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Would You Be Happier Living in a Greener Urban Area? A Fixed-Effects Analysis of Panel Data

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Abstract

Urbanization is a potential threat to mental health and well-being. Cross-sectional evidence suggests that living closer to urban green spaces, such as parks, is associated with lower mental distress. However, earlier research was unable to control for time-invariant heterogeneity (e.g., personality) and focused on indicators of poor psychological health. The current research advances the field by using panel data from over 10,000 individuals to explore the relation between urban green space and well-being (indexed by ratings of life satisfaction) and between urban green space and mental distress (indexed by General Health Questionnaire scores) for the same people over time. Controlling for individual and regional covariates, we found that, on average, individuals have both lower mental distress and higher well-being when living in urban areas with more green space. Although effects at the individual level were small, the potential cumulative benefit at the community level highlights the importance of policies to protect and promote urban green spaces for well-being.

Keywords

well-being, life satisfaction

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Mental health and well-being are of increasing concern to policymakers and public-health officials (Department of Health, 2010; Stiglitz, Sen, & Fitoussi, 2009). The World Health Organization (2008) states that unipolar depressive disorders are now the leading cause of disability in middle- to high-income countries. Evidence is growing that this rise may, in part, be associated with increased urbanization (Sundquist, Frank, & Sundquist, 2004) and detachment from the kinds of natural environments people evolved in and are thus best adapted to (Kaplan & Kaplan, 1989; Wilson, 1984). For instance, self-reported mental distress and rates of anxiety and depression are greater in areas of The Netherlands with lower levels of local green space, such as parks (de Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Maas, Verheij, et al., 2009; van den Berg, Maas, Verheij, & Groenewegen, 2010). However, several issues remain unclear. Our aim is to contribute to the field by addressing three of these issues.

First, the findings from The Netherlands are based on cross-sectional data from large samples (de Vries et al., 2003; Maas, Verheij, et al., 2009; van den Berg et al., 2010), which enables generalization from small studies, typical of psychological research in this area, to the general population. Their representativeness also allowed a range of potential sociodemographic confounds, such as income, to be controlled for (de Vries et al., 2003). Nevertheless, the use of cross-sectional data leaves open the possibility that the findings may be due to selection effects. For instance, people who are optimistic, have high self-esteem, and have low levels of neuroticism, all factors associated with higher levels of well-being

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(Diener, Suh, Lucas, & Smith, 1999), may be more likely to move to greener areas, perhaps because they have less need to be close to others for social support. Thus, an association between green space and well-being derived from cross-sectional data may merely reflect the fact that different sorts of, generally happier, people already live in greener areas. Cross-sectional studies are thus unable to control for potentially important time-invariant characteristics, such as personality, which may be influencing both the predictor and outcome variables. By contrast, in the present study, we used data from an 18-year panel survey to compare the self-reported psychological health of the same individuals at different points in time. People move home, sometimes to a greener area and sometimes to a less green area. By comparing people's responses in these different locations, we were able to estimate how living in areas with different amounts of green space may affect them while controlling for stable characteristics such as neuroticism and other time-invariant individual-level heterogeneity. Our research thus answers calls for longitudinal analyses in this area (e.g., Park, O'Brien, Roe, Ward Thompson, & Mitchell, 2011).

Second, previous research focused on the relationship between local-area green space and mental distress, for instance by using the General Health Questionnaire (GHQ; e.g., de Vries et al., 2003; Maas, van Dillen, Verheij, & Groenewegen, 2009; van den Berg et al., 2010). Improved psychological understanding indicates that mental well-being reflects more than the absence of mental distress and includes a range of positive ways in which people think and feel about their lives (Seligman, 2002). One indicator of this more positive approach, used in surveys around the world, is global life satisfaction (for a review, see Dolan, Peasgood, & White, 2008). Moreover, whereas GHQ is a measure of recent experiences, life satisfaction is a more evaluative measure drawing on context and comparison processes (Kahneman & Kruger, 2006). Although life satisfaction does correlate with measures of positive and negative affect, they are generally considered as separate aspects of subjective well-being (Diener et al., 1999). Thus, a second novel contribution of the current research is that we examined green space using a positive, evaluative measure of well-being (life satisfaction) alongside a more experiential marker of psychological ill health (the GHQ).

Third, previous studies have been unable to show how important a change in green space is relative to other changes that affect people's well-being. For instance, people tend to show higher well-being when they are married than when they are unmarried (Lucas, Clark, Georgellis, & Diener, 2003) or employed versus unemployed (Lucas, Clark, Georgellis, & Diener, 2004). It may be important for policymakers to know how green space measures up to these other influences. To fill this gap, we used a fixed-effects analytic approach, more often applied in economic analyses of the correlates of well-being using panel data (Dolan et al., 2008), to compare the effects of many different changes in the same analysis. A fixed-effects analysis derives estimates for predictors, controlling for other predictors, by comparing all the well-being scores of an individual in years when they are in one state (e.g., married, employed, living in an area with low green space) with all their well-being scores in the years when they are in a different state (e.g., unmarried, unemployed, living in an area with high green space) and pooling this information for all the individuals in the sample. Although we used longitudinal data in the model estimation, we did not conduct a time-series analysis. That is, we did not estimate the effects of sequential time points before and after green-space-change events (i.e., relocations to more or less green areas). Although we recognize the value in knowing, for instance, whether people adapt to living in areas with more or less green space (cf. Lucas et al., 2003, 2004, with respect to changes in marriage and employment status), our central aim was to quantify the impact green space might have on well-being relative to changes across other life domains using estimates unbiased by unobserved individual-level factors, such as personality, which remain constant (i.e., invariant) over time.

The only other study in this field that we are aware of that has used longitudinal data differs from our own in several ways. Specifically, Takano, Nakamura, and Watanabe (2002) related the amount of "walkable green space" around the home of elderly individuals in Japan to their mortality rate 5 years later and found lower mortality among those with higher green-space proximity. Differences from the current research include a focus on physical rather than mental health and on older people rather than all sections of the adult population. Moreover, the longitudinal aspect of Takano et al.'s study concerned mortality rates based on green-space access at an earlier time point, rather than the relationship between different amounts of green space for the same individuals at different times. The analysis was thus unable to control for both time-invariant individual heterogeneity and changes in green space and other domains that may have affected mortality in the intervening period.

In sum, in the current research, we used secondary panel data to examine whether the same people would be happier (i.e., show higher well-being and lower mental distress) when living in areas with more green space than in areas with less green space. To do this, we combined data from two large data sets and used a fixed-effects approach to model differences within people rather than between people, as with cross-sectional analysis. This approach also allowed us to compare within-persons differences in well-being associated with living in urban areas containing different amounts of green space with within-persons differences in well-being associated with other factors, such as being married (vs. unmarried) or employed (vs. unemployed).

Method

Sample

We drew data from the British Household Panel Survey (BHPS), a nationally representative longitudinal survey of households in the United Kingdom that was conducted annually from 1991 to 2008. It contained over 5,000 households and 10,000 individual adults, and it used data-collection techniques that maintained representativeness over time (Taylor et al., 2004). Because land-use data were available only for England, our BHPS analysis was also restricted to England. The GHQ was administered in all 18 waves of the BHPS, whereas life satisfaction was rated in only 12 waves. Consequently, although our analysis of GHQ scores was based on 87,573 observations from 12,818 individuals (mean observations per person = 6.83), analysis of life satisfaction was based on 56,574 observations from 10,168 individuals (mean observations per person = 5.56). Missing data, as with other panel surveys, reflects attrition, wave nonresponse, and item nonresponse. Descriptive statistics on the variables used in the study are given for both the GHQ and life satisfaction samples and for all BHPS observations from England in Table 1. Visual inspection suggests that the two samples were highly similar to the overall BHPS sample.

Measures

Green space. Data on local-area green space were derived from the Generalised Land Use Database (GLUD; Office of the Deputy Prime Minister, 2005). The GLUD classifies land use at high geographical resolution across England and has been applied to 32,482 lower-layer super output areas (LSOAs), a standard geographic unit used to report small-area statistics. LSOAs have been defined to encompass similarly sized populations, with each LSOA containing around 1,500 people. The mean physical area defined by an LSOA is 4 km^2. Area cover was accurate to approximately 10 m^2 at the time the data were collected (2005). To examine the potential importance of local green space in countering some of the psychological negatives of urbanization and to avoid confounding green-space area with levels of urbanity (Mitchell & Popham, 2007), we focused on the (English) BHPS observations (84%) in which individuals were resident in areas categorized as "urban."

The GLUD divides the total land cover in each LSOA into nine categories: green space, domestic gardens, fresh water, domestic buildings, nondomestic buildings, roads, paths, railways, and other (largely hard standing). Using these categories, we defined *green space* as the percentage of LSOA land cover accounted for by "green space" and "gardens" combined (and excluding paths and railways). Gardens account for roughly the same amount of land cover in urban areas (33%) as green space does (32%) and, even if not accessible to the public, may contribute to well-being by being visually appealing and helping to reduce stress (Ulrich, 1984). Following de Vries et al. (2003), we entered the percentage of fresh water separately in case there was a specific effect of aquatic environments even though the average was less than 2% (Table 1). The green space and water data for the LSOA in which an individual lived were distributed to his or her BHPS profile.

Mental health and well-being. Mental distress was measured with the short-form, 12-item GHQ. The GHQ is a widely used and reliable self-assessment screening tool to aid clinical diagnosis of mood disorders such as anxiety and depression (Goldberg et al., 1997). The short form asks respondents to consider how the "past few weeks" compare with "usual" in terms of six positive and six negative states (e.g., "been feeling unhappy and depressed"). For each item, there are four response options (which differ across items). In the standard coding scheme, two responses are considered to reflect low risk of mental distress and scored as 0 (e.g., "not at all" or "no more than usual"), and two are considered to reflect a risk of mental distress and scored 1 (e.g., "rather more than usual" or "much more than usual"). Thus, total GHQ scores range from 0 (*very low mental distress*) to 12 (*very high mental distress*). A robustness check showed that our substantive findings were unchanged by an alternative scoring of items from 0 to 3.

Well-being was measured using one question assessing global life satisfaction: "How dissatisfied or satisfied are you with your life overall?" Response options ranged from 1 (*not satisfied at all*) to 7 (*completely satisfied*). GHQ and life-satisfaction scores were almost identical for our subsample and for the overall BHPS sample (Table 1). On average, mental distress was low (1.92) and well-being high (5.20). The correlation between GHQ and life satisfaction was $r(56,080) = -.50$, $p < .001$, which suggests that people with higher GHQ scores had lower life satisfaction.

Control data. We included control variables at both the area and individual levels. LSOA-level (area) controls were taken from the English Indices of Deprivation (Department of Communities and Local Government,

Table 1. Descriptive Statistics for the British Household Panel Survey (BHPS) Sample and the Estimation Samples for Models Predicting General Health Questionnaire Scores and Life Satisfaction

Variable	All BHPS observations (urban and rural)[a]		Model 1: GHQ estimation (N = 87,573; urban only)	Model 2: life-satisfaction estimation (N = 56,574; urban only)
	N	Mean or percentage	Mean or percentage	Mean or percentage
General Health Questionnaire (GHQ) score	136,756	M = 1.88 (2.91)	M = 1.92 (2.92)	—
Life-satisfaction rating	90,084	M = 5.22 (1.25)	—	M = 5.20 (1.27)
LSOA-level variables[b]				
Green space (%)	139,632	M = 70.22 (18.93)	M = 64.64 (16.68)	M = 64.81 (16.64)
Water (%)	139,632	M = 1.82 (6.23)	M = 1.73 (6.32)	M = 1.73 (6.59)
Income	139,632	M = 0.14 (0.11)	M = 0.16 (0.12)	M = 0.16 (0.12)
Employment	139,632	M = 9.91 (6.47)	M = 10.85 (6.72)	M = 10.80 (6.72)
Education	139,632	M = 21.36 (18.30)	M = 23.70 (19.20)	M = 23.71 (19.32)
Crime	139,632	M = −0.05 (0.81)	M = 0.14 (0.75)	M = 0.14 (0.76)
Individual-level variables				
Age				
25 years old and under	139,632	17.17%	17.11%	16.68%
26–35 years old	139,632	19.22%	20.72%	19.97%
36–45 years old	139,632	18.56%	18.68%	18.99%
46–55 years old	139,632	15.99%	14.78%	14.99%
56–65 years old	139,632	12.09%	11.47%	11.87%
66–75 years old	139,632	9.62%	9.85%	9.73%
Over 75 years old	139,632	7.35%	7.39%	7.77%
Diploma or degree	137,780	36.34%	36.02%	39.86%
Married[c]	139,536	65.05%	64.01%	64.27%
Living with children[d]	139,632	28.29%	29.21%	28.94%
Household income[e]	124,409	M = 9.94 (0.64)	M = 9.93 (0.63)	M = 9.97 (0.62)
Work-limiting health status[f]	137,732	17.67%	17.97%	18.37%
Labor-market status				
Employed	139,039	59.39%	58.94%	59.84%
Unemployed	139,039	6.96%	7.41%	6.93%
Retired	139,039	19.31%	19.71%	20.25%
In education or training	139,039	6.19%	6.15%	6.06%
Family carer	139,039	8.14%	7.79%	6.93%
Household-residence type				
Detached	138,450	24.01%	18.50%	18.93%
Semidetached	138,450	35.95%	37.42%	37.69%
Terraced	138,450	26.73%	29.12%	29.27%
Flat	138,450	11.50%	13.63%	12.85%
Other (e.g., bedsit, sheltered)	138,450	1.80%	1.33%	1.25%
Household space[g]				
< 1 room per person	138,424	5.89%	5.83%	5.60%
1 to < 3 rooms per person	138,424	76.98%	76.99%	76.39%
≥ 3 rooms per person	138,424	17.13%	17.18%	18.01%
Commuting time				
None	136,484	42.65%	41.49%	40.46%
≤ 15 min	136,484	28.48%	28.72%	28.82%
16–30 min	136,484	17.12%	17.48%	17.91%
31–50 min	136,484	6.40%	6.65%	6.95%
> 50 min	136,484	5.34%	5.65%	5.86%

Note: Standard deviations are given in parentheses. LSOA = lower-layer super output area.
[a]BHPS observations were analyzed for England only. [b]For a detailed explanation of these variables, see Department of Communities and Local Government (2008). [c]Respondents living with a partner were coded as being married. [d]Only respondents living with their own children who were under 16 years old were counted. [e]For more information on household income, see note 1 at the end of the article. [f]Health was self-rated, and work-limiting health was indexed by the type or duration of work that could be undertaken, including work in the home. Data for this variable were lacking for 2 years, and values were imputed from adjacent wave values. [g]Household space excludes kitchens and bathrooms.

2008), as used in previous cross-sectional work examining self-reported health and green space in the United Kingdom (Mitchell & Popham, 2007). Specific area-deprivation indicators included income (based on social-benefit data), employment (based on unemployment data), education (based on school performance, participation in higher education, and qualifications of working age adults), and crime (based on crime records). To aid interpretation, we reversed scored the first three variables in the estimations so that higher scores indicated areas with higher levels of income, employment, and education, respectively. These area-level variables are similar to those used in exploration of regional well-being in the United States (e.g., Lawless & Lucas, 2011; Rentfrow, Mellander, & Florida, 2009). As with green space, area-level data were distributed to an individual's BHPS profile.

Inclusion of individual-level controls was based on a review of sociodemographic correlates of well-being (Dolan et al., 2008). Specifically, we included age, education (holding a diploma or degree), marital status (including living with a partner), number of children living at home, income,[1] work-limiting health status, and labor-market status (employed, self-employed, unemployed, retired, in education or training, family carer). Given our interest in people moving homes from one area to another, we also controlled for residence type (detached, semidetached, terraced, flat, other), household space (rooms-per-person ratio), and commute length in minutes. As is standard in fixed-effects analysis, time-invariant variables, such as gender and race, were not included because they are stable across all locations and thus provide no within-persons variance to compare.

Analytic approach

Analyses were conducted using the xt suite of functions in Stata 12 (StataCorp, College Station, TX). We used a fixed-effects regression approach that estimated the effects of green space based on scores for the same individuals at different points in time and thus controlled for personality and other stable factors that may influence both an individual's well-being and where he or she chooses to live. For modeling purposes, the samples included both people who did and did not move between LSOAs. We do not, therefore, present estimates of longitudinal trends that might be indicative of anticipation or adaptation effects. Rather, our models are applicable to understanding the relations between well-being and different states (e.g., levels of green space or employment status) rather than changes over time.

The basic model (for GHQ) can be expressed as follows:

$$GHQ_{it} = \alpha_i + \beta Green_{it} + {}_{\gamma}\chi_{it} + {}_{\gamma}Z_{it} + \varepsilon_{it},$$

where GHQ_{it} is a measure of individual *i*'s GHQ score at time *t*, α_i is the unobserved individual-level component, $Green_{it}$ is the percentage of the area designated as green space in which individual *i* lives at time *t*, and χ and Z are sets of individual- and area-level control variables, respectively. An equivalent equation was used for life satisfaction. Regression weights of predictors thus represent the effects of states after accounting for individual time-invariant factors.

Results

Main results

The GHQ measures mental distress, whereas life satisfaction measures well-being. Thus, if green space has a beneficial effect on psychological health, we would expect the relationship to be negative for GHQ but positive for life satisfaction. Results from the fixed-effects model (Table 2) supported this hypothesis, GHQ: $b = -0.0043$, $p < .001$; life satisfaction: $b = 0.002$, $p = .003$. How large were these effects? These unstandardized coefficients relate to the change in GHQ and life-satisfaction scores for a 1% increase in green space. A way of interpreting the relationship is to consider the effect of a more substantial change. For instance, compared with living in an LSOA with green space 1 standard deviation below the mean (48% green space), living in an LSOA with green space 1 standard deviation above the mean (81% green space) was associated with a 0.14 reduction in GHQ and a 0.07 increase in life satisfaction.

Effects associated with other variables were generally consistent with earlier research (Table 2). For instance, compared with being employed or married, being unemployed or unmarried was associated with higher GHQ scores and lower life satisfaction. Several variables (e.g., area-level education, number of children in the household, commuting more than 50 min) were significantly associated only with either GHQ or life satisfaction, which reflects the different aspects of well-being that the measures tap into. As noted previously, a key advantage of a fixed-effects approach is the ability to contextualize the importance of green space relative to other changes. So, for instance, living in an area 1 standard deviation above rather than 1 standard deviation below the mean level of green space was associated with a decrease in GHQ roughly a third as large (35%) as the decrease associated with being married rather than not married or a tenth as large (12%) as the decrease associated with being employed rather than unemployed. For life satisfaction, the effect of green space (1 *SD* above rather than 1 *SD* below the mean) was equivalent to 28% of the effect of being married rather than unmarried and 21% of being employed rather than unemployed.

Table 2. Results From the Fixed-Effects Analyses Predicting General Health Questionnaire Scores and Life-Satisfaction Ratings From Local Green Space and Key Sociodemographic Variables

	General Health Questionnaire (R^2 = .0639)				Life satisfaction (R^2 = .0468)			
Predictor	*b*	*SE b*	β[a]	*p*	*b*	*SE b*	β[a]	*p*
LSOA-level variables								
Green space (%)	–0.0043	0.0013	–0.02	< .001	0.0020	0.0007	0.03	.003
Water (%)	–0.0007	0.0028	–0.00	.795	0.0018	0.0014	0.01	.202
Income	0.7348	0.4312	–0.03	.088	–0.2736	0.2242	0.03	.222
Employment	–0.0084	0.0066	0.02	.205	0.0041	0.0034	–0.02	.228
Education	–0.0014	0.0019	0.01	.461	0.0020	0.0010	–0.03	.048
Crime	–0.0209	0.0329	–0.01	.527	0.0281	0.0173	0.02	.104
Individual-level variables								
Age (reference group: 46–55 years old)								
≤ 25 years old	–0.1363	0.0700	–0.02	.051	0.1922	0.0381	0.06	< .001
26–35 years old	0.0189	0.0540	0.00	.727	0.1274	0.0296	0.04	< .001
36–45 years old	0.0467	0.0415	0.02	.261	0.0350	0.0217	0.01	.107
56–65 years old	–0.3320	0.0454	–0.04	< .001	0.0560	0.0234	0.01	.017
66–75 years old	–0.3641	0.0715	–0.04	< .001	0.0020	0.0377	0.00	.957
Over 75 years old	0.1091	0.0904	0.01	.227	–0.1642	0.0481	–0.03	.001
Diploma or degree	0.0221	0.0444	0.00	.619	–0.0362	0.0226	–0.01	.108
Married[b]	–0.4053	0.0401	–0.07	< .001	0.2518	0.0209	0.10	< .001
Living with children[c]	0.0415	0.0371	0.01	.263	–0.0511	0.0193	–0.02	.008
Household income[d]	–0.0315	0.0214	–0.01	.142	0.0184	0.0106	0.01	.083
Work-limiting health status[e]	0.9062	0.0332	0.12	< .001	–0.2965	0.0168	–0.09	< .001
Labor status (reference: employed)								
Unemployed	1.1359	0.0606	0.10	< .001	–0.3356	0.0305	–0.07	< .001
Retired	0.1365	0.0644	0.02	.034	0.0054	0.0322	0.00	.868
In education or training	–0.0894	0.0632	–0.01	.157	0.1283	0.0316	0.02	< .001
Family carer	0.3883	0.0628	0.04	< .001	–0.1236	0.0319	–0.02	< .001
Household residence (reference: detached)								
Semidetached	–0.0794	0.0453	–0.01	.080	0.0500	0.0235	0.02	.033
Terraced	–0.0906	0.0514	–0.01	.078	0.0633	0.0263	0.02	.016
Flat	–0.1199	0.0609	–0.01	.049	0.0243	0.0311	0.01	.435
Other (e.g., bedsit, sheltered)	0.0099	0.1010	0.00	.922	–0.0399	0.0526	0.00	.449
Household space (reference: 1–3, noninclusive, rooms per person)[f]								
< 1 room per person	–0.0527	0.0513	–0.00	.304	0.0261	0.0260	0.00	.315
3 or more rooms per person	0.0318	0.0390	0.00	.415	0.0017	0.0194	0.00	.929
Commuting (reference: noncommuters)								
≤ 15 min	0.0004	0.0490	0.00	.994	0.0189	0.0243	0.01	.436
16–30 min	0.0714	0.0516	0.01	.167	–0.0228	0.0254	–0.01	.368
31–50 min	0.0861	0.0604	0.01	.154	–0.0164	0.0295	0.00	.577
Over 50 min	0.1623	0.0647	0.01	.012	–0.0149	0.0318	0.00	.638
Constant term	2.5678	0.2477	—	< .001	4.7737	0.1236		< .001

Note: The number of observations for General Health Questionnaire scores and life-satisfaction ratings were 87,573 and 56,574, respectively. General Health Questionnaire scores were obtained from 12,818 individuals, and life-satisfaction ratings were obtained from 10,168 individuals. LSOA = lower-layer super output area.

[a]Stata software (StataCorp, College Station, TX) does not generate standardized coefficients for fixed-effects models; these coefficients were calculated separately by specifying a fully standardized model. [b]Respondents living with a partner were coded as being married. [c]Only respondents living with their own children who were under 16 years old were counted. [d]For more information on household income, see note 1 at the end of the article. [e]Health was self-rated, and work-limiting health was indexed by the type or duration of work that could be undertaken, including work in the home. Data for this variable were lacking for 2 years, and values were imputed from adjacent wave values. [f]Household space excludes kitchens and bathrooms.

Further analyses

Mitchell and Popham's (2007) analysis of health using the same geographical database did not include gardens in their definition of green space. Rerunning the analyses excluding gardens did not change the substantive findings, as the coefficients for green space remained significant, GHQ: $b = -0.0023$, $p = .003$; life satisfaction: $b = 0.0011$, $p = .007$. Evidence that it is valuable to consider the effects of green space on both mental distress and a positive, evaluative measure of well-being comes from adding GHQ to the life-satisfaction model and vice versa. Controlling for life satisfaction, we found that the green-space coefficient predicting GHQ remained significant, $b = -0.0038$, $p = .02$. Green space also remained a marginally significant predictor of life satisfaction when we controlled for GHQ, $b = .0012$, $p = .06$ (the full models are available on request).

Discussion

Our analyses suggest that individuals are happier when living in urban areas with greater amounts of green space. Compared with when they live in areas with less green space, they show significantly lower mental distress (as indexed by GHQ scores) and significantly higher well-being (as indexed by life-satisfaction ratings). These effects emerged when we controlled for other differences at the different time points of data collection, such as income, employment status, marital status, health, housing type, and local-area-level variables (e.g., crime rates). That the effects were reduced but did not disappear when the other measure of well-being was added to the models suggests that some of the benefits of green space work on the area of shared variance between life satisfaction and GHQ, whereas other aspects work on life satisfaction and GHQ through different mechanisms.

As far as we are aware, this is the first longitudinal analysis of the relation between local-area green space and psychological health. Moreover, we also believe that this is the first time that research in this field has demonstrated a significant association between green space and psychological health using a positive, evaluative index of well-being. Our analytic approach also enabled us to compare the size of the psychological benefits of living in areas with more green space with other sociodemographic changes. For instance, the difference in GHQ scores between living in an area with green space coverage 1 standard deviation above versus below the mean was comparable with over a third of the effect of being married versus not married after accounting for individual heterogeneity.

Although the benefits to any given individual are small, green spaces such as parks are accessible to all, and thus the aggregate gains at the community level are likely to be important. The benefits of a marriage, for instance, will be fairly localized, whereas the benefits of a park may be universal. Moreover, other variables that might be expected to affect well-being, such as local crime rates and individual changes in income, were not even significant. This suggests that the green-space findings should not be ignored just because they are not large. Of course, our findings do not mean crime or income are irrelevant for happiness. Rather, controlling for the other factors in the model, we found that individuals were not, on average, significantly happier when they lived in areas with lower crime or had higher household incomes. These findings are not unique. For instance, previous research found that "increases in family income accompanied by identical increases in the income of the reference group do not lead to significant changes in well-being" (Ferrer-i-Carbonell, 2005, p. 1015). Although income tends to be positively related to well-being up to the point at which basic needs are met, beyond that point what counts as satisfactory depends on context (Diener & Seligman, 2004). By contrast, green spaces may have intrinsic value because they represent the environments in which humans spent the majority of their evolutionary and cultural history; this suggests an organism-environment fit that may be directly beneficial for well-being (Kaplan & Kaplan, 1989; Wilson, 1984).

Despite the major strength of our analysis, in terms of controlling for individual-level time-invariant heterogeneity, we recognize several limitations. First, our definition of green space was relatively simplistic, and a single measure taken in 2005 was applied to all time points despite possible changes in land cover over time. Although restricted by current data sets, significant improvements in assessing the quality as well as the quantity of green space are being developed. The Coordination of Information on the Environment project, for example, uses satellite imagery to distinguish 44 land-cover types, which may help finer-grained analysis in the future (e.g., Richardson & Mitchell, 2010).

Second, although we used longitudinal data, we did not use a time-series statistical approach. Thus, unlike Lucas and colleagues' (2003) analysis with respect to marriage, for instance, we were unable to address trends in well-being such as anticipation and adaptation effects before and after moving to areas with different amounts of green space. A full discussion of the relative merits of the different approaches is beyond the scope of the current article. Nonetheless, a major benefit of our approach for making meaningful comparisons about the relative impact of different variables is that we used all available individuals rather than only those who moved to a different LSOA during the sampling period. The result is that we obtained more robust estimates of all covariates in the model. We welcome future research that does use a time-series approach to see whether the positive effects of green space persist over time or whether, as with marriage, they tend to dissipate.

Third, although we controlled for time-invariant individual effects, we were unable to control for all potential explanatory variables, especially those at the area level. Causality cannot thus be assumed. Nevertheless, the results are consistent with a growing body of experimental work documenting improvements in mood and cognitive functioning following short-term exposure to green space (e.g., Berman, Jonides, & Kaplan, 2008; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Nisbet & Zelenski, 2011). It thus seems plausible that general well-being may improve following greater daily exposure to greener areas. We were also unable to examine mechanisms that might explain how green space could improve mental well-being by, for instance, reducing stress (Grahn & Stigsdotter, 2003), aiding cognitive restoration (Berman et al., 2008), encouraging physical activity (Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008), or promoting positive social interactions (Kuo, Sullivan, Coley, & Brunson, 1998). Our findings are thus a complement to, rather than a substitute for, other research in this area.

These limitations notwithstanding, our findings have potential implications for policy. Decision makers are increasingly recognizing the importance of improving population mental health and well-being and wondering what role natural environments may play in this process (Department for Environment, Food and Rural Affairs, 2011). Our data suggest that significant aggregate gains can be made from increasing the amount of green space in urban settings. Even small benefits to individuals can have large impacts if, like green space, they touch many people. Such a policy may also be easier to implement and may raise less ethical and political objections than interventions to improve societal well-being by, for instance, increasing marriage rates. Finally, because additional green space may be especially beneficial for the poorest members of society (Mitchell & Popham, 2008), such interventions may help address social inequalities in mental health and well-being.

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Note

1. Income was operationalized as the log of net annual household income in the preceding 12 months adjusted for household composition using the Before Housing Costs equivalence scale and was indexed to January 2010 prices (Jenkins, 2010). This number was distributed to each individual in the household.

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