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Psychological Impacts of Urban Environmental Settings: A Micro-Scale Study on a University Campus

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Abstract: The environment's psychological impacts on humans have been long studied, but many questions remain unanswered. We conducted a micro-scale study to examine the relationships among the objective characteristics of urban environmental settings, people's subjective perception of such settings, and the related psychological responses. We employed a geo-enabled survey tool to gather data on individuals' perceptions of the immediate environment within their daily activity space. The psychological processes assessed included emotional and affective states such as perceived stress and happiness. The data points were mapped on a high-resolution aerial image, which was classified to derive quantitative properties to examine the dose-response relationship between environmental exposure and psychological responses. Our results showed negative correlations between the momentary stress level and the amount of environmental elements such as water, trees, and grass. Positive correlations were detected between stress level and the amount of parking lot and barren land, as well as the distance to buildings. In terms of perceived happiness, positive environmental factors included water, trees, and artificial surfaces, with all other elements having negative correlations. Most of the correlations examined were not strong correlations. This could be due to the significant differences in how individuals respond to environmental stimuli.

Keywords: urban environment; psychological impact; stress; happiness; mental health; aerial image

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1. Introduction

Mental health disorders have been rising globally in urban populations [1]. Among other factors, this may be linked to the disconnection from nature in the built environments [2]. Wilson's theory of biophilia and the related psycho-evolutionary model [3–5] states that humans have a natural desire to connect with nature as natural stimuli evoke an immediate, active affective response in humans' brains and neuroendocrine systems [6]. Therefore, natural elements in the environment are associated with beneficial effects for mental wellbeing [3,7,8]. Hence, integrating natural elements such as greenspace into the growing urban environment is widely acknowledged as a nature-based solution to promote the mental health of urban dwellers [9,10]. Nature therapy, green prescriptions, and green infrastructure design have been applied widely to promote health in sustainable urban communities [11–14].

Stress is known to trigger or worsen mental health disorders such as depression and anxiety [15] as well as exacerbate other health co-morbidities [16–18]. Various practices and activities help individuals manage stress levels. Nature therapies or simple exposure to nature have long been supported as low-cost and effective means for physiological stress reduction [3,19–23]. Much research has demonstrated that greenspace, a major component of nature, lowers the risk of psychosocial and psychological stress [1,24,25] and stress-related disorders, including depression and anxiety [22,26–28]. The positive health benefits of exposure to trees and greenspace have been supported using both psychological measures and biomarkers such as hair cortisol for long-term stress and saliva cortisol and heart rate variability for daily stress [7,8,29–32].

Happiness is another psychological construct assessed in a growing number of studies when examining the health benefits of urban greenspace [33–36] in the context of subjective wellbeing (SWB, [37]). Urban greenspace has been demonstrated to contribute to residents' happiness at different spatial scales [33]. At a global scale, a nation's happiness level and its amount of greenspace is found to have an implicit positive correlation [35]. At a city scale, both access to and the types of greenspace available are found to be associated with happiness and mental wellbeing [34]. At the local scale, people's momentary happiness is found to be correlated with immediate microenvironment variables and built environment characteristics [36]. A study in an urban park indicates that trees are the most important element of nature contributing to a majority of participants' SWB [37].

The therapeutic effects of nature and natural elements on mental health are thought to operate through one or more of the following mechanisms. First of all, our perceptions of natural elements in the environment arise from a stimulus' objective characteristics. Previous research has indicated that such perceptions may reduce stress through a restorative effect [38,39]. Attention restoration theory (ART) [19,40] posits that intriguing stimuli invoke involuntary attention in a bottom-up fashion, allowing top-down directed-attention abilities a chance to replenish and thus offer restoration from stress and mental fatigue [41]. According to ART, a low energy state evoked by exposures to natural elements in the environment is associated with positive affect. While a full range of affective states includes both low and high energy states as described in the circumplex model of affect [42], a second theoretical model of psychological restoration, the psycho-evolutionary model [3] and the related stress recovery theory (SRT) [6], indicates that visual stimuli such as natural elements in our surrounding environment evoke an immediate, active affective response, impacting the brain and neuroendocrine system and causing happiness. The underlying assumption of this model is that because human beings developed in natural environments, these types of settings are more therapeutic than those associated with built environments. Besides the intrapersonal emotional benefits, natural settings also provide socio-emotional benefits. People are found to become more prosocial after nature encounters, including being agreeable, taking perspectives, having empathy, being trusting, and being generous and helping [43]. Increased social contact and sense of "belonging" within a community is a possible mechanism underlying the relation between exposure to nature (often when with others) and psychological wellbeing [28,32]. One other indirect mechanism of nature's therapeutic functions is increased physical activity level when people are in a natural environment [44,45].

According to ART, natural settings possess a particular set of properties that promote restoration from attention fatigue. SRT posits that nature offers specific attributes that our species has viewed as having inherent survival qualities, thus evoking awe and fascination. Both imply that the therapeutic functions are essentially dependent on some specific properties of the environment. In order to further understand the relationships between the environment and stress, happiness, health, and wellbeing, it is thus necessary to identify the specific components that make up the environment and measure the properties that have therapeutic qualities. Previous studies have explored associations between urban greenspace and mental health from various perspectives and at different scales, but several issues remain.

First, it has been noted that three different types of exposure to urban greenspace may be related to the 'pathways' through which greenspace influences health, which are availability, accessibility, and visibility [46]. Most previous studies have focused on measuring availability and accessibility when examining the exposure–health benefit relationships. The visibility factor has not been studied much when measuring environmental exposure and doses [46]. According to both ART and SRT, visual stimuli in the natural environment have either a restorative effect or trigger active affect. Visibility is thus directly functional in the pathway to stress reduction, happiness, and positive mental health. Recent studies [33,47] have pointed out the importance of examining specific visual properties of the landscape and greenspace in promoting mental health and happiness. A systematic review [48] showed that higher tree density in neighborhoods was associated with a lesser degree of psychological distress among adult residents. An American study [49] showed that spatial structures of urban greenspaces matter in the residents' psychological distress, as a disaggregated distribution of urban greenspaces are more effective than a few large greenspaces. Studies at the city or coarser scales, however, are not able to capture the fine-scaled visual factors and quantify the environmental exposures of individuals.

Second, there has been an abundance of research on the relationships between the urban environment and especially greenspace and mental health in recent years [25,33,46,48,50–52]. But there is still little evidence about the spatial scale(s) at which this relationship exists [9]. A majority of studies address the issue at the city, country, or global scales, with a lack of study on a fine scale [46]. One recent study examined the association between the elements of an urban greenspace and users' subjective wellbeing at a fine scale in a New York City park and identified specific environmental elements that contribute to visitors' perceived happiness [37]. The study, however, relied on interviews and subjective environmental perceptions of the participants and not objective measures of spatial exposures.

Third, the vast majority of studies addressing the environment's impact on urban residents' mental health have focused on residential proximity [51], and home addresses are commonly used for measuring objective spatial exposures [53,54]. A person's residential address, however, does not accurately reflect their environmental exposure, as we may spend less time at our residential address than other spaces. In other words, our activity space is dynamic, and so is our environmental exposure. This is in particular related to the visibility measure of environmental exposure [48]. One recent study assessed the impact of immediate environment in one's activity space on momentary happiness and revealed that momentary happiness is influenced by immediate microenvironment variables and built environment characteristics [36]. It has been noted that visits to natural settings are associated with positive mental wellbeing [51]. The usage of greenspace or natural settings, however, is measured only by the number of visits and not the personal experience in the natural settings, thus not capturing the actual exposure related to immersive experience.

The current research attempts to address the above three issues. We focus on the impact of fine-scale visual factors on individuals' psychological responses in their activity space. Specifically, this study examines (1) the objective characteristics of people's immediate environmental settings and (2) the subjective perceptions of such settings, focusing on perceived stress and happiness at a fine scale, where visibility and specific environmental elements play an important role in momentary psychological effects.

2. Materials and Methods

We employed a geo-enabled survey tool to gather data on individuals' perceptions of their immediate environment within their daily activity space. The survey was designed to assess momentary stress and happiness alongside a range of other subjective environmental perception measures. The collected data points were mapped on a high-resolution aerial image, which was classified, and specific environmental properties were derived. Quantitative measures were used to examine the dose- response relationship between environmental exposure and psychological responses at a fine scale.

Our study site is a university campus located in a suburban neighborhood 15 miles away from New York City. The 150-acre campus is dotted with woods, streams, and open space that offers an ample supply of natural elements. There are also clusters of academic buildings and dormitory buildings representing a densely built environment. As a commuter school, large parking lots filled with cars occupy a significant portion of the campus area. This suburban campus thus represents a mixture of different environmental settings that suits our study objectives. The study recruited students on campus to fill out a geo-enabled survey while they were spending time in their daily activity environment.

Recruitment happened in October 2022 when trees had full canopy and the foliage had not turned color. We recruited students from randomly selected classes held in the fall semester through email blasts. The email contained the purpose and a detailed description of the study. Interested students were instructed to access the survey with their cellphone while spending time outdoors on campus.

The survey tool we used was the ArcGIS Survey 123. The survey instrument was designed to measure participants' real-time momentary psychological responses to their immediate environment. In order to ensure momentary responses and minimize response time to each question, the survey contains only 5 sets of brief questions and takes one to three minutes to complete. Figure 1 shows the interface of the survey page on a participant's cellphone, and Table 1 lists all survey questions. The psychological experiences measured include emotional and affective states such as perceived happiness, sadness, stress, and fatigue levels, and were investigator-created or derived from the Positive and Negative Affect Schedule (PANAS) [55] and Philadelphia Geriatric Center Affect Scales (PGCAS) [56]. In order to examine how one's connectedness to the environment and their values affect subjective wellbeing, we specifically included a question on this in addition to the measures of positive and negative affect. Five-point ordinal scales were adopted following the PANAS [55], PGCAS [56], and previous studies [36]. The end of the survey asked participants whether they allowed their GPS location to be recorded and used. Upon agreement, such GPS location was mapped in GIS to derive the objective environmental characteristics at the location. In order to assess the subjective perception of the environmental contexts and investigate how the derived objective environmental attributes represent or correlate with the participants' subjective environmental interpretations, the first question in the survey asks about what the participants see around them (Figure 1).

Figure 1. Interface of the survey accessed from a participant's cellphone.

Table 1. Questions asked in the survey instrument.

	Question Text	Question Type	Options/Values
1	What do you see around you?	Multiple choice	Mostly trees, water, buildings, open space (grassland), sky (and clouds), roads and cars, other
2	How stressed are you feeling at this moment?	Scale	1–5
3	Please tell us how you feel right now, to what extent are you happy, interested, sad, worried?	Scales	1–5
4	How fatigued/tired are you feeling (both mentally and physically) right now?	Scale	1–5
5	How connected are you feeling with people, things, and ideas that matter to you?	Scale	1–5

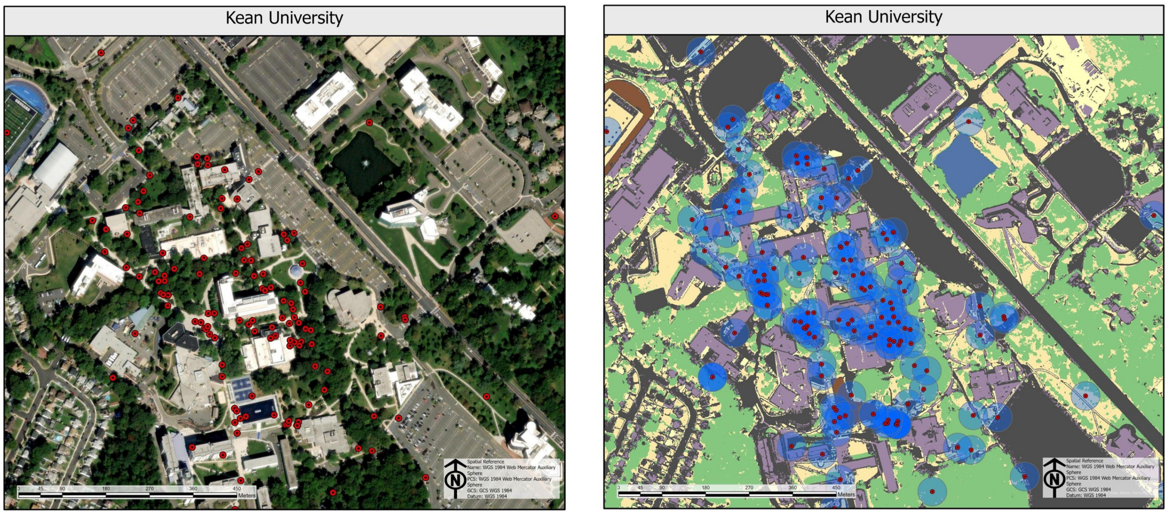
An aerial image of 0.5 m resolution was used for deriving the objective environmental properties. Because the study was at a fine scale with a small study area, we used supervised classification to achieve the best accuracy. Training samples were digitized as polygons for seven main classes: trees, grass, water, parking lot, building, artificial surface (such as a tennis court), and barren surface. For the building class, subclasses were identified with different colors and textures on the rooftops. The maximum likelihood method was first used to classify the image, followed by manual editing to correct misclassified areas or adjust boundaries using the "Reclassify" tool with ArcGIS Pro 2.8.

Buffers were created around the collected survey points. We interviewed pedestrians on campus, asking about the approximate distance they were paying attention to when walking on campus. Based on their answers, we adopted a 30 m buffer size in our analysis. This is a much smaller buffer size than most previous studies that often used 100 m+ buffers around residential addresses because our study focuses on correlates of the immediate environment with regard to psychological status and the visibility environmental exposure. As indicated in previous studies [36], small buffers have higher explanatory power for momentary happiness. We also experimented with different buffer sizes to examine how buffer size affects the association between the participants' perceived environment and our derived environmental properties.

The percent area of each of the seven classes within the buffers were calculated. For each survey location, its distance to the closest building was also measured. We included both positive environmental exposures (trees, water) and negative ones (parking lots, buildings) in the set of environmental variables. The relationships between the environmental variables and the recorded subjective psychological measures from the survey were evaluated using the Spearman correlation as the psychological measures are ordinal variables.

3. Results

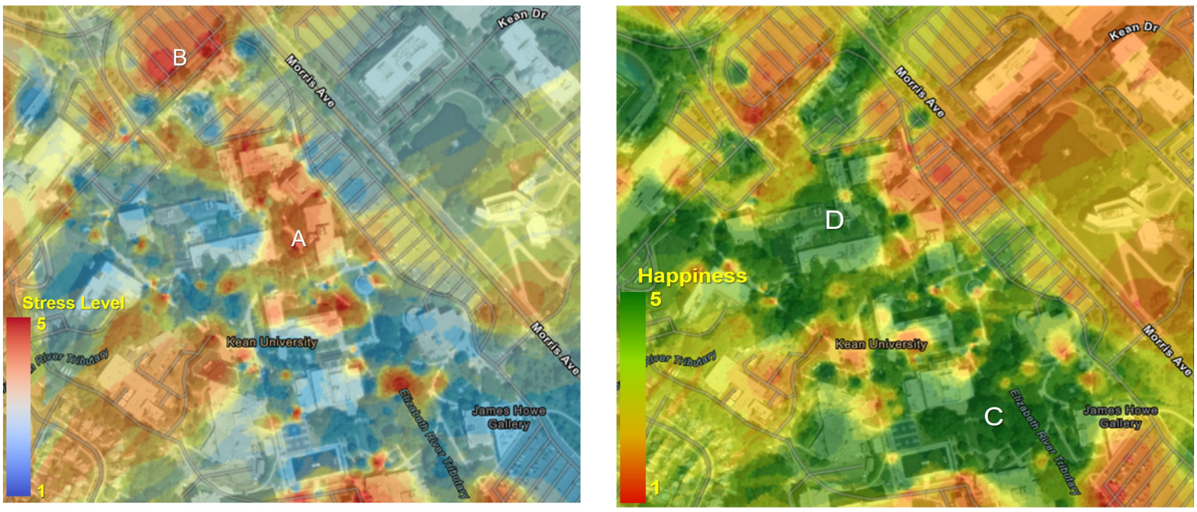
A total of 159 survey entries were collected in the fall semester of 2022. Data collection was achieved within two weeks to minimize the impact on environmental perception of other contextual environmental nuances such as seasonal differences. Because the survey was completely anonymous, identification and demographic data were not collected using the survey instrument. The exact demographics of the sample were unknown. With the random sampling strategy and voluntary participation in the survey, the sample was expected to represent a diversity of demographics, as the university is a designated minority-serving institution with a diverse student population (28.7% Hispanic, 17.0% Black, 39.1% Asian, and 11.9% White). Sixteen of the data points either fell outside of the campus area due to GPS errors or had incomplete responses to the survey questions. After removing the 16 points, we worked with the remaining 143 samples with ArcGIS Pro 2.8 and derived the environmental variables as described in the previous section. Figure 2a shows the sample locations over the aerial imagery, and Figure 2b shows the 30 m buffers over the classified images of the seven environmental classes.



(**a**) (**b**)

Figure 2. Study set and data. (**a**) Aerial image of the study site and geo-enabled survey locations; (**b**) classified image and buffers.

Figure 3 shows the maps of happiness and stress levels interpolated from the sample points using IDW interpolation. Figure 3a does show a few hotspots of perceived stress close to a cluster of academic buildings (A) and a major parking lot (B). And Figure 3b shows greater perceived happiness in an area with tall trees that is used as a reflection garden (C), but also in an open area surrounded by academic buildings (D). The patterns of perceived stress and happiness, though, do not show notable associations with each other.



(**a**) (**b**)

Figure 3. Interpolated maps from sample points. (**a**) Stress level; (**b**) happiness.

Table 2 lists the Spearman correlation results for the environmental attributes and psychological measures recorded from the survey. It shows that perceived stress is negatively correlated with the percentage of environmental elements such as water, trees, grass and artificial surfaces but is positively correlated with the percentage of barren land and parking. Most of the correlations are weak, with the percentage of trees and parking lots showing slightly greater correlations than other factors. The percentage of buildings shows a slight negative correlation, while the distance to buildings shows a much stronger positive correlation with stress levels. In terms of perceived happiness, positive environmental factors include water, trees, and artificial surfaces, with all other elements having negative correlations. The strongest negative correlation is the percentage of parking lot area. Perceived sadness, expectedly, shows reversed correlations with the corresponding environmental elements compared with perceived happiness. Perceived worriedness and fatigue levels more or less correspond to perceived stress levels. Interestedness corresponds to perceived happiness level, while connectedness shows different correlations from the rest of the psychological measures. Among all correlations examined, only four have a correlation coefficient greater than ±0.2. They are the positive correlations between perceived stress and the percentage of parking lot area in the environment and the distance to buildings, the positive correlation between worriedness and the percentage of buildings in the environment, and the negative correlation between interestedness and the percentage of barren land in the environment. The most-studied environmental elements, trees, on the other hand, do not show strong correlations with the psychological responses recorded.

Table 2. Spearman correlation coefficients between environmental variables and survey variables.

	Stress	**Happiness**	**Sadness**	**Worry**	**Fatigue**	**Interested**	**Connected**
Percent_Water	−0.078	0.074	−0.128	−0.081	−0.051	0.066	0.000
Percent_Trees	−0.165	0.107	−0.160	−0.072	−0.036	0.122	−0.012
Percent_Grass	−0.014	−0.008	0.091	0.017	0.040	−0.076	0.118
Percent_Barren	0.093	−0.162	0.098	−0.066	−0.081	−0.204	−0.027
Percent_Parking	0.228	−0.199	0.194	0.111	0.097	−0.079	0.024
Percent_Bldgs	−0.033	−0.083	0.143	−0.064	−0.067	−0.070	−0.072
Percent_Artificial	−0.115	0.096	−0.156	−0.068	−0.142	0.012	0.103
Distane_Bldgs	0.251	−0.028	0.053	0.210	0.157	−0.002	−0.040

Table 3 shows the p-values of the Spearman correlation between the percentage of three major environmental elements (trees, buildings, and parking lots) and the psychological responses. These environmental elements are typically positive and negative environmental stimuli that are present in the immediate environment of urban residents. Table 3 indicates that the only significant impacts of environmental stimuli on perceived stress, happiness, and sadness come from parking lot ($p < 0.05$). The impact of trees is significant only on perceived stress but not on emotional measures.

Table 3. Spearman correlation p-values between three major environmental elements and survey variables.

	Stress	**Happiness**	**Sadness**	**Worry**	**Fatigue**	**Interested**	**Connected**
Percent_Parking	0.006	0.017	0.020	0.188	0.251	0.346	0.779
Percent_Bldgs	0.697	0.325	0.089	0.449	0.424	0.404	0.391
Percent_Trees	0.048	0.202	0.056	0.393	0.666	0.146	0.888

In order to compare the environmental properties derived from the aerial image with the participants' subjective perception of the environment, we calculated the average percentages of environmental elements for each environmental type asked in the survey, which include "mostly trees", "mostly buildings", "mostly water", and so on. Figure 4 shows the average calculated percentages of the environmental elements within 30 m buffers. For the "mostly trees" type, the percentage of trees is the highest among all environmental elements. For the "mostly roads and cars" type, the percentage of parking lot area is the highest among all elements. The "mostly sky" type has the highest percentage of grass field and a high percentage of artificial surface, which is reasonable as the sky view in these areas is often not obscured by trees. For the "mostly building" type, the percentage of buildings is less than that of trees (within the same bar), but the average percentage of buildings for this type is the highest among all types (across the bars). This could be due to the prevalence of trees on campus and because the tree canopy covers a large area in the aerial image. Therefore, the percentage of trees derived from the aerial image is greater than what people see at eye level. The "mixture" and "mostly open space" types both have a mixture of similar percentages of the various environmental elements. The "mostly water" type does not seem to contain a high percentage of water. A close examination of the collected data points indicates that only five participants recorded this type, and the data points are located near a pond or a stream. The pond is adjacent to a grass field with dotted trees, and the stream runs through a wooded area with nearby academic buildings. Therefore, the buffers surrounding the points encompass significant portions of various environmental elements. This indicates that the water feature often captures one's primary attention, even if it occupies only a small portion in the visual field.

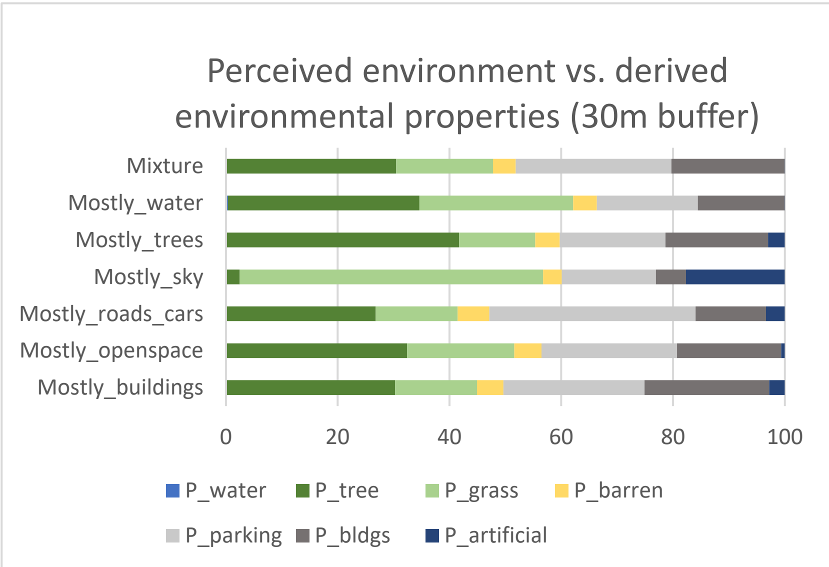
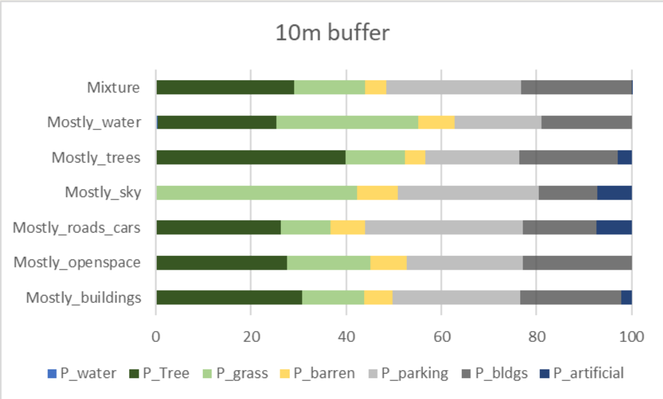
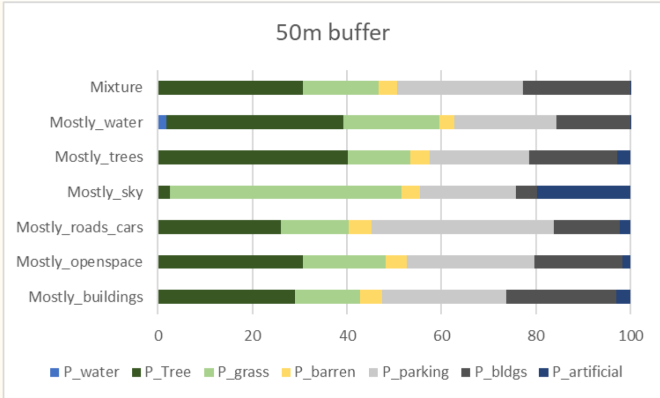


Figure 4. Calculated average percentages of different environmental elements for the seven surveyed environmental types.

In order to assess the impact of buffer size on the ability for the derived percentages to represent the perceived environment types, we experimented with two additional buffer sizes: 10 m and 50 m. Figure 5 shows the corresponding charts of the calculated average percentages with these buffer sizes. The 10 m buffer does not appear to differentiate the environmental types as well as the other two buffer sizes. The percentages of trees and buildings, for example, are very similar across several different environmental types. The results with a 50 m buffer size are very similar to that with a 30 m buffer size. With a 50 m buffer, the water percentage does increase in the "mostly water" type, but the percentage of trees increases at the same time and is almost comparable with that of the "mostly trees" type. Tables 4–6 show that the dominant environmental elements (with the highest calculated percentages) in the buffers are able to represent three perceived environmental types: "mostly trees", "mostly roads and cars", and "mostly sky". The "mixture" environmental type does have a relatively even distribution of several environmental elements. But, the "mostly buildings", "mostly open space", and "mostly water" environmental types cannot be accurately captured by the dominant environmental element in the buffers due to the prevalence of trees in this specific environment.



(a)



(b)

Figure 5. Calculated average percentages of different environmental elements for the seven surveyed environmental types. (**a**) With 10 m buffers; (**b**) with 50 m buffers.

Table 4. Participants' perceived environmental type vs. calculated percentages of environmental elements within a 10 m radius.

Perceived Environmental Type	Highest %	Element with Highest %	2nd Highest %	Element with 2nd Highest %	3rd Highest %	Element with 3rd Highest %
Mostly buildings	30.623	Tree	26.921	Parking	21.276	Buildings
Mostly open space	27.573	Tree	24.455	Parking	22.906	Buildings
Mostly roads and cars	33.327	Parking	26.125	Tree	15.368	Buildings
Mostly sky	42.284	Grass	29.617	Parking	12.287	Buildings
Mostly trees	39.838	Tree	20.729	Buildings	19.690	Parking
Mostly water	29.755	Grass	24.955	Tree	18.938	Buildings
Mixture	29.024	Tree	28.382	Parking	23.198	Buildings

Table 5. Participants' perceived environmental type vs. calculated percentages of environmental elements within a 30 m radius.

Perceived Environmental Type	Highest %	Element with Highest %	2nd Highest %	Element with 2nd Highest %	3rd Highest %	Element with 3rd Highest %
Mostly buildings	30.229	Tree	25.269	Parking	22.304	Buildings
Mostly open space	32.369	Tree	24.257	Parking	19.199	Grass
Mostly roads and cars	36.891	Parking	26.781	Tree	14.650	Grass
Mostly sky	54.296	Grass	17.676	Artificial Surface	16.834	Parking
Mostly trees	41.693	Tree	18.926	Parking	18.365	Buildings
Mostly water	34.259	Tree	27.529	Grass	18.077	Parking
Mixture	30.454	Tree	27.855	Parking	20.271	Buildings

Table 6. Participants' perceived environmental type vs. calculated percentages of environmental elements within a 50 m radius.

Perceived Environmental type	Highest %	Element with Highest %	2nd Highest %	Element with 2nd Highest %	3rd Highest %	Element with 3rd Highest %
Mostly buildings	29.015	Tree	26.224	Parking	23.366	Buildings
Mostly open space	30.585	Tree	27.113	Parking	18.533	Buildings
Mostly roads and cars	38.554	Parking	26.042	Tree	14.214	Grass
Mostly sky	49.113	Grass	20.268	Parking	19.781	Artificial Surface
Mostly trees	40.225	Tree	20.944	Parking	18.790	Buildings
Mostly water	37.593	Tree	21.578	Parking	20.336	Grass
Mixture	30.713	Tree	26.733	Parking	22.713	Buildings

Table 7 lists the Spearman correlation results for just the psychological measures reported by the participants. As expected, stress level is positively correlated with sadness, worry, and fatigue but negatively correlated with happiness. Happiness level is negatively correlated with sadness, worry, and fatigue. Interestedness, as an indicator of mindfulness at the moment, is positively correlated with happiness and negatively correlated with stress and other negative emotions. Connectedness to the environment also shows a similar correlation pattern to the psychological measures.

Table 7. Spearman correlation among psychological variables.

	Stress	Happiness	Sadness	Worry	Fatigue	Interestedness
Stress	1.000					
Happiness	−0.580	1.000				
Sadness	0.513	−0.452	1.000			
Worry	0.636	−0.524	0.508	1.000		
Fatigued Rank	0.406	−0.374	0.468	0.490	1.000	
Interestedness	−0.503	0.550	−0.331	−0.377	−0.285	1.000
Connectedness	−0.362	0.490	−0.212	−0.299	−0.223	0.566

4. Discussion

We recognize three different types of the "environment" in our environmental perception study. The first is the original holistic environment that contains various environmental stimuli (type 1). The second consists of a set of visual environmental attributes derived from the aerial images (type 2). And the third is the environment perceived by humans such as the existence and dominance of certain environmental stimuli (type 3). This perceived environment is the interpretation of the objective environment, which can be subjective and selective. It is this interpreted environment that is associated with psychological and behavioral responses, such as emotion, attitude, and behavior. Previous research has examined quantitative relationships between environmental attributes derived from imageries (type 2) with psychological measures [24,45,57]. Our data collection instrument allowed for the collection of the participants' interpreted environment (type 3) in terms of dominant environmental elements. Our results showed that the environmental compositions derived from aerial imagery were able to capture the participants' perceived environment when the dominant environmental elements were trees, roads and cars, and grass fields with open sky views. The aerial imagery, however, tends to exaggerate the amount of trees existing in the perceived environment when participants perceive a dominant presence of buildings at eye level instead. This is a limitation of using only aerial imagery to derive environmental properties, as tree canopies in an aerial view do not accurately reflect what people see at eye level. One other finding is that some environmental stimuli tend to be especially attractive, and their existence could overshadow other environmental elements. For example, even when a very small portion of the visual field was composed of water, participants considered it as the dominant environmental element.

Our results showed negative correlations between momentary stress level and the amount of certain environmental elements in the immediate environment, such as water, trees, and grass. Positive correlations were detected between stress level and the amount of other environmental elements, including parking lot and barren land, as well as buildings indicated by the distance to the buildings variable. In terms of perceived happiness, positive environmental factors included water, trees, and artificial surfaces, with all other elements having negative correlations. These environmental elements, trees, buildings, and parking lots, are typical positive and negative environmental stimuli that are present in the immediate environment of urban residents. Most of the correlations examined, however, were not strong correlations. The only significant associations between environmental stimuli and perceived stress, happiness, and sadness ($p < 0.05$) came from the amount of parking lot area. Trees were significantly correlated with perceived stress but not emotional measures.

It is not the environment per se but the interaction between its physical qualities and perceptions of these that affect our psychological status. Environmental perceptions are subjective as we select from aspects of the environment and combine different attributes to interpret and form a construction or narrative. Such perception, interpretation, and construction are embedded in complex webs of meaning derived from people's self-hood, personal experience, sociocultural surroundings, and wider political and economic contexts [58,59]. The environment–stress and environment–happiness interactions are, therefore, likely modulated by such variables, including aspects of individuality and cultural specificity. It has been widely noted that gender and sociocultural factors affect environmental perception and the relationships between environmental attributes and people's psychological responses [7,23,56]. Our study did not collect demographic variables to explore role in the relationships. This was to ensure that the instrument was as concise as possible, allowing for swift participant responses to record momentary reactions to the immediate environment. This could be one of the reasons why our results did not show strong correlations between the environmental variables and the reported psychological status; there are significant differences in how individuals respond to their environmental settings.

One individual difference that may play a role is the degree of connection that people feel to the environment [22] that can be assessed as both a trait and state [60]. Related to this, individuals' degree of openness to and awareness of their ongoing present-moment experiences may affect if and how they are impacted by various aspects of the environment. Indeed, mindfulness has been shown to have a reciprocal association with a sense of connection to nature [61]. Our study showed that the self-reported connectedness to the environment was positively correlated with happiness and negatively correlated with stress and other negative feelings. Interestedness, as an indicator of mindfulness at the moment, showed a similar correlation pattern with the psychological measures.

5. Conclusions

We presented a micro-scale study to examine the relationships among the objective characteristics of urban environmental settings, people's subjective perception of such settings, and psychological experiences. The geo-enabled survey tool was effective in collecting data on individuals' perceptions of the immediate environment within their daily activity space. When the collected sample locations were mapped on high-resolution aerial images using GIS, the classified image could be used to derive quantitative properties of the immediate environmental settings and further examine the dose-response relationship between environmental exposure and psychological responses.

Our results showed negative correlations between momentary stress level and the amount of environmental elements, such as water, trees, and grass. Positive correlations were detected between stress level and the amount of parking lot and barren land area, as well as distance to buildings. In terms of perceived happiness, positive environmental factors included water, trees, and artificial surfaces, with all other elements having negative correlations. Most of the correlations examined were not strong correlations. This could be due to the significant differences in how individuals respond to environmental stimuli.

Our results showed that the environmental properties derived from aerial imagery were able to capture one's perceived environment when the dominant environmental elements in the visual field were trees, roads and cars, and grass fields with open sky views. The aerial imagery was also found to exaggerate the amount of trees perceived in the environment because tree canopies are more extensive in an aerial view than those at eye-level. Additionally, water was found to be an especially attractive environmental stimulus, whose existence was often emphasized by humans even when it merely occupies a very small portion of the visual field.

Our study showed that connectedness to the environment was positively correlated with happiness and negatively correlated with stress. Interestedness, as an indicator of mindfulness, showed a similar correlation pattern with the psychological measures. This corroborates previous studies on how individuals' degree of openness to and awareness of their ongoing present-moment experiences affect their perception of the environment [60].

It has been suggested [46] that studies should consider conducting analyses at fine spatial scales and employing multiple exposure assessment methods to achieve a comprehensive and comparable evaluation of the association between urban environment and health along multiple pathways. And many studies have indicated the impact of personal traits on the association [51,62]. The current study is one of the first to be reported at a fine spatial scale. The scope of the current study, however, is limited in several aspects. First, the study site, a university campus, offers an environment with a specific mixture of natural and built elements. This may not be generalizable to a typical urban setting with a wider range of environmental characteristics. Second, the sample of college students captures a specific demographic with unique experiences and stressors that might not be representative of the general urban population. The recruitment method of selecting participants 'on campus' could also introduce selection bias in that students who spend more time in certain areas might be more likely to participate, potentially skewing the environmental exposure data. Third, the current study did not consider individuality and its impact on the environment–mental health relationship, and it relied on one exposure assessment method based on aerial imagery. We have designed a study to use both aerial imagery measures and environmental attributes derived from street view images in an ongoing experiment that expands the study site to residential neighborhoods. Detailed information on demographics and personal traits will also be collected to offer insights on the individual differences of the environment–mental health relationships.

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