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Is gardening associated with greater happiness of urban residents? A multi-activity, dynamic assessment in the Twin-Cities region, USA

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ABSTRACT

As cities seek to become more livable and environment-friendly, activities like bicycling, walking, and urban gardening (household and community-gardening) are receiving much attention. However, few field studies have measured well-being of urban gardening, particularly during household gardening. Our study develops protocols to measure emotional well-being (EWB) reported during household gardening, comparing it with other leisure and day-to-day activities. We also explore how gardening EWB varies across gardener type (vegetable vs ornamental), demographics, neighborhood type, and companionship during gardening. Using a recently developed app-based Day Reconstruction Method, EWB was measured across 370 participants in the Minneapolis-St. Paul Area, USA, wherein 118 (32%) reported engaging in household gardening. Innovatively, five measures of EWB were computed for each participant for each activity type: average net affect, average happiness, average meaningfulness, the frequency of experiencing peak positive emotions (happiness and meaningfulness). Among all three average EWB measures, gardening is among the top 5 out of 15 activities assessed, and, is not statistically different from biking, walking and eating out. All four of these activities fall behind other leisure/recreation activities, which ranks first. For frequency of experiencing peak happiness, only other leisure/recreation activities were statistically higher than all the remaining (14) activities. Average net affect of gardening was significantly higher for vegetable gardeners (vs ornamental), for low-income gardeners (vs higher income) and for women. Companionship while gardening at home, race/ethnicity and urban versus suburban location showed no significant difference. Livability and equity considerations based on these EWB findings, and their impacts on urban food plans, are discussed.

1. Introduction

We are currently living on an urban planet—wherein more than 50% of the world's population, (UN Desa, 2014) and more than 80% of the world's GDP is generated in urban areas (Dobbs et al., 2011). Seven key physical provisioning systems are essential to support people and economies in cities, affecting urban livelihoods and well-being. These are: energy supply, transportation, buildings, municipal water supply, food, sanitation/waste, and green/public space (Ramaswami, 2016). However, these provisioning systems are now placing large demands on planetary resources as they are associated with more than 86% of GHG emissions and > 95% of water withdrawals, globally (Pachauri, 2014; Ramaswami, 2016). Further, inadequate, poorly functioning and polluting infrastructure provisioning has been shown to have significant impact on health outcomes, such as disease burden, and premature mortality (Lim et al., 2012; IHME, 2018), with many of these premature deaths occurring in highly populated urban areas. Many sustainable development frameworks, including the United Nations' Sustainable Development Goals (SDGs) highlight the interaction between these provisioning systems, the environment, and, human health and well-being. For example, SDG #2 addresses food, SDG #6 addresses water and sanitation, SDG #11, sustainable cities and communities, SDG #13 addresses climate action, and SDG #3 addresses human health and well-being.

However, while much is known about the impact of urban infrastructure and food systems on the environmental dimensions of the SDGs (e.g., Hillman & Ramaswami, 2010; Boyer & Ramaswami, 2017) and on health (Rydin et al., 2012; Wilson, 2011; and Lim et al., 2012), relatively little is known about how infrastructure and food systems in cities shape broader aspects of human well-being, with a particular dearth of information regarding household gardening (Taylor & Lovell, 2014). As cities seek to enhance both livability and sustainability (e.g., Lowell et al., 2013), questions arise as to how to improve quality of life through different sectoral investments such as bicycle paths, parks, and other urban amenities. However, there are few instruments to directly measure human well-being in cities encompassing various activities and sectors that people interact with at the urban scale. Our paper focuses on developing an instrument that assesses subjective well-being in cities

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focusing on urban gardening activities, and comparing with other activities in cities. Furthermore, we focus on emotional wellbeing (EWB) given that it is sensitive to day-to-day variation in activities and interactions with the built environment (Helliwell, 2012), wherein gardening lies.

This introductory section provides an overview of different wellbeing measures, highlights the rationale for measuring EWB in cities, and reviews various methods to measure EWB.

Over the past two decades, methods have advanced to directly measure the subjective well-being (SWB) of individuals, where SWB is defined as judging one's life positively and frequently experiencing positive emotions (Diener, 1985; Diener, 2009; Tabor and Yull, 2018).

Standardized SWB surveys now explore two aspects of well-being, cognitive (how people think) and emotional (how people feel), as illustrated by surveys administered by the UK census since 2012 (Tabor and Yull, 2018). Cognitive wellbeing is measures through scales such as the Cantril Ladder of Life scale (Cantril, 1965) Diener's Satisfaction with Life scale (1985). Emotional wellbeing questions address both positive and negative emotions (happy, meaningfulness, sad, tired stress and pain), a standardized set of which have been used in the National American Time Use Survey (National Research Council, 2012). Some surveys also include questions to evaluate life purpose (meaningfulness), which is shown to influence both cognitive and emotional well-being (Helliwell, 2012).

While cognitive well-being questions are generally framed as a life assessments having participants think "about their life as a whole"(Helliwell, 2012), EWB when tracked through daily activities (Zhu & Fan, 2018), shows how day-to-day interactions impact people at the emotional level, affecting positive emotions, such as happiness and meaningfulness, as well as negative emotions, such as sadness, stress, tiredness, and pain (National Research Council, 2012). Hence the focus of this paper on EWB. Helliwell et al. argue the term 'happiness' can broadly be used for all aspects of SWB, although, by itself, it is an emotion. In this paper, we refer to happiness as an emotion, in the context of Emotional Well-Being (EWB).

National studies, such as the UK census and the ATUS, reveal broad factors such as income and employment, age, demography (race) and family structure that impact EWB (Kushlev, Dunn, & Lucas, 2015, Tabor and Yull, 2018, Yamashita, Bardo, & Liu, 2018); others have revealed that environmental factors, such as weather and pollution, also impact EWB (Tabor and Yull, 2018). However, these surveys do not address multiple built environment interactions within individual cities, and do not specifically inform how urban food production, including community gardening and household gardening, shape EWB.

Gardens are part of the concept of urban green infrastructure and "nature in the city", which includes trees, parks and urban farms. Several studies have evaluated the broader role that nature in the city plays in enhancing human health and well-being. Some studies have focused on the health benefits of green infrastructure (e.g. air pollution reduction, heat island reduction, etc.) (Tzoulas, 2007; Lee & Maheswaran, 2011). A recent review suggests that some of these direct health benefits may be small and/or highly uncertain (Keeler et al., 2019), while broader personal and community/social well-being benefits may be more significant and should be further studied (Petrovic, Simpson, Orlove, & Dowd-Uribe, 2019). Other studies, using qualitative methods, suggest benefits such as psychological benefits and social cohesion, through being more connected to nature and their community (Kim & Kaplan, 2004; Shanahan et al., 2017).

In the context of gardening, there have been many studies of community gardens and their impacts on social cohesion, but these studies do not directly measure EWB and are focused on community gardens (Alaimo, 2016; Litt, 2015; Soga, 2017). A few studies have directly measure emotions during gardening activities. MacKerron and Mourato (2013) tracks the single emotion of happiness when people interact with various nature-based activities nationwide in the UK (both urban and rural), including gardening, using the Experience Sampling Method, which randomly sampled participants twice a day. Bakolis et al. (2018) likewise track various aspect of mental wellbeing (e.g., optimism, energy, relaxation, closeness to other people) as people interact with nature, both urban and rural, in the UK. These studies do not cover the range of emotions (positive and negative) that have been used in composite EWB measures. More recently, researchers have also started to analyze Twitter posts to assess sentiments (Plunz, 2019) in urban green spaces.

These emerging studies, while showing the benefits of nature in the city, do not address the range of emotions tracked in national EWB studies, and, also do not offer a comparison with other urban activities that may also offer opportunities for leisure and relaxation.

Indeed, other activities in cities, including biking and walking, have been shown to improve EWB (Collier, 2018; Wolf, 2013; Lovell, 2014; Golden, 2013; Zhu & Fan, 2018; Fan, Brown, Das, & Wolfson, 2019). As cities consider investments in various infrastructures to enhance urban livability and quality of life, they are considering programs that support household gardening (Sickler, 2018), community gardening (Golden, 2013), and active-living infrastructures such as bicycle paths (Fishman, 2016), all of which can enhance quality of life and reduce environmental impacts. However, to-date, the impact of gardening on EWB has not been measured in comparison to other activities that have known positive impacts on EWB, e.g., bicycling, walking (Zhu & Fan, 2018, Pressman et al., 2009; Brajša-Žganec, 2011; Wei, 2015).

This paper seeks to develop a methodology to directly measure EWB of individuals while engaging in gardening activities, and compare it in the context of other human-infrastructure interactions and daily activities. Specifically, we study household gardening, which has been relatively under-studied, comparing it to other activities (e.g., walking, biking, eating out and other leisure/recreational activities), as well as different types of gardening within the category of household gardening (i.e., vegetable versus ornamental gardening, done alone or otherwise), and in different urban settings (urban vs suburban).

1.1. Objectives

Specifically, this study has three research objectives: (1) understanding human engagement (time spent per week and frequency) with gardening, in the context of time spent on other activities, (2) measuring EWB during household gardening and compare with other activities, and (3) focusing only on household gardening, exploring how the EWB of participants engaged in gardening varies across gardener type, income, neighborhood type, and companionship during the gardening activity.

While the pilot project reported here focuses on household gardening, future work seeks to compare the EWB of household gardening with community gardening in order to offer future policy insight on the well-being benefits of urban gardening as a public or private good.

2. Methods

2.1. Background on EWB Measurements

EWB instruments can be split into two categories: (1) Time-Oriented Techniques and (2) Event-Oriented Techniques (Kahneman, Krueger, Schkade, Schwarz & Stone, 2004). In Time-Oriented Techniques, such as pager-based experience sampling methods, participants report EWB measures at a prescribed or randomly sampled points in time (Krueger, 2014). In Event-Oriented Techniques, such as diary-based Day Reconstruction Methods, participants report EWB measures systematically linked to the participant's daily activities (Kahneman & Krueger, 2006). Literature has shown that time-based techniques have the advantage of extracting EWB information in real time without recall bias; event-oriented techniques have the advantage of capturing sequential and more complete EWB information throughout the day without activity sampling bias. Research comparing the time- and event-oriented techniques

has shown event-oriented techniques, which utilize the Day Reconstruction Method (DRM), to be accurate and reliable (Hektner et al., 2007; Kahneman et al., 2004); moreover, it enables comparing gardening with other events/activites, which is the purpose of this paper.

The DRM first asks participants to reconstruct their previous day's events in a diary. Then for each of the events, participants are prompted with questions about the specific situation of the event and their emotions during the event (Kahneman & Krueger, 2006). The method has been shown to offer reliable results, less burden on the participant, and a continuous log of the participants' events. We use the DRM, operationalizing it through a phone application called Daynamica™ (Fan, Wolfson, & Adomavicius, 2017; Fan et al., 2019).

The DRM measures 'remembered utility,' which reflects a participant's measure of the experience retrospectively (Kahneman, Fredrickson, Schreiber, & Redelmeier, 1993). Measurements used to express remembered utility, such as net affect, report a single EWB measurement for a collective event, in hopes participants are summing momentary utilities over the whole experience. Net affect is a common measure of subjective well-being in psychology literature and represents the mean of a participant's positive emotion scores during an event, minus the mean of a participant's negative emotional scores for the same event (Kahneman & Krueger, 2006). A positive net affect score indicates the positive emotions outweigh the negative emotions for the same event.

'Remembered utility' is heavily influenced by peak positive and negative emotions, no matter their relative duration, compared to the total duration of the activity (Kahneman et al., 1993), therefore in this paper we also develop a new metric to assess 'peak happiness", in terms of frequency of experiencing high levels of that emotion. Frequency of 'peak happiness' expresses events where participants report extreme positive emotion, since 'remembered utility' is weighted to the peaks and valleys of emotions. Literature suggests that people might remember negative emotions more than positive emotions; hence, some researchers have constructed an unpleasantness index called the U-index (Kahneman & Krueger, 2006). In this paper we focus on average net affect, average individual positive emotions, and the frequency of experienced peak happiness emotion as measures of EWB.

2.2. Survey design and implementation in smart phone

The data for this study comes from a larger the Neighborhood Environment, Daily Activity and Well-Being Study conducted by the authors in the Minneapolis Metro area over a period of a year, from October 17, 2016 to October 25, 2017. While the larger study focused on the broad features of the built environment (Fan et al., 2018), this paper reports EWB associated with gardening in the context of other human-infrastructure interactions.

Overall, the study recruited 404 participants to respond to an entry survey, a 7-day Day Reconstruction Method based diary tracked using the cell phone App Daynamica, and an exit survey that queried them if they engaged in any gardening during the past week. The percentages surveyed by the season over the study period were: 27% during the spring, 33% during the summer, 25% in the fall and 15% in the winter. Of the 404 recruited participants, 370 completed all parts of the study, which serves as the sample size in the analysis reported on this paper. Survey participants were recruited from six pre-selected neighborhoods, including four urban and two suburban, so as to cover a range of land use distribution, open space, housing type, community services, access to amenities, etc. seen across the city. Variation in income levels was also sought, hence, the urban setting consisted of two low-income and two medium-income neighborhoods, while the suburban setting consisted of one low-income and one-medium-income neighborhood.

Among the 2443 census blocks associated with the six selected neighborhoods, 921 were randomly selected to recruit the participants to the survey. Across these 921 census blocks, the ACS 2017 five-year estimates identify a population of 44,573 and an average household size of 2.90 persons. All homes in the randomly selected blocks were post carded with a brief study description and contact information for the research group. Interested participants then contacted the research group by phone or email, at which point, they received a more in-depth description of the project. If they were still interested in participating, the research team set up an appointment to meet with the participant.

This study used a three-phase interaction approach with participants. In the first phase, participants met with a member of the research team where an introductory survey was administered to obtain key demographic information. In the second phase, a phone with an application-based Day Reconstruction Method (Daynamica™) was administered to the participant to collect dynamic, EWB data linked to the participant's daily activities.

Daynamica™ (Fan et al., 2017; Fan et al., 2019) detects activities and trips in real time to construct sequenced activity/trip episodes throughout the day. It also allows the user to annotate the detected activities/trips with additional information such as emotional experiences during each activity/trip at their convenience. For each activity, participants are asked to rank (on a seven-point scale) six emotions (Happy, Pain, Sad, Tired, Stressed, and Meaningful). The Daynamica™ app was preloaded to a phone owned by the research team, which was supplied to the participant for the 7-day period.

In the third phase, an exit survey was administered by a member of the research team after one week. This survey was used as a check of completion and understanding with the application-based Day Reconstruction Method. During the exit interview, participants were asked "Did you grow some of your own food at your home or at a community garden?" This question was used to determine if participants who cited an activity in their log as including gardening were 'Ornamental Gardeners (having logged time gardening but having not produced their own food) or Vegetable Gardeners (having logged time gardening and produced their own food). Recruitment was conducted in a manner that gave no predisposition to the research team's interest in gardening activities. This was done to maintain unbiased EWB results.

Additionally, geo-location provided via the Daynamica™ application was used to determine the location of the gardening activity, thus denoting gardeners as household gardeners rather than gardeners who gardened away from their households as would be the case for community gardens. The overall methodology used in this study comes from previous work establishing EWB of transportation systems (Fan et al., 2019); here we use the same methodology to focus on the EWB of gardening.

For each the participants, data were collected over the course of a week. With the smartphone-enhanced Day Reconstruction Method, the research team calculated three types of EWB measures: average net affect scores, average positive emotion scores, and frequency of experienced peak emotion.

- Average Net Affect was calculated as outlined by Krueger et al. (2014) for each activity over one week. The mean of four individual, negative emotions measurements (tired, stress, sad, and pain) was subtracted from the mean of two individual positive emotions (happy and meaningful). For each individual event that a participant logs, a net affect score is calculated. From these data, an individual's average net affect score can be computed for each activity (e.g., biking, gardening, etc.) for each participant. . The survey population statistics for average net affect are then developed for gardening versus other activities.
- Average Positive Emotion (Happiness & Meaningfulness): Because gardening is an activity often associated with positive dynamic emotions in literature, we calculate both happiness and meaningfulness scores separately for each activity an individual engages in over the one week period. Individual average happiness scores and individual average meaningfulness scores can be assessed for each activity type (e.g., gardening, biking, working), from which

survey population statistics are developed.

- Frequency of Experienced Peak Emotion during Gardening versus other activities: Over a period of one week, we also wanted to understand which activities (gardening versus other activities) can contribute to a high level of positive emotions for each individual. Therefore, for each participant, a 90th percentile score for 'happiness' and 'meaningfulness' (henceforth this 90th percentile threshold will be referred to as a participant's 'peak happiness threshold' or 'peak meaningfulness threshold') was calculated across all the participant's events. For each participant and for each activity type (i.e. gardening, biking, working, etc.), we then assessed the frequency an activity type's 'happiness' and 'meaningfulness' scores for individual events exceeded the participant's peak happiness and peak meaningfulness threshold reported over the one week period.

2.3. Analysis

Average scores for net affect, average positive emotion and frequency of experiencing peak emotion was calculated across activities and attribute categories. These averages were then analyzed for difference using ANOVA tests and a post-hoc Tukey HSDs to calculate the p-value and 95% confidence intervals. In addition, a multivariable regression was performed on 'net affect' during gardening to strengthen results established through the ANOVA testing.

3. Results

We organize our results into four categories. First, we offer a demographic description of the study sample. Second, we present the engagement of participants in household gardening in the context of other activities. Third, five EWB measures (average net affect, average happiness, average meaningfulness, frequency of experiencing peak happiness, and frequency of experiencing peak meaningfulness) are reported for household gardening and are compared to reported EWB and frequency of peak happiness experienced during other activities. Last, the average net affect of household gardening is compared across the attributes of the gardener (by gender, income, urban-suburban location) and the type of gardening (ornamental vs vegetable gardening).

3.1. Study sample and demographics

Of the 370 survey participants, 126 (34.1%) were male and 244 (65.9%) were female. Seventy-three respondents (19.7%) self-reported as 'low-income' ($24,999 or less household income in 2017 before taxes), 130 (35.1%) self-reported as 'medium-income' $25,000-$74,999) and 167 (45.1%) self-reported as 'high-income' ($75,000 or greater). In addition, 266 (71.8%) lived in urban neighborhoods, based on census classification.

Of the 118 (31.4%) who logged *gardening*, 73 participants (19.7%) self-identified as vegetable gardeners and 45 (12.2%) were determined to be ornamental gardeners. Of the 118 gardeners only one gardening event was logged at a geo-location away from a participant's home geo-location. This event was removed from the sample so results could reflect 'household gardening'. Table 1

Table 1
Demographic Comparison between Minneapolis-St. Paul Metro Area and Survey Sample.

Metro	Variable	Sample
51%	**Gender**	66%
60%	**Living with Spouse/partner**	60%
37	**Age (median)**	50
63%	**Employed Full Time**	43%
19%	**Disabled**	20%
47%	**Children Under 18 Present**	31%
81%	**White**	77%
6%	**Asian**	4%
8%	**Black**	11%
1%	**American Indian**	2%
3%	**Multiple**	5%
5%	**LESS THAN $10,000**	7%
11%	**$10,000 TO $24,999**	10%
20%	**$25,000 TO $49,999**	16%
18%	**$50,000 TO $74,999**	19%
14%	**$75,000 TO $99,999**	17%
25%	**$100,000 OR MORE**	27%

3.1.1. Human engagement with gardening in the context of other sectors and activities

Table 2 expresses participant engagement in gardening in the context of other activities. Of the 168 h in a week, a vast majority (111.2 h, 66.2% of time spent over a week) is spent at home, which may include various sub-activities, such as sleeping, cooking or watch television, gardening, and others. The remaining 57 h (on average) per week are dominated by work (23.84 h, 41.9% of the remaining time), leisure/recreation (12.25 h, 21.5% of the remaining time) and then various modes of travel (23.84 h, 41.9% of the remaining time).

Each time the respondent changed location (tracked by the GPS), they were asked if the activity included sub-activities (multiple choice), such as gardening, volunteering, religious activity, etc. When the home-location included the sub-activity of gardening, it was identified as a household gardening activity.

Since household gardening was identified as a sub-label within an activity category (such as 'at home' or 'leisure/recreation'), we could not be certain how accurately respondents reported their time spent gardening at home. Therefore, we used the American Time Use Survey's (ATUS) as a reference, yielding an ATUS average of 1.53 h per week gardening, with 4.25 h per week representing a two standard deviations high-gardening time spent threshold. We then applied the 4.25 h as a cut-off to our study responses, excluding unusually high gardening times as survey error, and found our study average time for gardening per respondent was 1.45 h per week gardening. This result from our survey is reported in Table 2, and is similar to the American Time Use Survey's (ATUS) estimate of 1.53 h per week (calculated from the 2003–2016 Multi-Year American Time Use Survey database). When calculating an imputed average time spent per week gardening (the 164 gardening events with a duration greater than 4.25 h being imputed with the ATUS average of 1.53), the study's average time spent gardening per week is calculated as 1.52 h per week.

3.1.2. Key results in Table 2 and Table 3 are as follows:

- Of 370 people surveyed, 31% participate in gardening activities.
- Relatively few hours per week are spent gardening, at ~ 1.45 to 1.53 h per week on average, which is comparable to other leisure activities such as walking (1.64 h/wk) and eating out (2.30 h/week).
- For Ornamental Gardeners and Vegetable Gardeners, Table 3 shows similar levels of engagement with gardening, between 2 and 3 times per week, and do not prove to be significantly different.

3.1.3. Well-being measurements of gardening in the context of other sectors and activities

Fig. 1 shows the five different EWB measures for gardening in the context of other activities. Average net affect as well as the average individual emotions of 'happiness' and 'meaningfulness' are shown both as a mean (on the left side) for the specific activity of gardening across all participants. Also shown on the right panel, are the frequency of experiencing peak happiness and the frequency of experiencing peak meaningfulness for each identified activity averaged across all participants.

It is noteworthy that gardening is consistently among the top five

Table 2
Engagement in Various Activities across all 370 study Participants detailing A: Percentage of Participants Engaged in Individual Activates, B: Average Frequency of Engagement in Event over the Week, C: Time Spent Per Event, D: Population Weighted Average of Duration of Event (calculated as a product of A, B, and C).

	A) Percent of Participants Engaged in Individual Activities (%)	B) Average Frequency of Engagement in the Activity over the Week (count/wk)	C) Time Spent on Activity Per Week (Hr)	D) Population Weighted Average of Duration of Event (Hr)
Bike	18.6	1.46	0.50	0.25
Bus	21.6	1.36	0.53	0.30
Car	94.3	21.26	7.66	0.28
Eating Out	71.1	1.99	2.30	0.86
Education	30.3	0.99	2.99	2.25
GARDENING AT HOME	30.5	0.89	1.45	–
Leisure/Recreation*	86.2	5.35	12.25	1.70
Rail	11.4	0.44	0.21	0.36
Shop	85.4	4.54	3.14	0.51
Waiting	37.0	0.82	0.10	0.09
Walk	84.9	8.76	1.64	0.14
Work	66.2	4.75	23.84	3.70

n = 370 participants; *May occur at home or away from the home $^{\Phi}$ Time Spent and Durations for *Gardening* are reported from the American Time Use Survey NOTE: total hours in a week are 168 of which about 111 h are spent at home and are not reported as specific activities.

activities associated with high average net affect, average happiness, and average meaningfulness scores as well as the frequency in experiencing peak meaningfulness. All figures show which activities are significantly different from gardening. Confidence intervals are absent from gardening, since all confidence intervals express significant difference from gardening as the reference group. For example, in Fig. 1, a net affect during shopping is significantly different from gardening, but one cannot say there is significant difference between shopping and riding the bus.

Among all three average measures of emotions (net affect, happiness, meaningfulness), gardening is among the top 5 out of 15 activities assessed, and, is not statistically different from biking, walking and eating out. These three average metrics indicate gardening to be on par with eating out, walking and biking. Nominally, gardening is ranked 4th for average net affect and average happiness (focusing on that single emotion), while ranked 2nd in average meaningfulness. These results suggest that while other (unidentified) leisure activities are highly ranked, gardening soon follows in the top category. Gardening may have a particular role in being meaningful, and should be evaluated in further studies.

In contrast, the frequency of experiencing 'peak happiness' (1C) shows that only the top-ranked activity (leisure/recreation) is significantly different from gardening. For the frequency of experiencing 'peak meaningfulness' (1E), education nominally emerges second after other leisure/recreation, while gardening ranks 4th. However, none if these activities are statistically different from gardening. The only activities significantly different from gardening are at the extreme bottom of the ranked activities (i.e. travel by car, shopping, travel by rail).

The shifting in ranks of the various activities offers nuance about their role in shaping EWB in urban areas, and could be further explored in future studies.

3.1.4. The features of gardening and gardeners as they are associated with EWB

Fig. 2 explores the demographic attributes influencing average net affect scores while gardening, and compares them with the top five activities by net affect, as identified by Fig. 2*A* (i.e. gardening, leisure/recreation, eating out, biking and walking). The socio-demographic variables depicted in Fig. 2 are: gardener type (vegetable vs ornamental), gender, income and race, as well as urban vs suburban location, and companionship during gardening. We also conduct a multivariable regression focused solely on net affect during gardening (shown later in Table 4).

For Fig. 3A, 3B, 3D and 3F, ANOVAs tests and post-hoc Tukey HSDs were used to calculate the p-value and 95% confidence intervals; thus, confidence intervals are absent from the reference group in each activity grouping (i.e. Vegetable Gardener in 3A, Low-income in 3B, By One's Self in 3D, and White in 3F). In addition, significance is only shown in comparison to the reference group and does not express significant difference between the second, third, fourth, and/or fifth bars. For example, in Fig. 2A, the average net affect score for 'vegetable gardeners' is significantly different than 'non-gardeners' while walking. One cannot say, from Fig. 2A, there is significant difference between the average net affect score of 'ornamental gardeners' and 'non-gardeners'. In contrast, t-tests were used, since only two factors were compared, to calculate the p-value and 95% confidence intervals for Fig. 2C and 3E, for race and gender, respectively.

3.1.5. Key take-away from Fig. 2.

Focusing only on net affect associated with gardening, Fig. 2 overall shows average net affect experienced during gardening differs significantly by gardening type (Fig. 2A vegetable vs ornamental), income level (Fig. 2B), and gender (Fig. 2C). Other factors such as companionship during gardening (2D), urban vs suburban location (2E) and race (2F) did not have a significant impact on average net affect experienced during gardening.

Fig. 2A (gardener type) shows vegetable gardeners have significantly greater average net affect during gardening compared to ornamental gardeners. Vegetable gardeners appear to also generally have significantly higher average net affect for all five activities

Table 3
Engagement in Gardening across Gardener Type detailing A: Number of Participants, B: Average Frequency of Engagement in Event over the Week.

	A) Number of Participants	B) Average Frequency of Engagement in the Activity over the Week (count/wk)
Ornamental Gardeners	45	2.40
Vegetable Gardeners	73	3.05
Survey Responds Across All Participants (gardeners and non-gardens from Table 1)	370	0.89

Significance denoted between Ornamental and Vegetable Gardeners:*:p-value < 0.05; **:p-value < 0.01; ***: p-value < 0.001.

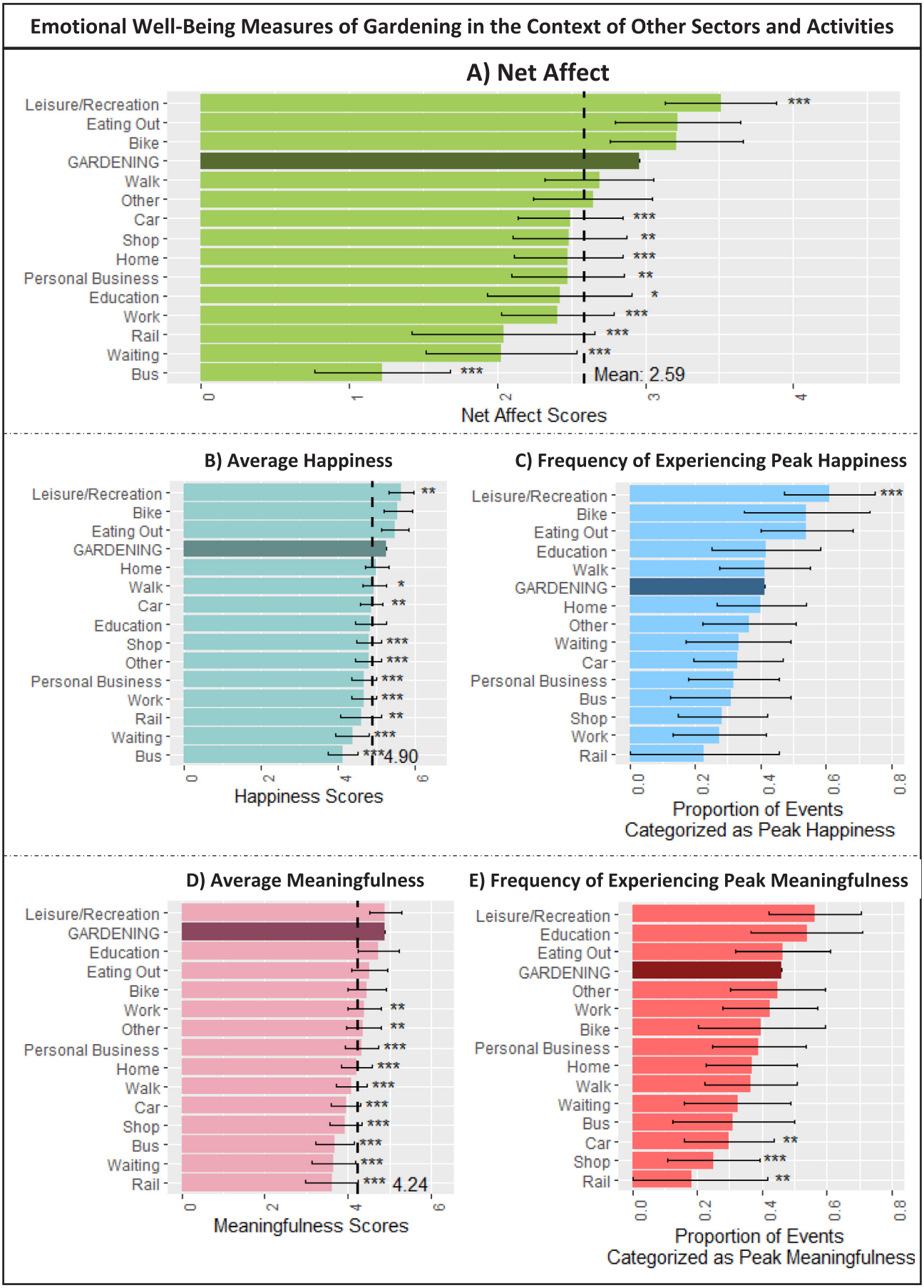

Fig. 1. Emotional well-being measures of gardening in the context of other sectors and activities.

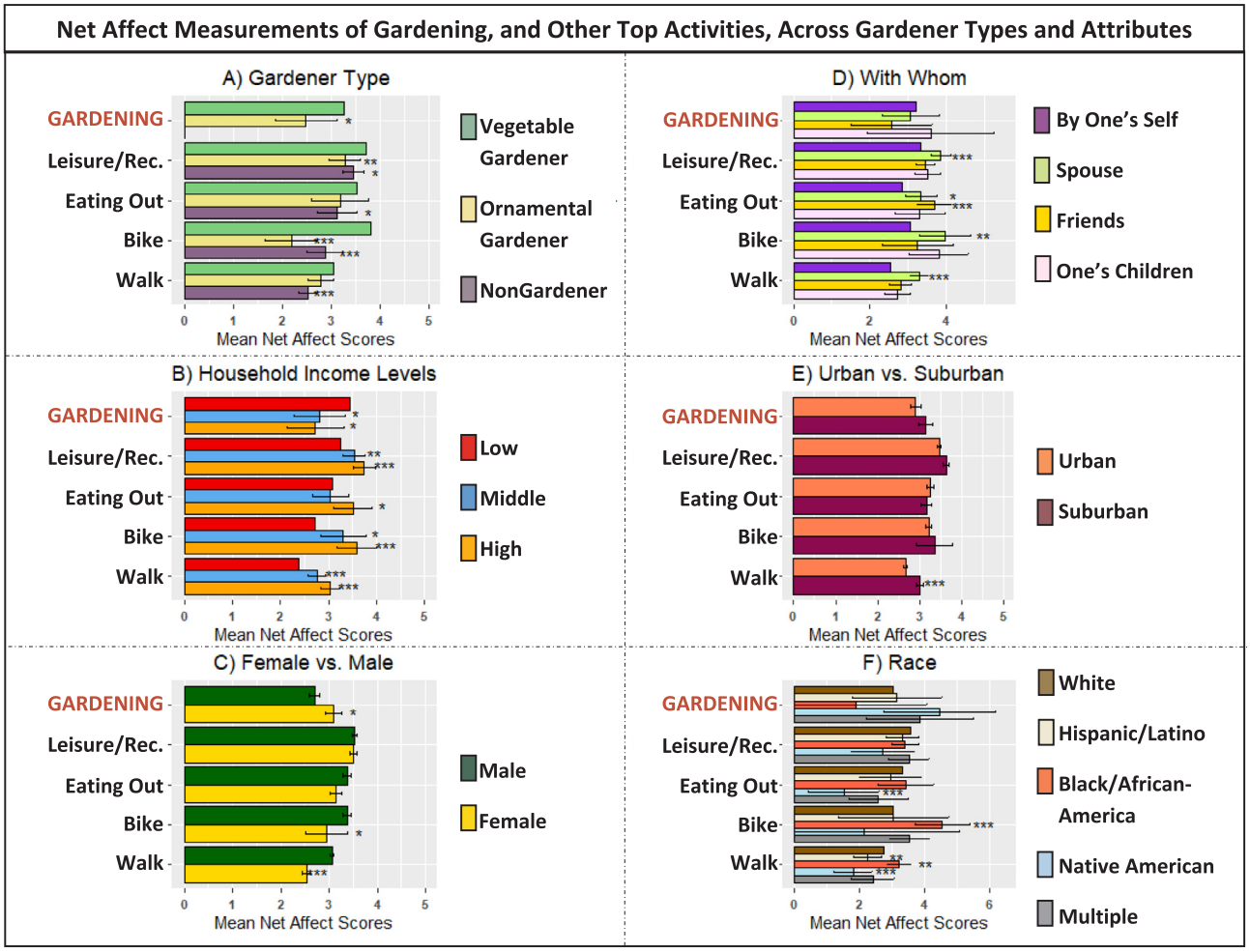

Fig. 2. Net affect measurements of gardening, and other top activities, across gardener types and attributes.

compared to non-gardeners, and significantly higher scores than ornamental gardeners for three specific activities: gardening, bike and leisure/recreation. These results suggest vegetable gardeners may be a sub-population experiencing higher net affect over a range of activities.

Focusing on income, Fig. 2B shows low-income survey respondents reported significantly higher average net affect compared to medium and high-income respondents. Likewise, gardening is the only activity in the top five activities where female participants have significantly higher average net affect scores than male participants (Fig. 2*C*). Gardening thus seems to be different from the other activities, such as leisure/recreation, biking, walking and eating out, as it is associated with a significant and positive response for women and lower income survey respondents.

Companionship during gardening ("with whom"), suburban or urban location, and race (*Figures 3D, 3E, 3F*) do not show a significant impact on a participant's net affect while participating in gardening events. It is notable that companionship while gardening is not significant since existing literature touts gardening, particularly gardening at community gardens, as important due to its social and communal connections for gardeners. However, our results show that net affect scores of household gardeners not significantly impacted by companionship.

In addition, for all activities other than gardening, participating in the activity with 'one's spouse' showed a significantly higher average net affect score when compared to participating in the activity 'by oneself.' Across all activities for the attributes 'suburban or urban' and 'race', differences in average net affect scores prove to be either insignificant or inconsistent.

Table 4 presents a multi-variable OLS regression that explores the association of various sociodemographic variables and average net affect reported during gardening. The results, consistent with Fig. 2, show that income, type of gardening (vegetable vs ornamental) and gender are key significant variables associated with EWB during household gardening. Diener's Satisfaction with Life Scale (SWLS)(1985) scores for each participant were used as a proxy to account for potential general EWB variations across participants.

4. Discussion

4.1. Urban planning and policy context

Urban gardening, whether household or community gardening, intersects with three urban planning and policy agendas. First, gardening is one of many activities, such as biking and walking, that can contribute to enhancing EWB in urban areas, which is a measure of quality of life. Enhancing quality of life of residents, while promoting environmental sustainability, is a goal of several cities' livable and sustainability plans (e.g., Melbourne, Australia; Lowe et al. (2013)), including for the City of Minneapolis, where this study was conducted. While there are numerous indicators of quality of life (e.g., the Mercer Index, Economic Intelligence Unit; Korpela et al., 2016), they do not address the diversity of activities in urban areas. New protocols, such as those developed in this paper, directly measure well-being of urban residents, in the context of multiple activities, can offer new ways of informing which activities and sectors shape quality of life for which demographic groups in cities.

Table 4
Multiple Regression for Net Affect while Gardening.

n = 118; Multiple R-squared: 0.3436; Adjusted R-squared: 0.3077

	Estimate	P-values
Gardening Type		
Vegetable Gardeners		
Ornamental Gardeners	−0.7560	0.0009***
Household Income		
Low (< 50 k)		
Middle (50 k-100 k)	−0.6670	0.0406*
High (greater than100 k)	−1.2507	0.0004***
With Whom		
By Oneself		
Spouse	0.0675	0.5715
Friends and Acquaintances	−0.0840	0.6253
One's Children	−0.1392	0.4359
Urban/Suburban		
Suburban		
Urban	−0.1625	0.4631
Race		
White		
Hispanic	0.6209	0.1739
Asian/Asian-American	0.3955	0.6604
Black/African-American	−0.1885	0.7568
Native American	0.0008	0.9996
Multiple	0.0779	0.1082
Education Level		
Less than Bachelors		
Bachelors	−0.0779	0.7911
Greater than Bachelors	−0.2002	0.4964
Gender		
Male		
Female	0.3939	0.0371*
Age (continuous; 19–87)	0.0126	0.0398*
SWLS Score (continuous; 5–35)	0.1472	0.0000***

*:p-value < 0.05; **:p-value < 0.01; ***: p-value < 0.001 NOTE: Attributes are discrete: estimate values are relative to the first attribute in the group. Values are 'continuous' as marked.

A second urban planning agenda more specifically focuses on urban agriculture, wherein, more than 187 cities worldwide have signed on to the Milan Urban Food Policy Pact (MUFP, 2015). Increasing the amount of urban agriculture is listed as one among several key strategies that can contribute to food security, livelihoods and livability in urban areas. While many studies have assessed the impacts of community gardens on these factors, very few have assessed the benefits of household gardens in the global north (Taylor & Lovell, 2014).

Last, and more broadly, the promotion of local food production is considered to be more environmentally sustainable although the science is not yet conclusive (Santo, Palmer, & Kim, 2016). Several cities are also including greenhouse gas emissions associated with food production in their city scale carbon footprint accounts, and often promoting local agriculture as a means to reduce its carbon footprint (Ramaswami, Hillman, Janson, Reiner, & Thomas, 2008; Goldstein, 2017). Thus a better understanding of urban agriculture is consistent with SDG #11, sustainable cities and communities.

4.2. Significant of the study results

Despite an increased interest in policy and research on urban gardening, few studies have explored the EWB impacts of household gardening, nor compared gardening in the contexts of other activities. This paper pilots a new method for better quantitative understanding of EWB associated with gardening, exploring five measures of EWB across a range or urban activities important to shaping livability. The results of this paper yield four main takeaways, which are discussed below.

4.2.1. Household gardening is associated with high-EWB, similar to biking and walking

This study makes a significant contribution to the literature by finding, among 15 diverse urban activities, gardening is ranked near the top for three different measure of EWB including, average net affect, average happiness and average meaningfulness. Nominally, gardening ranks – fourth for average net affect and average happiness; it ranks behind other 'leisure/recreation' for these two measures, and is not statistically different from biking, walking and eating out. For meaningfulness, gardening ranks second behind events participants denoted as 'leisure/recreation', but is not statistically different from either leisure/recreation, biking, walking, or eating out. However, in the context of frequency of experiencing peak happiness, only leisure/recreation stood out from the other (14) activities; therefore, gardening may not offer the frequency of experiencing peak happiness to the extent that events participants denote as 'leisure and recreation' do. In whole, the results of this study suggest gardening is not different (statistically) from other activities recognized to offer high EWB, such as bicycling and walking. However, the percentage of people engaged in gardening in our survey sample (30%) is higher than those biking (18%). Yet, bicycling programs have received far more attention from urban planners. This study thus suggests that cities consider investments supporting household gardening as they consider other ways to enhance urban livability.

4.2.2. Vegetable gardening vs ornamental gardening

In addition to gardening's EWB measures in the context of other activities, the study also elucidated the impacts of gardener types and gardener attributes on gardening's net affect scores. First, vegetable gardeners, on average, had a 0.75 higher net affect score while gardening (calculated from six emotions on a seven-point scale) compared to ornamental gardeners. The connection between gardening and mean meaningfulness, as a proxy of life purpose, might explain the net affect differences between vegetable and ornamental gardeners while gardening. The additional importance of producing food or maintaining a connection to a larger identity, such as the identity linked to producing one's own food, may play a role in the higher EWB scores for vegetable gardeners (Collier, 2018; Petrovic et al., 2018). With these results in mind, promoting interventions focused on vegetable gardening, rather than gardening more broadly, could offers the greatest opportunity for EWB impacts.

4.2.3. The equity implications of household gardening

It is also interesting that, in this study, for all activities (leisure/recreation, eating out, walking and biking) other than gardening, low-income and female participants report average net affect scores that are significantly lower than both medium-income, high-income and male participants, respectively (Fig. 2B&C). This demonstrates gardening is an outlier activity in the sense that being low-income and female does not appear to lower one's net affect scores while engaging in gardening, as is the case with other activities.

Our results show low-income gardeners having 0.667 higher net affect scores than medium-income gardeners and 1.251 higher net affect scores than high-income gardeners. In addition, female gardeners report, on average, 0.394 higher net affect scores than their male counterparts. These results raise interesting equity questions on which activities to invest for creating more livable and equitable cities, because our findings indicate that household gardening was the only activity that disproportionally benefited women and low-income participants. Indeed, a pilot backyard gardening intervention in Pittsburgh found qualitative, self-reported improvement in wellness, eating habits and access to fresh produce for low-income residents participating in a household gardening program (Sickler, 2018). Both our study and the study in Pittsburgh are among the few that address household gardening, since most of the previous studies in the US have focused on the multiple benefits of community gardening

4.2.4. EWB while gardening at home alone is no different from with company; implications for community gardening

Lastly, our results (Fig. 2D) found that there was no significant different in net affect between participating in a gardening event by one's self and participating with a companion. This suggests household gardening may be different from community gardening, which has been touted as an integral social settings for cross-cultural and generational interactions (Armstrong, 2000; Beckie & Bogdan, 2010), as well as a keystone for community building activities and organization (Teig, 2009; Holland, 2004). This sense of agency and social connectivity during community gardening has been shown to improve self-reported mental health when comparing community gardeners to non-gardeners in urban settings (Teig, 2009, Litt, 2015). However, other literatures confirm that nature-based experiences do not need companionship to yield EWB benefits (Korpela, 2014). Thus, our study interestingly shows that high EWB, commensurate with EWB levels associated with biking and walking, can be achieved at home while gardening alone.

4.3. Our results in the context of other studies

Prior studies of leisure activities' impact on EWB have found "do-it-yourself" activities, such as urban gardening, are associated with greater EWB outcomes due to the participants association with accomplishment, identity, and social connectivity rather than a specific 'positive mood' in the moment (Collier, 2018; Wolf, 2013). "Do-it-yourself," here, refers to the cultural movement of creating products at home or 'from scratch,' rather than 'doing it by yourself' (i.e. without companionship). These studies emphasized the 'life purpose' aspect of gardening and show the dynamic, affective emotions linked to gardening are low compared to other leisure activities like baking, photography and painting (Collier, 2018). The insights from prior studies are consistent with our results, since gardening ranks in the top two for average meaningfulness.

This study is the first attempt, to our knowledge, to evaluate EWB associated with urban household gardening in the global north. However, we acknowledge urban gardening may also have health disbenefits depending on the environmental context, e.g. lead in may urban soils in the US where gardening is not advised (EPA, 2020) and in the developing world, where soil and water contamination by fecal coliforms can be wide spread (Miller-Robbie and Ramaswami, 2017). In these situations the health concerns might outweigh any EWB benefits of urban gardening.

4.4. Limitations

While this is a pilot study which has made key contributions, there are some limitations. First, because this was a pilot study limited to six neighborhoods in the Twin-Cities, the results cannot be generalized. Second, while the team made all efforts possible to avoid any sort of selection bias, because the potential respondents were asked to contact the study team via phone and email, those who do not have access to or are uncomfortable with using these means to communicate may be excluded from the study. There may also be bias based on peoples' levels of comfort using smartphones provided for the study. Third, since Daynamica™ is an app-based Day Reconstruction Method, we recognize the data collected represents recalled EWB data (remembered utility). While time-based methods (i.e. contacting the respondent one or two times per day) may offer a reduction in recall bias, it will not track the varied activities we are comparing in this paper (e.g. household gardening, with other leisure and day-to-day activities), which will require significantly more record keeping by the participant which diminishes participant retention. Finally, gardening was not one of the primary activity categories collected by the Daynamica™ app but rather was a sub-category.

4.5. Future works

Future work can advance the methodology as well as the focus of study. First, in terms of the method, the Daynamica™ app could integrate gardening more specifically as a primary activity similar to biking or walking.

Second, our results should be repeated with community gardeners, exploring how it differs both qualitatively and quantitatively from household gardening. Quantitative comparisons can address both the fraction of urban residents who engage in community gardens, as well as the association with EWB. Such studies can help in the design of city supported gardening interventions, helping understand if greater quality of life benefits to more people are offered through household or community gardens, and, to shape the experience in ways that track with the different measures and nuances highlighted here.

Third, qualitative studies exploring how the experience of gardening contributes to improved EWB is needed. For example, household gardener may garden alone and find the activity meaningful contributing to greater EWB; while community gardeners may find their social interactions contribute to increased EWB. By further exploring these through the more nuanced methods shown and with interviews, practitioners and planners can better understand the nuances when implementing gardening interventions.

5. Conclusion

Urban gardening intersects with three major planning agendas in cities: (1) livable city agendas, which seek to enhance quality of life; (2) the Milan Urban Food Pact, which focuses on urban gardening as one of multiple factors associated with food security; and (3) the SDGs, particularly SDG #11, which identifies sustainable cities and communities as a key goal. This paper has developed a protocol to measure EWB benefits associated with household gardening, in the context of other infrastructure provisioning and leisure activities, which can inform the triple goals of developing livable, equitable and sustainable cities. More specifically, this paper establishes a protocol for urban decision makers to better assess the quality of life benefits from urban household gardening both in the context of other activities, and who receives these benefits by income, race and gender.

Our results highlight four key takeaways.

- Household gardening is associated with high-EWB, which is similar to Biking and Walking.
- Vegetable gardening is associated with higher EWB than ornamental gardening.
- Household gardening is the only activity, in this study, where women and low-income participants report higher EWB than men and medium/high-income participants respectively.
- EWB while gardening at home alone is no different from gardening with company.

Therefore, household vegetable gardening should be considered amongst other livability investments, such as biking and walking infrastructure, in cities. Additionally, backyard gardening alone may provide EWB benefits similar to the purported EWB benefits of community gardens, thus both should be considered as cities address livability investments. While this implies the importance in the act of vegetable gardening itself, nuances between household and community gardeners' EWB still needs to be unpacked.

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Graham Ambrose: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Kirti Das:** Conceptualization, Methodology, Writing - review & editing, Project administration. **Yingling Fan:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition, Project administration. **Anu Ramaswami:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Funding acquisition, Project administration.

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