend (1 = Weekend)	-0.101 *	(0.040)	-0.078	(0.043)
Monthly dummies	Y		Y	
Interaction terms				
log_g_exp:g_ratio	0.241 ***	(0.047)	0.196 ***	(0.051)
log_g_exp:weekend_flag	0.063 ***	(0.018)	0.034	(0.020)
g_ratio:weekend_flag	0.381 *	(0.172)	0.383 *	(0.187)
g_ratio:log_in_green	-0.047 ***	(0.012)	-0.031 *	(0.013)
weekend_flag:log_in_green	-0.015 *	(0.006)	-0.006	(0.007)
log_g_exp:g_ratio:weekend_flag	-0.202 ***	(0.058)	-0.165 **	(0.062)
g_ratio:weekend_flag:log_in_green	0.036 *	(0.016)	0.020	(0.017)
(Intercept)	2.634 ***	(0.042)	1.710 ***	(0.046)
N	12,058		12,058	
R2	0.090		0.039	

Note: *** p < 0.001; ** p < 0.01; * p < 0.05.

Result

Discussion

Green Exposure are positively associated with metal health **(Stress soothing effect)**

- Main effects:
  - Higher green exposure on weekdays is associated with better mental health (lower stress).
  - Higher densely exposed ratio is associated with better mental health (lower stress).

- Interactions:
  - The beneficial effects of green exposure on mental health are reduced as the densely exposed ratio increases.
  - The beneficial effect of green exposure on mental health is less pronounced on weekends
  - The beneficial effect of a higher densely exposed ratio on mental health is reduced on weekends.
  - The combined beneficial effects of green exposure and densely exposed ratio on mental health are more pronounced on weekends.

Discussion

Green Exposure are positively associated with lowering anxiety

- Main effects:
  - Higher densely exposed ratio is associated with better mental health (lower anxiety)
- Interactions:
  - The beneficial effect of a higher densely exposed ratio on anxiety is reduced on weekends.
  - The combined beneficial effects of green exposure and densely exposed ratio on anxiety are more pronounced on weekends.

Further Study

- **Group comparison** (Y = m_health, anxiety)

  - Densely high green expose group **vs.** High green expose group

- Using Difference in GE (2023 – 2022) → Health outcome

- Clustering Analysis with Green Exposure variables

- **Quasi Experiment Design**

  - Do the same survey again after one month (cost?).

    - The advantage of EMBRAIN panel survey is that we can track them continuously →
      Build customized panel data

  - Poor Mental Health Group

    - **Does GE sooth the mental disorder?**

Further Study

- **IV Regression (1)**

  - **Instrument:** Green Exposure and Green Ratio

  - Social Media Usage (or Screen time) → Mental Health **(Endogeneous)**

  - 1st Stage: SNS = f(Green Exposure)

  - 2nd Stage: Mental Health = Estimated SNS usage

- **IV Regression (2)**

  - **Instrument:** Distance (Home to Green | Home to Green corrider)

  - Social Media Usage (or Screen time) → Mental Health **(Endogeneous)**

  - 1st Stage: SNS = f(Green Exposure)

  - 2nd Stage: Mental Health = Estimated SNS usage

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