Impacts of mental health and household flooding on perceptions of vacant lot greening designs in Detroit, Michigan

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Abstract:

This study aims to contribute to empirical evidence about how design of green stormwater infrastructure (GSI) might benefit individuals in vulnerable populations such as those with poor mental health or those who experience recurrent household flooding. Past studies have linked flooding experience and neighborhood vacant land with negative mental health outcomes, and greenspace experiences with positive effects on mental health. Landscape design elements at the microscale can operate as cues to care (CTC) or cues to safety (CTS) that affect greenspace experiences. For vacant lot greening treatments characterized by varying microscale landscape elements, we examined whether residents' perceptions of care and safety are associated with their self-reported depressive symptoms (DS) and previous household flooding experience. We surveyed 316 Detroit households to measure residents' perceptions of care and safety of GSI designs with varying CTC and CTS. These included fourteen alternative design treatments on two replicate sites and a control vacant lot. Respondents' DS impacted perceived care and safety differently. Those with DS perceived significantly less care across all treatments than did those without DS, but DS did not significantly impact perceived safety. Flooding experience did not significantly impact perceived care or safety. We also found perceptions of care and safety were not significantly affected by three-way interactions among flooding experience, DS, and CTC. Most importantly, our findings suggest that people with depression may not benefit from greenspace exposure in the same way as others. Future research should examine how specific microscale landscape elements might differentially affect people with differing mental health conditions.

1. Introduction

1.1. Study overview

Legacy cities like Detroit, Michigan have faced deindustrialization and disinvestment, leading to a loss of employment opportunities, shrinking populations, and high rates of property vacancy (Carlet, Schilling, and Heckert, 2017; Garvin et al., 2013; Dewar & Thomas, 2012). These challenges disproportionately impact residents of neighborhoods that have been subject to racism and structural discrimination (McClure et al., 2019), social stigmas and anxiety (Garvin et al., 2012), fear of crime, and less contact with neighbors (Kruger et al., 2007) – all of which have been associated with neighborhood property vacancy.

Vacant land greening has immediate implications for the well-being of residents, including benefits to mental health (Carlet, Schilling, and Heckert, 2017; Garvin et al., 2013). Greening design and maintenance to increase perceptions of care and safety may help improve the well-being of residents of legacy cities (Nassauer & Raskin, 2014; Nassauer et al., 2021). A growing body of evidence suggests contact with nature offers mental health benefits for those living near vacant property (Bratman et al., 2019; Jimenez et al., 2021, Kondo et al., 2018; Bratman et al., 2012).

The potential for stress reduction in nature has led to the concept of a ‘nature pill’ in which nature experiences could be prescribed as a treatment alternative for individuals with stress-related ailments (Hunter et al., 2019). More specifically, urban greenspace experiences have been associated with improvements in heart rate, violence, and mortality, as well as mood, attention, and physical activity levels (Kondo et al., 2018). The importance of these potential effects is underscored by the many studies that have found stronger relationships between health outcomes and greenspace experiences among those who have experienced inequities in greenspace access (Lachowycz & Jones, 2014; Maas et al., 2009).

Metrics employed to measure greenspace access may not account for the quality of the greenspace experience offered (Ekkel & de Vries, 2017). For example, safety of accessible greenspace affects its quality, and may introduce inequities even where amount of greenspace appears to be equitable (Williams et al., 2020). Further, commonly used tools to identify greenspace, like the Normalized Difference Vegetation Index (NDVI) may not distinguish relevant greenspace qualities. Used alone, this measure may include vacant lots, which undermine neighborhood well-being, as apparent greenspace (Deng & Ma, 2015; Sivak et al., 2021).

In addition to inequities in greenspace quality (Williams et al., 2020), neighborhoods in Detroit are also impacted disproportionately by household flooding. In Detroit, risk of flooding is directly related to poor housing conditions, where impervious surfaces, clay soils, flat topography, homes and basements in need of maintenance and a combined sewer system contribute to a high risk of household flooding (Larson et al., 2021; Sampson et al., 2014). Recent studies have found that flooding impacts communities of color disproportionately in the United States (Larson et al., 2021; Tate et al., 2021; Messager et al., 2021). Flooding experience has been linked to negative mental health outcomes (Cianconi et al., 2020; Lawrance et al., 2021).

In the United States, extreme storm events due to climate change have become common and have increased the extent and severity of flood risks in the Midwest (Angel et al., 2018). Climate threats disproportionately impact some communities (Thomas et al., 2019), and in the United States, populations that are most vulnerable to negative health impacts from flood events include those who are nonwhite, poor, chronically ill/uninsured, low in educational attainment, children or elderly, female, and those who rent their homes (National Academies of Sciences, 2019). In affected populations, the experience of even one natural disaster can lead to significant mental health impacts, increasing the risk of PTSD, anxiety and depression (Cianconi et al., 2020). Individuals with a preexisting mental illness are more likely to have their physical and mental health impacted by the effects of climate change (Lawrance et al., 2021). Direct effects of climate change such as rising temperatures and extreme weather events, especially when combined with existing societal inequities, can lead to greater negative mental health outcomes for vulnerable groups (Lawrance et al., 2021).

Design of urban greenspace to intentionally maximize residents' perceptions of care and safety may help to address inequities in greenspace qualities and experiences, while also providing ecosystem services related to stormwater management that support communities adapting to climate change (Nesshöver et al., 2017; Nassauer & Raskin, 2014). Implementing green stormwater infrastructure (GSI), as currently defined by the United States Environmental Protection Agency as "the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspiration stormwater and reduce flows to sewer systems or to surface waters", could reduce localized flooding and improve residents' greenspace experiences – especially where effective GSI designs occur on vacant property (Environmental Protection Agency, 2023).

1.2. Microscale elements of vacant lot greening interventions and mental health

Effective greenspace designs are multifunctional, offering satisfying aesthetic experiences and achieving other specified ecosystem services. Aesthetic experiences of urban landscapes are affected by microscale elements, which Nassauer et al. (2021) defined as "immediately perceptible fine grain landscape characteristics of plants, landform, water, and structural materials". In neighborhoods characterized by vacant properties, microscale elements can operate as cues to care (CTC): "immediately recognizable as designed, and that signal continuing human presence to care for a landscape" (Li and Nassauer, 2020) or cues to safety (CTS): "immediately recognizable as promoting the safety of people or nearby property" (Nassauer et al., 2021). Nassauer et al. (2021) concluded that, for vacant properties near their own homes in Detroit, residents most prefer greening designs that include more CTC (e.g., a regular mowing regime, low-growing shrubs and forbs with showy flowers) and a CTS, bollards that separated vacant lots from public access. Additionally, perceived care of the greening designs was a strong predictor of preference; when considering both perceived care and perceived safety, perceived care was necessary in order for perceived safety to significantly affect preferences of residents (Nassauer et al., 2021). Studying Philadelphia greening interventions, Branas et al. (2011) also identified microscale elements which conveyed care and safety to residents, including: fences around lots, planted trees, mown grass, smoothly graded land, removal of litter, and consistent maintenance. Aside from Branas et al., (2011) and (Nassauer et al., 2021), greening investigations have not studied microscale landscape elements. Further, while experience with greenspaces perceived as more cared for and safe have been associated with better mental health (Kondo et al., 2018), neither of these previous studies investigated associations between residents' mental health and their perceptions of microscale landscape elements.

Sivak et al. (2021) conducted a systematic review of literature pertaining to the impacts of vacant lots and related greening interventions on human health. Living near greened (i.e., well-cared for) lots was associated with lower self-reported feelings of depression and stress, and more physical activity and time spent outdoors than living near unmaintained lots. Similarly, South et al. (2018) found that self-reported depression in Philadelphia residents was lower among individuals living near a greened vacant lot when compared with those living near control lots.

Building on this past work, we examine whether residents' mental health and previous flooding experience are associated with their perceptions of the care and safety of greening treatments characterized by different microscale elements. This study aims to contribute to empirical evidence about how design of green stormwater infrastructure (GSI) might benefit individuals in vulnerable populations, specifically people living with depression or who have recently experienced household flooding.

1.3. Research questions

In the present study we address three research questions:

1)

a) Is the experience of depressive symptoms (DS) or household flooding associated with perceived **care** of neighborhood landscapes?

b) Is the experience of depressive symptoms (DS) or household flooding associated with perceived **safety** of neighborhood landscapes?

2)

a) Does the association between DS or household flooding experience and perceived **care** of neighborhood landscapes vary with alternative design and maintenance treatments characterized by different microscale elements?

b) Does the association between DS or household flooding experience and perceived **safety** of neighborhood landscapes vary with alternative design and maintenance treatments characterized by different microscale elements?

Figure 1: GSI pilot sites in the Warrendale neighborhood of Detroit, MI, USA. Included in the design are different CTC (e.g., flowering shrubs) and CTS (i.e. bollards preventing vehicular access to the site).

3)

a) Does the experience of DS interact with the experience of household flooding to affect the association of greening treatments with perceived **care**?

b) Does the experience of DS interact with the experience of household flooding to affect the association of greening treatments with perceived **safety**?

2. Methods

2.1 Collaborative design process

This investigation is part of a multi-year transdisciplinary research project that involved many Detroit community members, practitioners, and researchers from social science, natural science, engineering, planning, design, and law disciplines. Working together, the team iteratively designed, implemented, and refined alternative experimental treatments for GSI on vacant lots in Detroit, MI, USA (Nassauer et al., 2021).

2.2 Study areas

We surveyed households throughout the Upper Rouge Tributary (URT) of the Rouge River Watershed, a designated target for GSI interventions by the Detroit Water and Sewerage Department (DWSD). We identified survey participants in two ways: 1) a census survey of households located near our project's four GSI pilot sites (Figure 1), which were installed in two replicate pilot study areas of the Warrendale neighborhood in 2015, two years prior to data collection, and 2) a stratified cluster sample of households distributed across the remaining area of the URT (Figure 2).

In the Warrendale neighborhood, we conducted a census survey of all occupied households within 250 meters of our pilot sites in each of the two replicate study areas. Households that we determined to be occupied according to parcel and occupancy data (Data Driven Detroit, 2014) and Google maps were mailed invitations to participate in the survey. We then adjusted the estimate of occupied households by postal returns. In addition, our trained interviewers, who were current or past Detroit residents, used their local knowledge to identify signs of occupancy (Sampson et al., 2018). These steps resulted in our final area frame for the Warrendale Neighborhood (n = 399), and the response rate survey was 43.0% (N = 171/399). Power analyses (Salkind, 2010) conducted prior to administration of the survey indicated a sample of at least 160 would be sufficient to detect significant effects when exploring associations between treatment alternatives, perceptions, and perceived or anticipated impacts in the Warrendale neighborhood.

In remaining areas of the Upper Rouge Tributary watershed, we employed a stratified cluster sample based on four variables: vacancy, income, household flooding, and potential cost reduction from GSI. We defined the first two strata based on United States Census (2015) census block group data for percentage of vacant properties and median household income. We drew the second two strata from Tetra Tech (2017) urban stormsewer subcatchment data defined by the sewer collection network (mean size: 27.9 acres) (figure 2). Those strata represent: number of homes reporting basement flooding during the 2014 flood of record (FEMA) within each subcatchments and potential cost reduction for the combined sewer overflow system if GSI were sited within the subcatchment based on Tetra Tech SWIMM modeling. Subcatchments approximately nested within census block groups. We then grouped values for each variable into quartiles and collapsed each variable into two categories indicating low and high levels for each (i.e., 1's and 2's = low; and 3's and 4's=high).

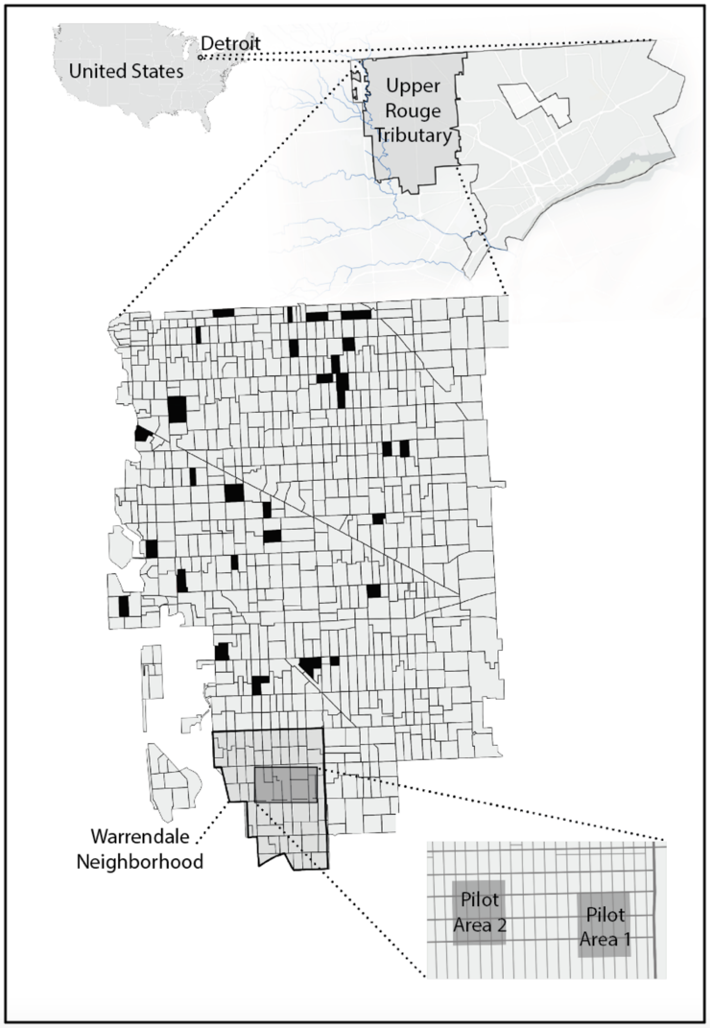

Figure 2: The location of Detroit, the Upper Rouge Tributary watershed, the Warrendale neighborhood, and location of the Warrendale neighborhood replicate pilot study areas. In the Warrendale replicate pilot study areas, we conducted a census survey of all occupied households within 250 meters of our constructed pilot sites. In remaining areas of the Upper Rouge Tributary watershed, we employed a stratified cluster sample. The subcatchments included in the stratified cluster sample are shown in black.

Of the 16 possible combinations of high and low categories of our four sampling variables, we sampled only from the eight strata representing areas that were high in CSO cost reduction potential; these households were most likely to be the sites of future GSI in our study area. Within each of the eight remaining sampling strata (Table 1), four subcatchments were randomly selected; any random selection where a subcatchment was located at the edge of census blocks that differed in terms of median household income and vacancy was replaced and resampled. One

	Low Vacancy		High Vacancy	
	Low Income	High Income	Low Income	High Income
Flooded Homes - Low	103	210	188	81
Flooded Homes - High	66	169	93	53

Table 1: Number of subcatchments from which the Upper Rouge Tributary cluster sample was drawn. Four subcatchments were sampled in each stratum. Note that only subcatchments identified as having high potential CSO cost reduction with GSI were included.

selected subcatchment contained no residential parcels; it was replaced and another cluster was randomly selected from the same stratum. Thirty-two subcatchments were selected in this process (Figure 2). The number of residential parcels that could be surveyed (those with buildings) within each subcatchment was counted next. Four of the 32 clusters had fewer than 30 occupied parcels, and all households were invited to participate in the survey. for the remaining 28 clusters, the 20-25 occupied residential parcels nearest the centroid of the subcatchment were selected to be invited. These steps resulted in the final sample frame for the URT Area (n = 701), with a response rate of 20.7% (N=145/701).

2.3 Alternative treatments with varied microscale elements

To study the effects of microscale elements in alternative landscape treatments, we developed eight treatments that varied in microscale elements, notably CTC (mown turf, flowery forbs, and flowery shrubs) and CTS (bollards to prevent vehicular entry and illegal dumping). Each CTC treatment was shown with and without a CTS (bollards), and each was shown on two different sites. This resulted in 28 images of 14 total alternative treatments. With the addition of the control vacant lot, 29 images were used in the survey. Drawing on previous research by our team (Nassauer et al., 2021), which found similar preferences for treatments with similar microscale elements, our analysis grouped the seven CTC treatments into five categories with distinct microscale elements: existing, flowers with shrubs and shrubs, many trees, trees and mown, and control and weedy (Figure 3).

	Site 1	Site 2

1. Existing

Existing Treatment:

+ 5 species of perennial flowering forbs, 9 species of flowering shrubs. Regularly mown turf. Planted area covers the bioretention basin and back slope.

+ Requires complex hand-weeding and complex mowing patterns.


2. Flowers with Shrubs and Shrubs

Flowers with Shrubs Treatment:

+ 5 species of perennial flowering forbs, 2 species of flowering shrubs. Regularly mown turf. Planted area covers the bioretention basin and back slope.

+ Require hand-weeding and more complex mowing patterns.


Shrubs Treatment:

+ 2 species of flowering shrubs. Regularly mown turf. Planted area only on edges of the bioretention basin and back slope.

+ Requires little weeding maintenance and a complex mowing pattern.


3. Many Trees

Many Trees Treatment:

+ 2 species of trees. Regularly mown turf. Planted area includes a row of deciduous trees facing the street and another at the back of the lot.

+ Requires a complex mowing pattern due to are many trees.


4. Trees and Mown

Trees Treatment:

+ 1 tree species. Regularly mown turf. No flowers or shrubs. Planted area includes a row of trees only at the back of the lot.

+ Allows an efficient mowing pattern because there are few trees.


Mown Treatment:

+ Regularly mown turf. No flowers, shrubs or trees – except in situ at property boundaries.

+ Requires only regular mowing in an efficient pattern.


5. Weedy and Control

Weedy Treatment:

+ Existing treatment, including all the species above, along with five commonly occurring weedy forbs and volunteer woody species.

+ Assumes only annual mowing.


Vacant Treatment:

A vacant lot in the study area that was maintained by local government, mown several times each growing season, but not regularly.

Figure 3: Alternative CTC Treatments. The survey visualizations shown here represent the 14 alternative treatments replicated on each of 2 sites, along with the control: vacant treatment, for a total of 29 images. Each treatment (aside from the control) on each site was shown with and without bollards.

2.4 Survey administration

The University of Michigan Institutional Review Board reviewed and approved this survey and associated protocol in 2017. Trained interviewers visited households in our area frames on multiple occasions from fall of 2017 to spring of 2019. Households that ultimately did not participate either verbally refused (i.e., were not interested or did not have time), no person ever was home, or did not have anyone over the age of 18 at home. Interviews lasted 30-40 minutes and were conducted in-person by a trained interviewer with an adult who was 18 or older in each participating household. A $25 gift card was given to each survey participant as a token of appreciation.

2.5 Measures

In the interview, each participant was shown ten of the 29 images (Figure 3): the control site, two existing sites in the Warrendale neighborhood, and seven treatments that were randomly assigned to one of four different survey sets, which were then randomly assigned for each household interview. These were glossy, photographic prints (28 x 43 cm). Participants had as much time as they needed to view the prints and respond.

- *Mental health* was measured using The Center for Epidemiological Studies-Depression (CES-D) scale. The measure, developed by Radloff (1977), consists of 20 items that ask participants to rate the frequency with which they experienced symptoms of depression in the last week. The CES-D uses a 4-point Likert scale ranging from 0= Rarely to 3= Most or Almost All of the Time. Responses were summed, resulting in a total score that can range from 0 to 60, with higher values indicating experience of more DS. We used a standard cutoff score of 16 to identify those with DS (16 points or more) and without DS (less than 16 points) (Weissman et al., 1977).
- *Flooding experience.* Participants reported how many times their household had experienced standing water in their basement within the last year (i.e. never, 1-2 times, 3-5 times, more than 5 times). We dichotomized responses into those who had experienced flooding within the last year, and those who had not.
- *Perceived care.* For each treatment respondents viewed, they were asked to rate perceived care, neatness, and attractiveness on five-point Likert scales (i.e., well cared for, somewhat cared for, neither neglected nor cared for, somewhat neglected, neglected). The average score of the three questions (care, neatness, and attractiveness) make up the perceived care variable. Because response distributions were skewed toward the positive end of the scales and combining categories from Likert scales allows for more accurate parameter estimates and standard errors, we recoded the data into three categories: (e.g., 1 = neglected/somewhat neglected/ neither; 2 = somewhat cared for; 3 = well cared for) (DiStefano, Shi & Morgan, 2021). Cronbach's alpha was 0.95.

- *Perceived safety* was measured as a single item asked on a five-point Likert scale: respondents rated each treatment as safe, somewhat safe, neither dangerous nor safe, somewhat dangerous, or dangerous. For the same reasons as our aggregation of perceived care, we recoded perceived safety responses into a three-point scale: (1 = dangerous/somewhat dangerous/neither; 2 = somewhat safe; 3 = safe).

2.6 Data Analysis

Survey data were analyzed using R 4.1.2 (R Core Team, 2021). Data were structured with 10 rows of data for each respondent, one for each of the 10 images that each respondent saw (N=3160). The non-independent nature of these data was accounted for through the inclusion of a respondent-level random intercept.

Mixed effects modeling (multi-level linear regression) was conducted using the 'lme4' package in R to address our research questions. Missing data were handled using listwise deletion, which resulted in a final analytic sample size of N=2750.

The independent variables in the main effects models were: flooding experience (flooding experience vs no flooding experience as the reference group), self-reported mental health (those with DS vs. those with few, infrequent, or no DS as the reference group), survey area (located outside of Warrendale vs located within Warrendale as the reference group), treatments characterized by CTC (existing, flowers & shrubs/shrubs, many trees, trees/mown, and weedy/control as the reference group), and CTS (bollards vs no bollards as the reference group). Demographic characteristics of participants (i.e., age, gender, race, and education) were also included.

Because our data as aggregated for analysis were characterized by broad nominal or ordinal classes, we decided to use a broader threshold for determining statistical significance. Therefore, a p-value of <0.01 was adopted to evaluate statistical significance of main effects, which is consistent with the sensitivity of our data (Rabe-Hesketh & Skrondal, 2008).

To answer research question 2 we explored the interactions between DS and flooding experience and microscale elements of different treatments (CTC x DS, CTC x flooding experience, CTS x DS, CTS x flooding experience).

To answer research question 3, whether potential interactions between DS, flooding experience, and greening that employs CTC might impact perceived care and safety, we ran two three-way interaction models (DS x flooding experience x CTC treatment). These contained the same independent variables as the main effects models as well as all possible two-way interactions that comprise the three-way interaction. For this model, the treatments characterized by CTC variable was recoded into a binomial variable (all CTC treatments vs. weedy/control as the reference group) by combining the existing, flowers & shrubs/shrubs, many trees and trees/mown treatments.

3. Results

3.1 Demographic characteristics of respondents

Table 2 shows the demographic characteristics of our survey respondents. Compared with the study area population, our survey respondents tended to be older and more often identified as female, as well as be higher income households with higher rates of high school education and a higher unemployment rate. The percent of people who were Black and household size were similar in the study area population and our survey respondents.

When compared to Detroit (U.S. Census Bureau, 2020), our respondents included more individuals who were Black (77.1% in Detroit) and identified as female (52.7%). Additionally, the respondents had higher rates of high school education (18.1% less than high school), slightly higher rates of unemployment (10.1%) and higher income (39.9% income below 25,000). The household size was very similar to that of Detroit (2.4 people).

Table 2: Respondents to our survey of households in the combined Warrendale neighborhood (response rate = 43.0%) and the greater Upper Rouge Tributary (response rate = 20.68%), with their household characteristics, compared with study area population.

	Survey Respondents (N = 316)		***Survey Area Population*** [a]
Respondent Characteristics	***%***	***Mean (SD)***	
Age (18-99)		47.8 (16.6)	33.4[b]
Gender (% female)	67.0		54.2
Race (% Black)	90.2		89.7
Income below $25,000/year	33.9		40.8[c]
Less than High School Education	9.8		15.8
Unemployment rate	10.1		8.7
Years in neighborhood		15.4 (13.9)	N/A
Household Characteristics			
Household Size		2.3 (1.6)	2.5
Housing tenure (% owners)	53.2		49.4

Notes: [a] Study area population data are pooled five-year estimates (2016–2020) from the American Community Survey obtained from socialexplorer.com (Census Bureau, 2020). Data were aggregated across 34 census block groups that comprise the study area; [b] median age of all residents in study area census blocks; [c] percentage of households with income less than $24,999.

3.2 Descriptive results

Descriptive results in Table 3 offer general insights into our research questions, which are thoroughly examined in the model results section below. Overall, mean scores of perceived care and safety were lower among individuals with depressive symptoms. When comparing the mean scores of individuals who had experienced flooding to those who had not, those who had flooding experience perceived more safety and care across treatments. All treatments containing

CTC were perceived to be more cared for and safe than the weedy/control treatment. Additionally, treatments containing bollards, a CTS, were perceived to be more cared for and safe across all groups.

Table 3: Distribution of respondents across depression and flooding groups and N of each treatment in analytic sample . Mean and standard deviation (Mean (SD)) of perceived care and safety of treatments with different CTC and CTS among participants in different depression and flooding groups

	Depressive Symptoms, Flooding Experience			Depressive Symptoms, No Flooding Experience			No Depressive Symptoms, Flooding Experience			No Depressive Symptoms, No Flooding Experience			
		Percieved Care	Percieved Safety		Percieved Care	Percieved Safety		Percieved Care	Percieved Safety		Percieved Care	Percieved Safety	
	N	*M (SD)*	*M (SD)*	N	*M (SD)*	*M (SD)*	N	*M (SD)*	*M (SD)*	N	*M (SD)*	*M (SD)*	Total N
Treatments by CTC													
Weedy/Control	96	1.13 (0.43)	1.25 (0.56)	156	1.06 (0.26)	1.15 (0.37)	114	1.15 (0.45)	1.42 (0.69)	226	1.13 (0.40)	1.32 (0.61)	592
Trees/Mown	96	2.49 (0.60)	2.46 (0.82)	156	2.37 (0.62)	2.37 (0.77)	114	2.51 (0.56)	2.57 (0.68)	226	2.52 (0.57)	2.48 (0.70)	592
Many Trees	48	2.52 (0.63)	2.38 (0.82)	78	2.48 (0.56)	2.36 (0.74)	57	2.63 (0.55)	2.58 (0.63)	113	2.62 (0.53)	2.50 (0.71)	296
Flowers & Shrubs/													
Shrubs	96	2.77 (0.42)	2.70 (0.63)	156	2.63 (0.51)	2.60 (0.62)	114	2.84 (0.35)	2.84 (0.45)	226	2.82 (0.40)	2.79 (0.49)	592
Existing	144	2.80 (0.44)	2.65 (0.65)	234	2.68 (0.52)	2.62 (0.66)	171	2.84 (0.43)	2.80 (0.55)	339	2.81 (0.42)	2.75 (0.55)	888
Treatments by CTS													
Bollards	218	2.56 (0.69)	2.53 (0.76)	350	2.44 (0.70)	2.44 (0.79)	257	2.57 (0.68)	2.58 (0.70)	513	2.57 (0.69)	2.55 (0.73)	1338
No Bollards	262	2.21 (0.85)	2.14 (0.92)	430	2.12 (0.83)	2.08 (0.86)	313	2.29 (0.85)	2.36 (0.86)	617	2.26 (0.84)	2.26 (0.86)	1622
Total N	480			780			570			1130			2960

Notes: In the analytic sample, the total number of times that specific treatments were shown to the N = 316 respondents is preliminarily reduced from 3160 to 2960 due to missing values among some respondents.

3.3 Model Results

*3.3.1 Is the experience of DS or household flooding associated with **perceived care or perceived safety** of neighborhood landscapes?*

Our results indicate that DS was significantly associated with perceptions of both care and safety (Table 4, Figure 4) while household flooding was not significantly associated with perceived care or perceived safety (Table 5, Figure 5). This effect of DS on perceived care and safety varied across treatments with differing microscale elements; it was only significant with treatments emphasizing vivid flowers: flowers with shrubs and shrubs. Participants with household flooding experience had marginally stronger perceptions of care and safety for all CTC treatments (Figure 5), though there was no significant difference between perceptions of those with and without experience of flooding. Related to CTS, the interaction between the presence of DS or flooding experience with the presence of bollards was not statistically significant.

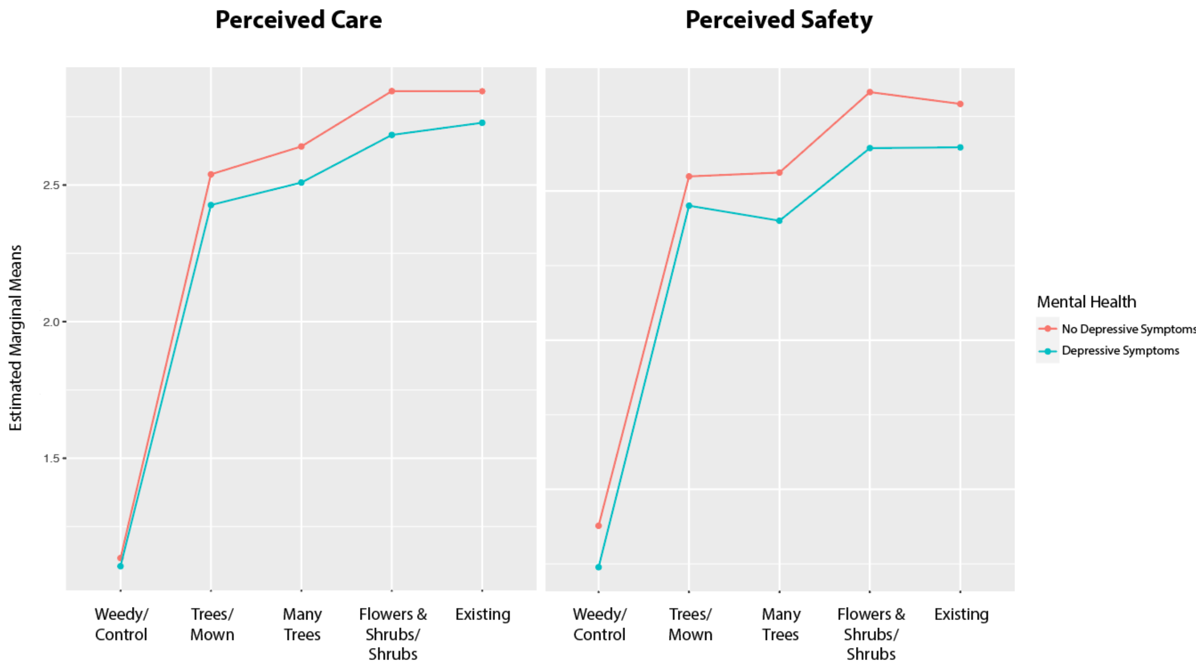

Figure 4: Impact of DS on perceived care (left) and perceived safety (right) of CTC.

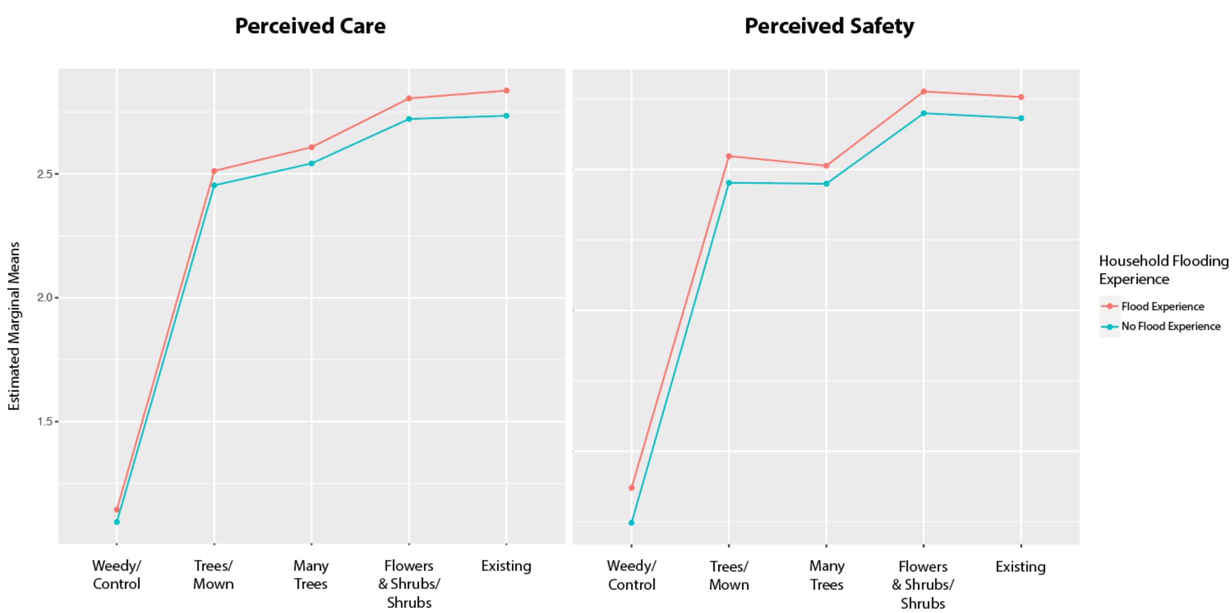

Figure 5: Impact of flooding experience on perceived care (left) and perceived safety (right) of CTC treatments.

Tables 4 and 5: Main and interactive effects of depressive symptoms, flooding experience, CTC, and CTS on perceived care (Table 4) and perceived safety (Table 5). Shown are the unstandardized regression coefficient (b) and the standard error (SE) for each independent variable. The overall model fit is given by the N-adjusted BIC.

N = 275	Main Effects Model			Interactions Effects Model		
Independent Variables	b	SE		b	SE	
Depressive Symptoms	-0.11	0.03	**	-0.05	0.05	
Flood Experience	0.08	0.04		0.06	0.05	
Trees/Mown	1.37	0.02	***	1.40	0.04	***
Many Trees	1.46	0.03	***	1.50	0.04	***
Flowers & Shrubs/ Shrubs	1.65	0.02	***	1.69	0.04	***
Existing	1.67	0.02	***	1.68	0.03	***
Bollards	0.07	0.02	***	0.06	0.02	**
CTC Interaction with Depressive Symptoms						
Trees/Mown				-0.08	0.05	
Many Trees				-0.10	0.06	
Flowers & Shrubs/ Shrubs				-0.13	0.05	**
Existing				-0.09	0.04	
CTC Interaction with Flooding						
Trees/Mown				0.01	0.05	
Many Trees				0.02	0.06	
Flowers & Shrubs/ Shrubs				0.03	0.05	
Existing				0.05	0.05	
CTS Interaction with Depressive Symptoms						
Bollards				0.04	0.03	
CTS Interaction with Flooding						
Bollards				-0.02	0.03	
N-adjusted BIC	3256.65			3371.27		

Notes: Signif. codes: '***' 0.001 '**' 0.01

N = 275	Main Effects Model			Interactions Effects Model		
Independent Variables	b	SE		b	SE	
Depressive Symptoms	-0.15	0.05	**	-0.19	0.06	**
Flood Experience	0.09	0.05		0.14	0.06	
Trees/Mown	1.19	0.03	***	1.19	0.05	***
Many Trees	1.18	0.04	***	1.21	0.06	***
Flowers & Shrubs/ Shrubs	1.44	0.03	***	1.48	0.05	***
Existing	1.42	0.03	***	1.44	0.04	***
Bollards	0.10	0.02	***	0.07	0.03	
CTC Interaction with Depressive Symptoms						
Trees/Mown				0.04	0.06	
Many Trees				-0.02	0.08	
Flowers & Shrubs/ Shrubs				-0.05	0.06	
Existing				-0.07	0.06	
CTC Interaction with Flooding						
Trees/Mown				-0.03	0.07	
Many Trees				-0.06	0.08	
Flowers & Shrubs/ Shrubs				-0.05	0.07	
Existing				-0.05	0.06	
CTS Interaction with Depressive Symptoms						
Bollards				0.09	0.04	
CTS Interaction with Flooding						
Bollards				-0.03	0.04	
N-adjusted BIC	4781.43			4891.77		

Note: Signif. codes: '***' 0.001 '**' 0.01

*3.3.2 Does the association between DS or household flooding experience and **perceived care or perceived safety** of neighborhood landscapes vary with alternative design and maintenance treatments characterized by different microscale elements?*

Our main effects models suggest that microscale elements affect both perceived care and safety (Tables 4 and 5). All treatment options containing CTC were perceived to be significantly more cared for and safer than the control or weedy treatments. Further, treatments having more CTC were associated with greater perceived care and safety, supporting our hypothesis. Comparing treatments with and without a CTS, treatments with bollards were perceived to be significantly more cared for and safer in both main effects models.

*3.3.3 Does the experience of DS interact with the experience of household flooding to affect the association of greening treatments with **perceived care or perceived safety**?*

Our three-way interaction models (Tables 6 & 7) suggest that there is not a significant three-way interaction of effect between DS, household flooding experience, and CTC on both perceptions of care and safety. As with the main and two-way interaction effects models (Tables 4 & 5), which included analysis of specific CTC treatments and perceptions of care, any treatment containing CTC was perceived to be more cared for and safe than those without those microscale elements.

Tables 6 and 7: Interactive effects between depressive symptoms, flooding experience, and CTC treatment variables on perceived care (Table 6) and perceived safety (Table 7). Shown are the unstandardized regression coefficient (b) and the standard error (SE) for each independent variable. The overall model fit is given by the N-adjusted BIC.

N = 275	***Interactions Effects Model***		
Independent Variables	b	SE	
Depressive Symptoms (DS)	0.04	0.06	
Flood Experience (FE)	-0.16	0.06	**
CTC Treatment	-1.58	0.05	***
Two Way Interactions			
DS x FE	0.13	0.07	
DS x CTC Treatment	-0.02	0.07	
FE x CTC Treatment	0.09	0.06	
Three Way Interaction			
DS x FE x CTC Treatment	-0.11	0.08	
N-adjusted BIC	3485.63		

Note: Signif. codes: '***' 0.001 '**' 0.01

N = 275	***Interactions Effects Model***		
Independent Variables	b	SE	
Depressive Symptoms (DS)	0.14	0.08	
Flood Experience (FE)	-0.08	0.08	
CTC Treatment	-1.35	0.06	***
Two Way Interactions			
DS x FE	0.00	0.1	
DS x CTC Treatment	0.03	0.09	
FE x CTC Treatment	-0.04	0.08	
Three Way Interaction			
DS x FE x CTC Treatment	-0.03	0.11	
N-adjusted BIC	4903.24		

Note: Signif. codes: '***' 0.001 '**' 0.01

4. Discussion

Past research has linked flooding experience with negative mental health outcomes (Cianconi et al., 2020; Lawrance et al., 2021) and greenspace experiences with positive effects on mental health (Kondo et al., 2018). We found evidence that microscale elements interact with mental health status to influence perceptions of GSI treatments. Below we draw on our findings and reflect on how to design and implement GSI in a way that may be most beneficial for the well-being of residents.

4.1 Effects of mental health and flooding experience on perceptions of GSI treatments on vacant lots

4.1.1 Mental health impacts

Many studies have found experience in nature to benefit humans across measures of concentration, attention, impulse inhibition, memory, and mood (Bratman et al., 2012). In this study, we found that individuals with DS perceived significantly less care across all treatments than did those without DS. Since the presence of DS may relate to the broader experience of mood, and perceived care of GSI is related to the experience of greenspace, this is a notable finding as it adds nuance to the general finding linking greenspace experiences and elevated moods (e.g. Bratman et al., 2012). Through this lens, while we did find that well-maintained designed treatments for vacant lots were linked with greater perceptions of care and safety for all respondents, our results suggest that those who have DS may not benefit to the same extent or in the same ways as those without DS. Further study is needed to better understand the impacts of depression and other specific mental health conditions on perceptions of everyday landscapes.

Perceptions of safety were also associated with the mental health of respondents, but in different ways. Considering bollards as a CTS, bollards seemed to enhance perceptions of safety for people with DS even more than for those without DS. From this finding, we speculate that, for people experiencing DS, perceptions of safety may be more salient than perceptions of care.

Interestingly, when Nassauer et al. (2021) examined the relationship between perceptions of care and safety related to preferences for a vacant lot near one's home, they found that the perceived care of bollards was significantly related to preferences, and perceived safety played a lesser role. In line with these findings, results of the Nassauer et al. (2021) preference study indicate that, for the overall population, perceived care may dominate concerns for landscapes near one's home.

4.1.2 Impacts of flooding experience

In our study, respondents with some flooding experience in the past year marginally perceived greater care in all treatments than did those without flooding experience though this was not statistically significant. Possibly, when presented with green infrastructure treatments, these respondents understood the need for GSI because of their personal experience with household flooding and consequently perceived GSI as inherently a form of care for their neighborhood. This is in line with findings from a systematic literature review conducted by Venkataramanan et al., (2020) who found that people surveyed across 21 studies tended to have a moderate to strong understanding that GSI plays an important role in mitigating flooding.

Aside from the term green infrastructure, the survey did not describe the function of presented GSI treatments. However, respondents in the Warrendale neighborhood may have been exposed to educational signage installed on the four pilot sites that included information about how the GSI practice was designed to soak up water and keep it out of the sewer system (Figure 1). Additionally, all respondents may have been exposed to other GSI signage within Warrendale or other Detroit neighborhoods.

Respondents who had flooding experience did not perceive significantly greater safety than did those without flooding experience. In our study, respondents may not have considered safety in the context of safety from flooding. Rather, they may have considered safety from undesirable activities in their neighborhood. Therefore, past flooding experience would not necessarily lead one to think that it would be any safer than for anyone who had not experienced flooding. Nevertheless, results from our study do suggest that having maintained GSI rather than a control vacant lot or weedy GSI may make a difference for people who have experienced flooding and may experience care and safety differently. This is an interesting finding as it relates to enhancing neighborhood resilience in the face of climate change which will continue to increase the extent and severity of flood risks in the Midwest (Angel et al., 2018). Residents who have experienced household flooding may have a “just do something” attitude given the stress and trauma associated with flooding noted in studies like Cianconi et al. (2020) and Lawrance et al. (2021).

4.2 Implications for the design of GSI treatments

Overall, our findings were consistent with Nassauer et al. (2021), which found that perceived care and safety were strongly associated with what residents preferred for vacant lots near their homes. In this study, we learned that different microscale landscape elements likely make a difference in how the care and safety of greenspace is perceived by neighborhood residents. The greatest difference we noted is in comparing any well-maintained greenspace design with unmaintained, weedy designs or controls (i.e., vacant lots). Overall, respondents perceived more care and safety in treatments that included varied microscale elements conveying CTC and CTS than treatments that did not (the weedy or control treatments). This suggests that any of the well-maintained designed treatments would deliver better every day landscape experiences with potential related health benefits for neighborhood residents.

As for the impact of microscale elements of design on perceived care, respondents with and without DS perceived significantly more care in designs with more microscale elements. This suggests the importance of investing in designs with more CTC and better maintenance to enhance the outdoor experiences of people living with depression. However, we found that among individuals with DS, perceptions of care were more weakly associated with microscale elements than among those without DS, suggesting that those with DS may not benefit from greenspace experience to the same extent as those without DS. In order to further examine this finding, future research needs to examine how microscale elements may differently affect people with various mental health conditions so that design can be adapted to better serve vulnerable populations.

4.3 Limitations

Certain limitations of our data prevent us from drawing more definitive conclusions. While we found that household flooding experience and residents’ self-reported DS was related to perceptions of GSI, we could not directly examine how flooding impacted mental health because flood experience and DS were reported on different time scales. Respondents reported household flooding within the past year, while they reported their DS only within the past week. This difference, along with the cross-sectional nature of the study, prevented us from investigating a possible causal relationship between flooding and development of DS. This is an important limitation given that flooding experiences tend to worsen mental health (Cianconi et al., 2020; Lawrance et al., 2021). In order to better explore the relationship between flooding and DS in the future, longitudinal studies could be conducted which could better establish causality.

Further, our measurement of DS by self-reports limits reliability of those data. We used the CES-D scale, a widely accepted measure of DS, but any self-reported measure is not as reliable as screening tools implemented by health practitioners or as biological markers of stress, which have been applied in some other studies. These different measures could produce different results. In future studies that follow our report, multiple measures, including both psychological scales and physiological measures like salivary cortisol levels (e.g., Hunter et al., 2019; Tyrväinen et al. 2014) should be considered.

Another limitation is that the design alternatives presented in our study were designed to reflect local conditions and context. The survey was designed in this way (controlling on site and configuration variables) so that results could be sensitive to microscale landscape elements that might affect perceptions. Consequently the results are generalizable only to similar situations in similar legacy city contexts. Future studies, informed by our results, might hold microscale landscape elements constant while varying site area and/or pattern configuration.

5. Conclusion

Our study examined the nexus of mental health, household flooding experience, and perceptions of care and safety of neighborhood greening interventions. We learned that, overall, neighborhood residents perceived all maintained treatments with at least some CTC and CTS to be more cared for and safe than design treatments that appeared to be weedy or the control vacant lot that included no CTC and CTS. Those who had experienced household flooding perceived even higher levels of care for all treatments, suggesting that they may have a "just do something" attitude when it comes to installing GSI on a vacant lot near their home. In contrast, those experiencing DS perceived a specific CTS, bollards at the outer edge of the vacant lot, as significantly safer than designs without bollards. In legacy cities in neighborhoods where more residents experience DS, microscale elements that connote safety may be particularly relevant to well-being.

Our findings introduce an important nuance to the existing literature that concludes greenspace experiences can support well-being, including mental health. Our results suggest that the mental health benefits of GSI, and urban greenspace more broadly, may vary depending on mental health status of residents. Importantly in our study, those who were more vulnerable by virtue of experiencing DS obtained lower perceived benefits from each GSI treatment than did others. This suggests that "nature pill" prescriptions for mental health (Hunter et al., 2019) should be titrated to account for specific mental health conditions – with more vulnerable residents possibly requiring a "greener" experience. It also has implications for urban greening interventions: greater attention to microscale landscape characteristics that enhance perceptions of care and safety may be warranted in neighborhoods with higher incidence of depression. These findings suggest that further study is needed to anticipate greening benefits of other specific mental health conditions.

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