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Urban green space and mental health among people living alone: The mediating roles of relational and collective restoration in an 18-country sample

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ABSTRACT

Rates of living alone, especially in more urbanised areas, are increasing across many industrialised countries, with associated increases in feelings of loneliness and poorer mental health. Recent studies have suggested that access to nature (e.g. parks and green spaces) can reduce the stressors associated with loneliness, partly through providing opportunities to nurture personal relationships (relational restoration) and engage in normative community activities (collective restoration). Such associations might vary across different household compositions and socio-demographic or geographical characteristics, but these have not been thoroughly tested. Using data collected across 18 countries/territories in 2017–2018, we grouped urban respondents into those living alone (n = 2062) and those living with a partner (n = 6218). Using multigroup path modelling, we tested whether the associations between neighbourhood greenspace coverage (1-km-buffer from home) and mental health are sequentially mediated by: (a) visits to greenspace; and subsequently (b) relationship and/or community satisfaction, as operationalisations of relational and collective restoration, respectively. We also tested whether any indirect associations varied among subgroups of respondents living alone.

Analyses showed that visiting green space was associated with greater mental well-being and marginally lower odds of using anxiety/depression medication use indirectly, mediated via both relationship and community satisfaction. These indirect associations were equally strong among respondents living alone and those living with a partner. Neighbourhood green space was, additionally, associated with more visits among respondents living with a partner, whereas among those living alone, this was sensitive to the green space metric. Within subgroups of people living alone, few overall differences were found. Some indirect pathways were, nevertheless, stronger in males, under 60-year-olds, those with no financial strain, and residents in warmer climates. In conclusion, supporting those living alone, as well as those living with a partner, to more frequently access their local greenspaces could help improve mental health via promoting relational and collective restoration.

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1. Introduction

The number of people living alone is increasing across OECD countries, especially in northern Europe (Eurostat, 2022b; Organisation for Economic Co-operation and Development, 2016)). Between 2009 and 2021, the number of one-person households without children increased by 28.5% in the European Union; and the increase was evident in all adult age groups, and for both females and males (Eurostat, 2022b).

Although living alone is not equivalent to being lonely, living alone increases the risk of experiencing social adversities such as social isolation and loneliness (Hawkley et al., 2022; Perissinotto and Covinsky, 2014) as well as having poor physical and mental health (Davidsen et al., 2022; Dhindsa et al., 2020; Joutsenniemi et al., 2006). The detrimental effects of loneliness, in particular, have been recognised as major risks for coronary heart disease (Valtorta et al., 2016) and premature mortality (Hakulinen et al., 2018). Measures to reduce loneliness and social isolation are currently being developed in academic research (Hsueh et al., 2022; RECETAS, 2022), and implemented at the policy level (e.g. the 'loneliness strategy' in the United Kingdom; HM Government, 2022).

Single-person households tend to be more common in cities compared with rural areas in almost all countries in the European Union (Eurostat, 2022a). In urban areas, availability of accessible green spaces such as parks and forests is often worse than in rural areas (Haaland & Konijnendijk van den Bosch, 2015). Green spaces, nevertheless, have been consistently shown to benefit mental and physical health (Hartig et al., 2014; Houlden et al., 2018; van den Bosch and Ode Sang, 2017; Yang et al., 2021). These associations might be particularly important in urban areas at least partly due to green areas' potential role in mitigating urban environmental stressors such as air pollution, noise, and the urban heat island effect (Markevych et al., 2017). A recent systematic review, however, found the evidence to support this effect modification by urbanicity overall mixed (Browning et al., 2022). Nevertheless, mental health was not included as an outcome in this review, although it is one of the most consistently linked health outcomes in relation to green space (Jimenez et al., 2021; Nguyen et al., 2021), and issues with mental health tend to be more prevalent in urban areas (Peen et al., 2010).

Most studies examining green space in relation to mental health have assessed green space exposure by geospatial metrics linked with residential location but lacked information on actual exposure such as visits to or views of green space (Kondo et al., 2018; Markevych et al., 2017). Earlier theoretical and empirical work have suggested that merely viewing green space or other types of natural environments is beneficial for mood and health (Kaplan and Kaplan, 1989; Ulrich, 1983; Velarde et al., 2007), and this effect has also been demonstrated in experimental studies on short-term mood outcomes (McMahan and Estes, 2015). Recent evidence has, nevertheless, highlighted that in everyday life, regular visits seem to be the key type of exposure associated with mental health compared with indicators reflecting neighbourhood green space (Tester-Jones et al., 2020; Turunen et al., 2023; White et al., 2021) or viewing green space (Turunen et al., 2023). Furthermore, the association between green space exposure and health has overall shown heterogeneity in different demographic and socio-economic subgroups (Markevych et al., 2017). One of the identified demographic groups that have been shown to visit green spaces less often is those who live alone or who are not married (Colley et al., 2022; Neuvonen et al., 2022), even when controlling for the amount of neighbourhood green space (Boyd et al., 2018).

While there are a number of potential mechanisms linking visits to green space with mental health (Markevych et al., 2017), recent theoretical and empirical advances have stressed social restoration processes (Astell-Burt, Hartig, Putra, Walsan, Dendup, & Feng, 2022; Hartig, 2021). Theoretically, two types of processes have been identified. First, relational restoration theory (RRT; Hartig, 2021) proposes that green spaces can strengthen the quality of interpersonal relationships by providing avenues to meet one's current restoration needs on a regular basis. This can mean not only spending time with people with whom one has developed personal relationships (such as family, friends, colleagues and neighbours), by providing an opportunity to nurture those relationships, but also spending time alone in a restorative setting, by providing restoration for personal needs which may, in turn, positively reflect on personal relationships. Second, collective restoration theory (CRT), suggests that restorative experiences can spread from individuals to their wider communities by, for example, positive emotional contagion (Hartig, 2021). This might occur, for instance, in situations where people unknown to each other have pleasant encounters in public places such as parks, or merely witness others engaging in similar activities at similar times, both leading to a collective sense of trust through positive informal interactions and/or shared normative behaviours (de Vries et al., 2013; Hartig et al., 2013; Kaźmierczak, 2013; Weinstein et al., 2015).

Both RRT and CRT (jointly referred to as 'social restoration processes' hereon) highlight the idea that the restorative benefits of being in contact with natural environments can spread from individuals to their personal relationships and communities more widely (Hartig, 2021). The majority of previous studies focusing on social aspects of restoration in relation to green space exposure have, nevertheless, been conducted at the individual level, often assessing loneliness as the outcome (Astell-Burt et al., 2022). Loneliness can entail social, emotional, and existential aspects (Bolmsjö et al., 2019). Theoretically, both relational and collective restoration experiences alleviate loneliness, which can consequently lead to better mental health (Astell-Burt et al., 2022b).

Supporting the idea that social restoration processes take place in green areas, Hammoud et al. (2021) found that momentary feelings of loneliness tend to be less common when visiting green spaces and other natural areas as opposed to densely populated or overcrowded locations. Evidence on the population level has supported this finding by showing that loneliness is less common in greener neighbourhoods (Astell-Burt et al., 2022c; Maas et al., 2009; van den Berg et al., 2019)). What is more, recent longitudinal evidence suggests that the protective effect of green space on loneliness may be particularly pronounced among people living alone (Astell-Burt et al., 2022a).

However, empirical studies assessing relational and collective restoration are relatively scarce, and mainly rely on small experimental or geographically restricted samples (Astell-Burt et al., 2022b). Furthermore, studies have rarely accounted for household composition (Astell-Burt et al., 2022b), although people living alone tend to live in more urbanised areas, at least in Europe (Eurostat, 2022a), and experience social isolation more commonly than those who do not live alone (Hawkley et al., 2022; Perissinotto and Covinsky, 2014). Regarding different household compositions, having a stable intimate partner, often defined by being married or cohabiting, has been identified as a one of the factors that are consistently associated with better mental health (Dolan et al., 2008).

Despite the results showing that living alone is, on average, associated with a lower level of mental health (Joutsenniemi et al., 2006), people living alone have shown high heterogeneity in terms of perceived mental and general health (Pasanen et al., 2021). Some of these health disparities among people living alone can be explained by socio-demographic factors such as gender and age, with male gender (Joutsenniemi et al., 2006; Lindström and Rosvall, 2019) and mid-adulthood typically associated with worse health status (Henning-Smith and Gonzales, 2020). Similarly, there are large cross-national variations in not only the prevalence of living alone (Eurostat, 2022b) and mental health symptoms (OECD, 2021), but also urban green space availability (Kabisch et al., 2016) and associated nature-based recreation patterns (White et al., 2021). Hence the way these factors are connected might also vary by geographical location.

The present study aimed to address these research gaps in the topic of social restoration processes (i.e. small sample sizes, lack of geographical variation, and no information on household composition or visits to

green space), and examine the potential mediating role of social restoration processes in the mental health-green space association. With harmonised samples from 18 countries/territories around the world (including 14 in Europe), we assessed the following three research questions:

1) For people living alone in urban areas, is the relationship between exposure to green space and mental health mediated by relationship satisfaction (suggestive of relational restoration), and community satisfaction (suggestive of collective restoration)?
2) Are these mediation pathways different for people who live with a partner?
3) Are these mediation pathways different among subgroups of people living alone (based on gender, age, financial strain, and geographical location)?

Furthermore, we considered both neighbourhood green space and visits to green space, with the assumption that greater coverage of residential greenery is associated with more visits, but visits are required to experience relational and collective restoration (illustrated in Fig. 1). These patterns were assessed with path modelling, suitable for assessing complex interconnected relationships and specifically recommended to be used in the assessment of mechanisms linking green space and health (Dzhambov et al., 2020; Markevych et al., 2017).

2. Materials and methods

2.1. Dataset

The cross-sectional BlueHealth International Survey was collected in four waves, covering all seasons, during 2017–2018, from 18 different countries/territories: Queensland (Australia), Bulgaria, California (USA), Canada, Czech Republic, Estonia, Finland, France, Germany, Greece, Hong Kong (China), Ireland, Italy, Netherlands, Portugal, UK, Spain, and Sweden. YouGov collected the data using online participant panels in each country/territory and ensured representative quota samples from each country/territory, typically based on gender, age and geographical region, across the four seasonal waves. Recruitment emails were sent gradually throughout the data collection period, until approximately 250 responses per wave/country were obtained. More details on the data collection procedure are documented in Elliott and White (2020).

To link the responses with area-level geospatial information, the respondents were asked to identify their current home location by placing a pin on a Google Maps API. The coordinates of the home locations were subsequently rounded to three decimal degrees to minimise the risk of individual identification while maintaining good precision. Exact details on the survey procedure are provided in the technical report (Elliott and White, 2020).

The original sample consisted of 18 838 cases. After excluding potentially inattentive respondents ("straightliners", n = 202) and possibly unreliable home locations (n = 1186; Elliott and White, 2020), we restricted the sample to those living in urban areas, defined as living within a 1 km^2 grid cell that had a population density of >150 inhabitants (Dijkstra and Poelman, 2014; Elliott and White, 2020). The urban sample consisted of n = 11 390 cases, of whom n = 8460 were included in the main analyses based on their living alone status (that is, n = 2549 cases who live with people other than their partner excluded; see the next section). Sensitivity analysis was run with a higher population density cut-off at >300 inhabitants to identify the sample living in more densely populated areas (Dijkstra and Poelman, 2014). The measure for population density was obtained from Gridded Population of the World (Version 4), adjusted to match the 2015 Revision of the United Nation's World Population Prospects country-level totals (Center for International Earth Science Information Network, 2017).

The survey procedure conformed to the ethical principles of the Declaration of Helsinki, and was approved by the University of Exeter Medical School Research Ethics Committee (Ref: Aug16/B/099).

2.2. Measures

2.2.1. Living alone versus with a partner (main effect modifier)

Household type was based on both household size and marital status. *Living alone* was defined as a household size of one person and not being married/cohabiting/in common law marriage by marital status. *Living with a partner* was defined as a household size of two or more people and being married/cohabiting/in common-law partnership by marital status (thus, these households may or may not have included children). Those who chose 'prefer not to say' for their marital status were excluded.

Respondents *living with people other than their partner*, that is, whose household size was two or more and who were single/divorced/widowed/other by their marital status, were expectedly heterogenous group potentially containing e.g. single parents and adults living with roommates or their aging parents, but who nevertheless likely lack continuous presence of a stable partner. Accordingly, to ease interpretation of the results, our primary interest was in the potential differences between the groups 'living alone' and 'living with a partner', and we provide the main models for the 'living with other people' group as an online appendix (Figure A1).

2.2.2. Mental health (outcomes)

Reflecting the dual continuum model of mental health (Iasiello and van Agteren, 2020), we used indicators of both positive and negative mental health. *Mental well-being* (i.e. positive mental health) was measured with the World Health Organisation (WHO) 5-item mental well-being scale (WHO-5) which asks about how the respondent has felt over the last two weeks. Each item is positively phrased and rated on a scale from 0 "At no time" to 5 "All of the time". According to conventions, the responses were summed and scaled to range between 0 and 100. The scale is widely used internationally and has good psychometric properties (Topp et al., 2015). The Cronbach's alpha reliability of the scale was 0.92.

An indicator of negative mental health, the use of *anxiety or depression medication* was assessed with the European Health Interview Survey (Eurostat, 2013) question "During the past two weeks, have you used any medicines for any of the following conditions that were prescribed

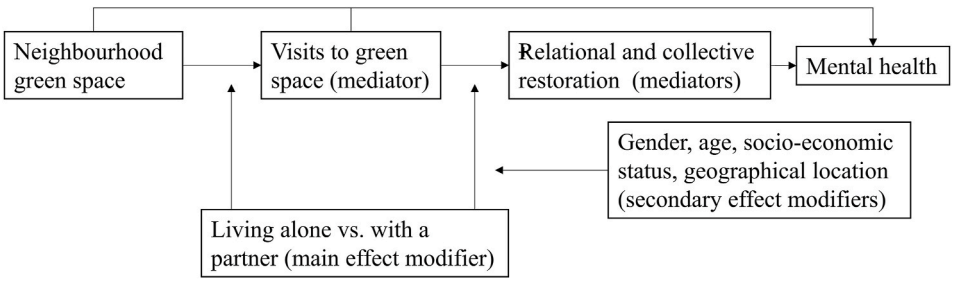

Fig. 1. Theoretical model linking exposure to green space to mental health via social restoration processes.

for you by a doctor?" (Yes or No). We merged the responses to the options "Depression" and "Tension or anxiety" into a binary variable indicating whether or not the respondent had been prescribed either (or both).

2.2.3. Green space – residential (exposure) and visits (mediator)

Neighbourhood green space coverage (%), a continuous measure, was obtained from Global Land Cover 30 dataset (Jun et al., 2014), a 30 m-resolution raster dataset based on Landsat and Landsat-like image data that was based on landcover in 2010 (Elliott and White, 2020). The types of green space included were cultivated land, forest, shrubland, and grassland. In our main analyses we used a 1 km buffer zone calculated from each respondent residential location in line with previous evidence on a similar topic -showing stronger associations between green space and loneliness-in larger buffer sizes (Astell-Burt et al., 2022a). To check if the results are sensitive to the choice of neighbourhood green space metric, we ran additional sensitivity models with the following green space indicators: a) a 300-m buffer, b) green land cover categorised into 0%, >0–25%, and >25%; and c) Normalised Difference Vegetation Index (NDVI) at 1000 m resolution (Didan, 2015). The NDVI data was obtained from MODIS Terra satellite imagery from the data collection period (June 1st, 2017 to March 31, 2018), using the product "MOD13A3 vegetation indices monthly L3 global 1 km". A home geocode was assigned an NDVI value of the 1 km pixel it fell in; this was the average of the best available images of that pixel from across the study period to reduce seasonal biases. The finest 30 m resolution was not feasible due to issues with computational power in this global dataset. Image quality evaluation was based on pixel reliability rank, in which the highest quality was not available for 1055 residential locations in this sample (Elliott and White, 2020), and hence the sample was smaller in this model.

The number of green space visits was calculated as the total number of reported visits to 12 different types of green space categories in the past four weeks (e.g. large urban parks, woodlands, allotments etc.), following the procedure in White et al. (2021). To reflect the same time frame as the outcome (i.e., last two weeks), this was divided by two. Furthermore, these visits were capped at 28 which is equivalent of visiting green space twice a day over a two-week period (White et al., 2021).

2.2.4. Social restoration processes (mediators)

Relational and collective restoration were approximated using two questions from the Personal Well-being Index scale (PWI) (Cummins et al., 2003). Respondents were asked how satisfied they were with: 'your personal relationships' (indicative of relational restoration processes), and 'feeling part of your community' (indicative of collective restoration processes), both rated on a scale from 0 "not at all satisfied" to 10 "completely satisfied".

2.2.5. Gender, age, financial strain, geographical location (secondary effect modifiers)

Among urban respondents living alone, further subgroups were formed based on *gender* (male or female), *age group* (18–39; 40–59; 60+; approximating young, mid- and late adulthood), perceived *financial strain* (i.e. coping with present income – grouped into 'coping/living comfortably'; 'finding it difficult/very difficult', 'don't know' responses excluded) and *geographical location*. For this, the countries/territories were grouped based on similar latitude, climatic conditions and the amount of daylight: Finland, Sweden, Estonia and Canada were in the 'North' group; Spain, Italy, Greece, Portugal, California (US), and Queensland (Australia) were in the 'South' group; and Bulgaria, Czech Republic, France, Germany, Ireland, Netherlands, and UK in the 'Middle' group. We excluded Hong Kong from this comparison due to difficulties in identifying an appropriate grouping and because the sample living alone there was very small (n = 23). While recognising the limitations of grouping countries with approximations based on latitude, climatic conditions and the amount of daylight, these factors can affect the frequency, type, and quality of visits to green space (e.g. Gatti et al., 2022).

2.2.6. Covariates

A range of covariates were included to control for their potential confounding effect on green space visits, social restoration processes and/or mental health. Of these, some variables were also specified as secondary effect modifiers (in previous subsection); these were included in the main analyses as covariates.

Gender (binary measure; male or female) and *age* (asked in 10-year categories: 18–29, 30–39, 40–49, 50–59, and 60+) can affect not only green space visit frequency (Pyky et al., 2019), but also social and mental health (Barreto et al., 2021; Dolan et al., 2008; Hawkley et al., 2022).

Indicators of socio-economic status, known to associate with social isolation and loneliness (Kung et al., 2022), green space exposure and mental well-being more generally (Dolan et al., 2008) included *employment status* (grouped into employed; unemployed; in education; at-home carer; retired; other), highest level of obtained *education* (primary or lower; secondary; tertiary), and perceived *financial strain* (coping/living comfortably; finding it difficult/very difficult; don't know).

Whether one has a *long-term illness or disability* that hampers one's daily activities was asked using a single question, recoded into a binary measure indicating absence or presence, at least to some extent, of such an illness. Due to its potential overlap with anxiety/depression medication use, we ran a sensitivity model without this covariate. To control for the effects of physical activity on mental health and the potential confounding effects of green space visits (Pyky et al., 2019), we included a measure on days of conducting *physical activity* in the past week (range 0–7).

Car and *dog ownership* were both binary yes/no measures that have previously been associated with green space visits (Boyd et al., 2018; Pyky et al., 2019). *Season* might affect outdoor recreation patterns and mental health (as hypothesised by collective restoration theory) and accordingly, this was included as a covariate (spring, summer, autumn, or winter; with inverse coding for Australian respondents).

Finally, all analyses controlled for *population density* (Center for International Earth Science Information Network, 2017) to control for its potential effects on social restoration processes (although the evidence on density and loneliness has been mixed; Bower et al., 2023). Approximately 2.5% of the density values were unreliably large, most likely due to densely built coastal locations with only a small land cover in the grid cell (Center for International Earth Science Information Network, 2017), and these were capped at 23 870, which was comparable to the world's most densely populated area Macau (with 21 055 inhabitants/km^2; The World Bank, 2022). Furthermore, due to considerable between-country differences in population density, we standardised the capped population density by country/territory in the analyses so that it reflects relative density within the geographical/cultural context. We also ran a sensitivity model with the unstandardised measure to assess whether this biased our results.

2.3. Analytical strategy

2.3.1. Descriptive analyses

Prior to the main path models, we descriptively compared the bivariate relationships between the samples living alone and living with a partner in terms of all key variables in the analyses. For continuous variables, we calculated means and their 95% confidence intervals (CI), and the categorical variables were compared with cross-tabulations. All bivariate assessments were weighted according to the sex, age, and region (Elliott and White, 2020), using the package 'svyr' (Freedman Ellis, Lumley, Żółtak, Schneider and Krivitsky, 2022) in R version 4.0.4 (R Core Team, 2021). To detect potential multicollinearity of the

covariates, we checked the scaled generalised variance inflated factors in R package 'car' (Fox and Weisberg, 2019), suitable for both continuous and categorical variables (Fox and Monette, 1992), with values below 2.5 considered acceptable (Johnston et al., 2018).

2.3.2. Main models with effect modification by living alone versus with a partner

To investigate the associations between residential green space and mental health among people living alone via the potential serial mediation of green space visits and social restoration processes (RQ1) and to compare these processes to respondents living with a partner (RQ2), we specified a multigroup path model using Mplus version 8.7 (Muthén and Muthén, 2017). The multigroup modelling approach is a more flexible analysis method than stratification, because within it, any parts of the model can be either estimated freely in each group or constrained to equal, and the resulting difference in overall model fit can be likewise tested using the Wald's test (Muthén and Muthén, 2017).

The main models, depicted in Fig. 1, contained serial mediation pathways from neighbourhood green space coverage to mental health via the number of visits to green space and both relationship and community satisfaction. The residual terms of relationship and community satisfaction were allowed to correlate in all models. We did not include the direct paths from neighbourhood green space to relationship and community satisfaction to avoid creating a fully saturated model and because relevant theories suggest that the potential social benefits of green space exposure operate through actual contact with green space (Markevych et al., 2017). Yet, due to some earlier work suggesting a positive effect of mere visual views of nature (Velarde et al., 2007) which might not need an actual visit to a green area, we specified a sensitivity model including direct paths from neighbourhood green space to relationship and community satisfaction.

Because the two mental health outcomes were measured on different scales, they had to be assessed in separate models using different technical specifications. For mental well-being, a continuous measure, the multigroup structure was specified with the 'grouping' option in Mplus. For anxiety/depression medication use, a binary measure, to correctly estimate the odds ratios for the exponentiated indirect effects and associated bootstrapped confidence intervals, the 'knownclass' option was used (Muthén and Muthén, 2017). The mediators were modelled as 'continuous' due to them having at least 11-point-scales, which is generally more than enough to use parametric methods (Norman, 2010). Indirect effects were calculated with the product-of-coefficient approach with confidence intervals based on bootstrapped sampling.

All path estimates were calculated separately for both groups (living alone/living with a partner). Whether there was a difference in the indirect effects from neighbourhood green space or visits to green space to mental health outcomes was assessed qualitatively (by looking at the strength and direction) and quantitatively with the Wald's test. In case the Wald's test indicated a difference in the total indirect effects (based on the χ^2 value with $p < 0.05$), pairwise comparisons for the specific indirect effects were calculated to identify the effects that differed and their direction. All models were estimated with the maximum likelihood estimator with robust standard errors (MLR). MLR does not assume normally distributed observed variables, which was appropriate here due to non-normally distributed mediators (social restoration mediators were skewed to the left and green space visits to the right, with a floor effect at 0).

The covariates were selected a priori based on those identified as being important in earlier literature and availability of relevant items in the dataset (Section 2.1.6). To fully adjust for potential confounding, all paths from the covariates to all mediators and mental health outcomes were estimated. One of the one covariates, days of physical activity, was identified as potentially being in the effect pathway between green space visits and mental health (e.g. Markevych et al., 2017), and hence we tested an additional model excluding it to assess whether controlling for it affected our results on the social restoration processes.

The significance of indirect effects (n.b. the word "effect" is common terminology in mediation modelling, and it does not mean a causal effect here or elsewhere in this paper) and their pairwise comparisons were based on 95% bias-corrected bootstrapped confidence intervals with 500 draws. Model fit was evaluated with the χ^2 test, correlation residuals (residuals $>|0.10|$ considered large; Kline, 2016), and the following fit indices/criteria available in MLR estimation: Root Mean Square Error of Approximation (RMSEA) $< 0.05/0.08$; Comparative Fit Index (CFI) $< 0.90/0.95$; Tucker-Lewis Fit Index (TLI) $< 0.90/0.95$; and Standardised Root Mean Squared Residual (SRMR) < 0.08 (Browne and Cudeck, 1992; Hu and Bentler, 1999; Yu, 2002). In the models with the binary outcomes, however, the only available information on model fit was pseudo R^2 (calculated with the McKelvey-Zavoina methodology) and different information criteria which do not measure actual model fit.

Due to the 18-country/territory structure of the data, country was initially controlled for in two different ways: by adding countries as dummy-coded explanatory variables (similar to Tester-Jones et al., 2020) and by specifying a multilevel structure, based on country, with random intercepts for all mediators and the outcome (similar to White et al., 2021). These two approaches yielded almost identical estimates for our key pathways. Nevertheless, we report results using the dummy-coding method (with Spain as the reference as having the highest average mental well-being; White et al., 2021) due to a warning in the multilevel model about the number of model parameters exceeding the number of clusters, and hence potentially unreliable standard errors for some variables. Addressing this warning would have required post-hoc adjustments in the model and/or measures.

2.3.3. Secondary models with effect modification by gender, age, financial strain, and geographical location among respondents living alone

The models for subgroups among people living alone (RQ 3) were based on the secondary effect modifiers. These models were only estimated for mental well-being due to the smaller sample sizes in the subgroups and concerns with statistical power with medication use, a binary measure, as the outcome. Models with binary outcomes generally require larger samples than those with continuous outcomes (Jiang, 2022), and considering that no comprehensive information on model fit was available using multigroup mediation modelling with a binary outcome, we refrained from testing the secondary effect modification models for depression/anxiety mediation use. In the model stratified for age, we recoded the employment status into a binary measure (employed or not employed) due few cases with some combinations using the original categories (e.g. very few retired respondents among the 20-39-year-olds).

3. Results

3.1. Bivariate relationships between the study variables and living alone versus with a partner

The samples living alone and those living with a partner showed different patterns in most of the socio-demographic covariates (Table 1). For example, respondents living alone had higher proportions in the youngest (16.5% versus 10.4%) and oldest (33.5% versus 26.9%) age groups, slightly more females (51.5% versus 47.8%), and more issues with financial strain (33.0% versus 18.6%) than those living with a partner (Table 1). Differences between the countries in the proportion of respondents living alone were also notable (Table 1). No multicollinearity in the covariates (including neighbourhood green space) was detected in either sample (online appendix Tables A1 and A.2).

In terms of the key variables in this study, people living alone had consistently lower levels of mental wellbeing (55.96 versus 61.21; Table 2), higher prevalence of anxiety/depression medication use (16.9% versus 12.3%; Table 1), and they were less satisfied with their relationships (6.18 versus 7.63) and communities (6.29 versus 6.73) compared with those living with a partner (Table 2). Moreover, they had

Table 1
Bivariate relationships and χ^2 test values between categorical study variables and cohabitation status (living alone versus living with a partner).

		Living alone		Living with a partner	
Variable	Category	n	%	n	%
Anxiety/depression medication use ($\chi^2 = 34.7$, df = 1, p < 0.001)	No	1724	83.1	5602	87.7
	Yes	351	16.9	784	12.3
Gender ($\chi^2 = 10.8$, df = 1, p = 0.001)	Female	1069	51.5	3050	47.8
	Male	1006	48.5	3335	52.2
Age ($\chi^2 = 116.8$, df = 4, p < 0.001)	18–29	343	16.5	663	10.4
	30–39	322	15.5	1322	20.7
	40–49	340	16.4	1409	22.1
	50–59	376	18.1	1275	20.0
	60+	695	33.5	1717	26.9
Employment status ($\chi^2 = 325$, df = 5, p < 0.001)	Employed	1039	50.0	3935	61.6
	Unemployed	313	15.1	464	7.3
	In education	114	5.5	141	2.2
	Carer	24	1.1	480	7.5
	Retired	505	24.3	1185	18.6
	Other	81	3.9	178	2.8
Highest obtained education ($\chi^2 = 37.1$, df = 2, p < 0.001)	Primary or lower	245	11.8	462	7.2
	Secondary	774	37.3	2455	38.5
	Tertiary	1057	50.9	3468	54.3
Perceived financial strain ($\chi^2 = 210.8$, df = 2, p < 0.001)	Coping	1363	65.7	5168	80.9
	Finding it difficult	685	33.0	1189	18.6
	Don't know	27	1.3	28	0.4
Long-standing illness or disability ($\chi^2 = 136.6$, df = 1, p < 0.001)	No	1174	56.6	4317	67.6
	Yes	901	43.4	2068	32.4
Dog ownership ($\chi^2 = 136.6$, df = 1, p < 0.001)	No	1735	83.6	4485	70.3
	Yes	340	16.4	1900	29.8
Car ownership ($\chi^2 = 706.8$, df = 1, p < 0.001)	No	756	36.4	694	10.9
	Yes	1319	63.6	5688	89.1
Survey season ($\chi^2 = 2.8$, df = 3, p = 0.425)	Spring	515	24.8	1607	25.2
	Summer	454	21.9	1327	20.8
	Autumn	524	25.2	1699	26.6
	Winter	583	28.1	1752	27.4
Country of residence[a] ($\chi^2 = 392.6$, df = 17, p < 0.001)	Australia	73	21.7	265	78.3
	Bulgaria	62	16.9	307	83.1
	California	129	31.9	276	68.1
	Canada	114	32.2	240	67.8
	Czech Republic	100	21.7	363	78.3
	Estonia	111	27.1	298	72.9
	Finland	147	42.4	200	57.6
	France	164	29.8	387	70.2
	Germany	233	40.9	336	59.1
	Greece	101	22.5	347	77.5
	Hong Kong	23	5.8	371	94.3
	Ireland	72	16.2	371	83.8
	Italy	68	14.2	413	85.8
	Netherlands	243	30.8	545	69.2
	Portugal	64	14.8	371	85.3
	Spain	47	10.0	420	90.0
	Sweden	143	31.7	308	68.3
	United Kingdom	180	24.1	568	75.9

[a] Row-wise proportions.

less neighbourhood green space (24.2% versus 30.4%) within 1 km from home and they made almost two fewer visits to green spaces over the last two weeks compared to those living with a partner (Table 2). People living alone tended to live in areas with greater population density (0.46 vs 0.23 in the standardised metric), but engaged in physical activity on as many days as those living with a partner (2.34 and 2.40). Mean differences in the alternative continuous explanatory variables used in sensitivity analyses are provided in online appendix Table A.3.

Table 2
Bivariate relationship between continuous study variables and cohabitation status.

Variable	Living alone		Living with a partner		
	n	Mean [95% CI]	n	Mean [95% CI]	*t*-test[a] for the mean difference
Mental well-being (WHO-5, 0–100)	2075	55.96 [54.97; 56.95]	6377	61.21 [60.68; 61.75]	t = 9.3, df = 3328,p < 0.001
Green space (%) within 1 km from home	2044	24.18 [22.89; 25.47]	6217	30.41 [29.61; 31.21]	t = 8, df = 3731,p < 0.001
Visits to green space in the past two weeks	2075	4.07 [3.86; 4.29]	6367	5.93 [5.77; 6.08]	t = 13.7, df = 4294,p < 0.001
Relationship satisfaction (0–10)	2075	6.18 [6.07; 6.28]	6385	7.63 [7.59; 7.68]	t = 25.1, df = 3003,p < 0.001
Community satisfaction (0–10)	2075	6.29 [6.19; 6.39]	6385	6.73 [6.68; 6.78]	t = 8, df = 3276,p < 0.001
Standardised population density (by country)	2075	0.46 [0.41; 0.51]	6385	0.23 [0.21; 0.26]	t = −7.9, df = 3323,p < 0.001
Days of physical activity (0–7)	2075	2.34 [2.24; 2.44]	6383	2.40 [2.35; 2.46]	t = 1.1, df = 3479,p = 0.287

[a] Welch test, not assuming equal variances.

3.2. RQ1: Mediation from green space exposure to mental health via social restoration processes among respondents living alone

3.2.1. Mental well-being

The main model for mental well-being as the outcome showed good fit with the data in all available fit indices ($\chi^2 = 5.3$, df = 4, $p = 0.285$, RMSEA = 0.008, CFI = 1.00, TLI = 0.99) and all its correlation residuals were small (maximum absolute value 0.026).

Among respondents living alone (n = 2062), neighbourhood green space coverage within 1 km from home location was not associated with visits to green space, and accordingly it showed no indirect effects on mental well-being (Fig. 2). Instead, each additional visit to a greenspace in the last two weeks was positively associated with both relationship (b = 0.04) and community satisfaction (b = 0.06; Fig. 2), and via these, indirectly with 0.08 and 0.11 greater evaluation of mental well-being, respectively (Fig. 3; Appendix Table A.4). These resulted in a total indirect effect of 0.19, holding all covariates constant (Fig. 3). In addition to the indirect pathways via relationship and community satisfaction, each bi-weekly visit to green space was also directly associated with a 0.54-point increase in mental well-being.

The relationships between all covariates and mediators and both mental health outcomes are provided as online supplementary material (Appendix Tables A.5 and A.6).

3.2.2. Anxiety/depression mediation use

In the model for anxiety/depression medication use, a similar pattern, although less consistent, to the model for mental well-being was seen. The path estimates between neighbourhood green space, number of visits to green space, and relationship and community satisfaction were very close to those in the model for mental well-being (online appendix Figure A2). Moreover, each additional visit to a greenspace in the last two weeks was associated indirectly, via greater relationship satisfaction, with lower odds of anxiety/depression medication use (OR = .996 [0.992; 0.999]; Fig. 4). The indirect association via community satisfaction was non-significant although in the same direction (OR = 0.997 [0.993; 1.003]). Together these constituted a total indirect effect of 0.994 (Fig. 4; online appendix Table A4). Controlling for these

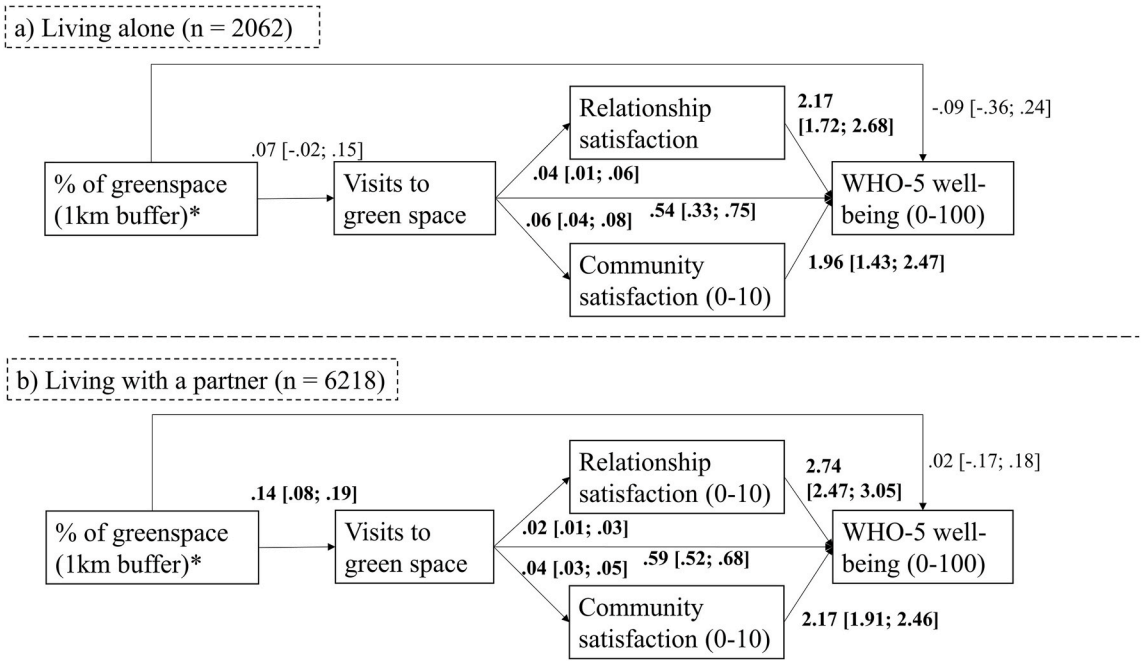

Fig. 2. Estimated models for mental well-being among (a) the sample living alone and (b) those living with a partner. All mediators and outcomes control for population density, gender, age, education, employment status, financial strain, long-standing illness, physical activity, car ownership, dog ownership, country of residence, and season/survey wave. The residuals between relationship and community satisfaction were allowed to correlate but this estimate is not shown for clarity (*Divided by 10 so that a 1-unit increase corresponds to 10% net increase in neighbourhood green space).

indirect effects, the direct effect of visits to green space on anxiety/depression medication was exactly 1.000, indicating no association in either direction.

The pseudo R^2, calculated with the McKelvey-Zavoina methodology, suggested significant variance explained (0.33, online appendix Table A.5).

3.3. RQ2: Mediation from green space exposure to mental health via social restoration processes among respondents living with a partner

3.3.1. Mental well-being

Among respondents living with a partner, the pathways from green space visits to mental health via social restoration mediators showed a similar pattern to those living alone (Fig. 2). In addition, neighbourhood green space was associated with visiting green space in this group: for each ten percent unit increase in green space within 1 km from home, the respondents made .14 [0.08; 0.19] more visits to green space over a two-week period. Furthermore, neighbourhood green space showed a total indirect effect, via visits to green space and both social mediators, of 0.10 [0.06; 0.14] points in mental well-being (Fig. 3). However, the Wald's test indicated no significant difference in total indirect effects between these groups for either neighbourhood green space ($\chi^2 = 0.95$, df = 2, $p = 0.62$) or green space visits ($\chi^2 = 1.78$, df = 2, $p = 0.41$).

3.3.2. Anxiety/depression mediation use

As for anxiety/depression medication use among respondents living with a partner, the indirect effect of one additional visit to a greenspace in the last two weeks via relationship satisfaction was .999 [0.997–1.000] and via community satisfaction 0.997 [0.995; 0.999], which summed to a total indirect effect of 0.996 [0.993; 0.998] (Fig. 4, online appendix Table A4). Controlling for these indirect effects, visiting green space was not directly associated with the odds of taking anxiety/depression medication (OR = 1.01). Similar to mental well-being, neither the indirect effects from neighbourhood green space ($\chi^2 = 1.23$, df = 2, $p = 0.54$) nor from green space visits ($\chi^2 = 1.33$, df = 2, $p = 0.51$) significantly differed from the respondents living alone.

3.4. RQ3: Mediation from green space exposure to mental well-being among subgroups of respondents living alone

3.4.1. Grouping based on gender

Among both males and females living alone, all the indirect associations (via relationship and community satisfaction, as well as their combined indirect effects) from the number of visits to green space on mental well-being were positive (Fig. 3). Additionally, among males also all indirect effects from neighbourhood green space to mental well-being were positive. The Wald's tests comparing the effects for males and females indicated, however, only marginal differences in the indirect effects from both neighbourhood green space ($\chi^2 = 5.10$, df = 2, $p = 0.08$) and green space visits ($\chi^2 = 5.80$, df = 2, $p = 0.06$).

3.4.2. Grouping based on age

Among respondents aged 60 and over, the only indirect effect that differed from 0 was the one from the number of visits to green space to mental well-being via satisfaction with community, whereas in both younger age groups, all indirect effects from the number of visits to green space (yet none from neighbourhood green space) were positive (Fig. 3). However, the Wald's test comparing the indirect effects across age were not significant for either neighbourhood green space ($\chi^2 = 1.60$, df = 4, $p = 0.81$) or for visits to green space ($\chi^2 = 7.69$, df = 4, $p = 0.10$).

3.4.3. Grouping based on perceived financial strain

In either group, none of the indirect effects from neighbourhood green space to mental well-being differed from 0 (Fig. 3). Among those who were coping or finding it comfortable with their current income, all indirect pathways from visits to green space to mental well-being were positive, whereas among those who found it difficult or very difficult, only the indirect effect from the number of visits to green space on mental well-being via community satisfaction was positive. The Wald's test comparing the indirect effects across financial strain groups was, again, not significant for either neighbourhood green space ($\chi^2 = 1.21$, df = 2, $p = 0.55$) or for visits to green space ($\chi^2 = 5.37$, df = 2, $p = 0.07$).

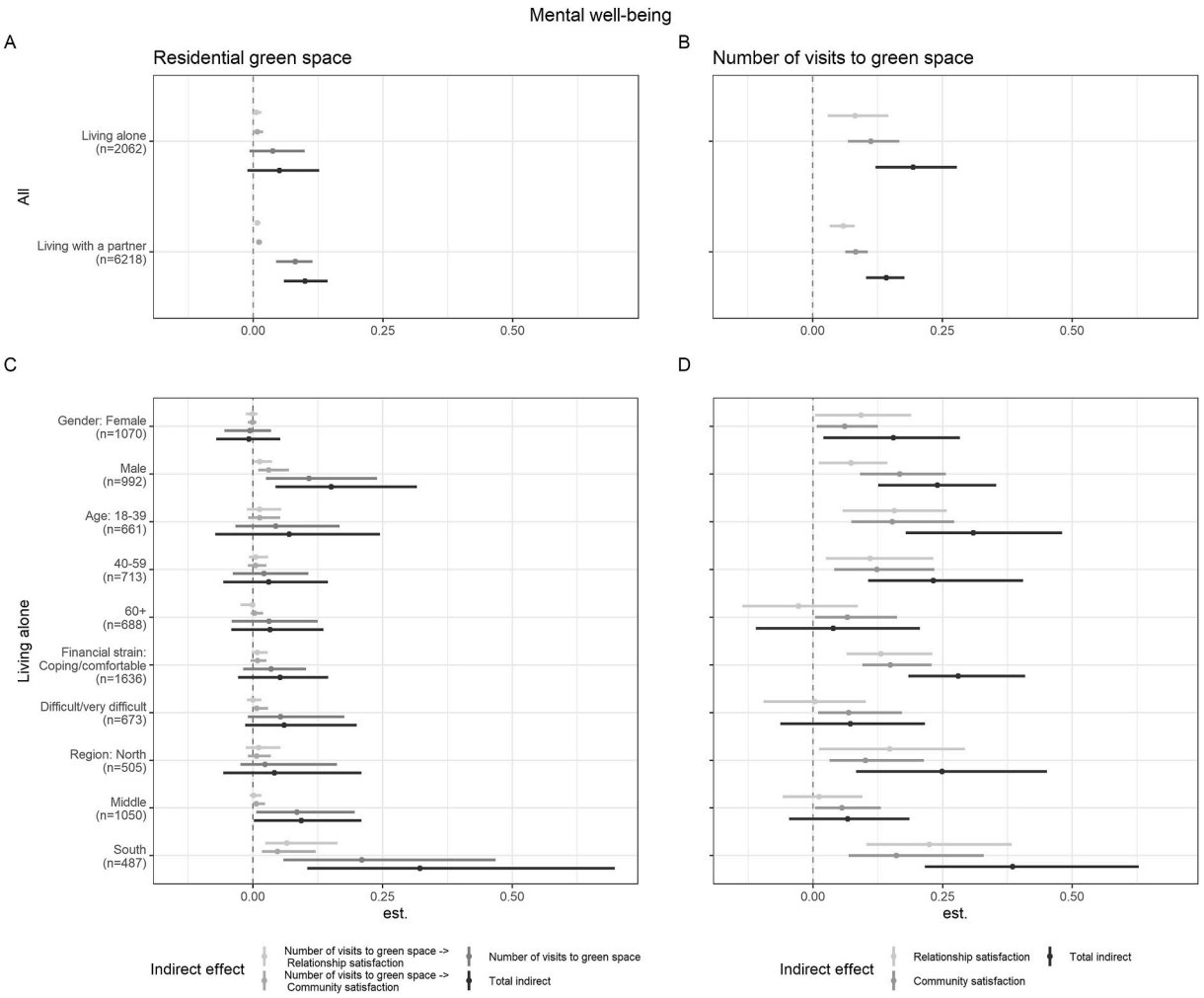

Fig. 3. Indirect effects from neighbourhood green space (A and C) and green space visits (B and D) to mental well-being among urban respondents living alone and with a partner (A and B) and subgroups among respondents living alone (C and D).

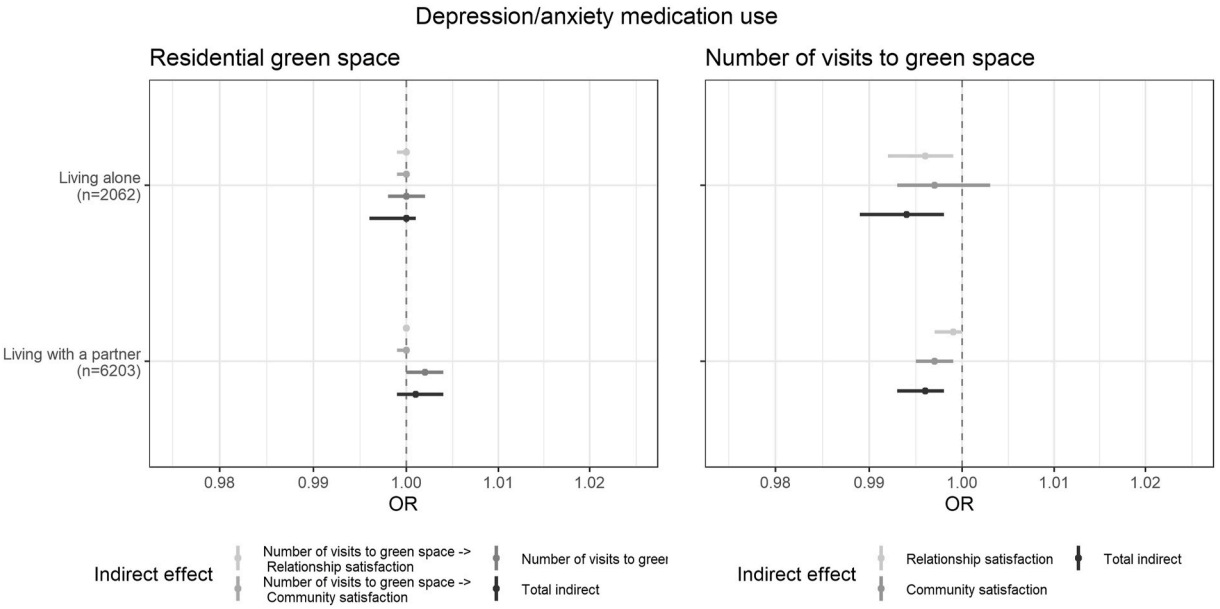

Fig. 4. Indirect effects from neighbourhood green space (left) and green space visits (right) to anxiety/depression medication use among urban respondents living alone and those living with a partner.

3.4.4. Grouping based on geographical region

In the northern countries, indirect effects from the number of visits to green space to mental well-being via both relationship and community satisfaction, as well as their combined effect, were positive (Fig. 3), whereas in the middle-latitude countries only the effect from green space visits via community satisfaction was positive and different from 0. Among respondents in the South group, instead, all indirect pathways from both neighbourhood green space and green space visits were positive (Fig. 3). The Wald's test did not indicate a difference in the indirect effects from neighbourhood green space to mental well-being ($\chi^2 = 5.85$, df = 4, $p = 0.21$), but there was a difference in the effect of green space visits ($\chi^2 = 10.25$, df = 4, $p = 0.04$). Specifically, the effect of green space visits on mental well-being via relationship satisfaction was stronger in the southern compared with the middle-latitude countries (difference −.21, 95% bootstrapped CI [-0.41; −0.06]).

3.5. Sensitivity models

There was no essential difference in the main findings for mental well-being in the models using a) the >300 population density per 1 km^2 threshold to identify residence in densely populated urban areas (n = 7418; of whom 1889 lived alone and 5529 with a partner); b) a categorised measure for neighbourhood green space (1 km buffer); c) the unstandardised measure for population density; and d) model with paths from neighbourhood green space to relationship and community satisfaction. In this last model, these paths were close to 0 (on relationship satisfaction: b = -0.02, 95% CI [-0.07; 0.01] for those living alone and b = -0.01 [-0.04; 0.001] for those living with a partner; on community satisfaction: b = -0.03, 95% CI [-0.07; 0.01] for those living alone and b = -0.002 [-0.02; 0.02] for those living with a partner) and their inclusion had no effect in the key results.

In the sensitivity models with green space measured with a 300 m buffer and the 1 km NDVI buffer, neighbourhood green space was positively associated with visits to green space also among people living alone (b = 0.07, 95% CI [0.001, 0.15] for the 300 m buffer and b = 1.93, 95% CI [0.50; 3.28] for NDVI with 1 km buffer; online appendix Figure A3); and consequently indirectly with mental well-being via visits to green space and the social restoration mediators (e.g. total indirect effects 0.054 [0.004; 0.117] for the 300 m buffer and 1.34 [0.37; 2.74] for NDVI with 1 km buffer).

In the sensitivity model for anxiety/depression medication use excluding long-term illness as a covariate, the ORs for indirect effects from green space visits were in the same direction and marginally (by a third decimal place) lower both among people living alone (e.g. total indirect effect OR = 0.992 [0.987; 0.997]) and those living with a partner (OR = 0.995 [0.992; 0.997]). Contrary to the other models, among respondents living with a partner, visits to green space were, directly associated with higher odds of anxiety/depression medication use (OR 1.02 [1.01; 1.04]).

Finally, excluding days of physical activity (as a covariate) from the models lead to larger path estimates between visits to green space and mental well-being (living alone: 0.54 -> 0.70, living with a partner: 0.59 -> 0.69) but it had no effect on the indirect pathways testing social restoration processes. For anxiety/depression medication use, exclusion of physical activity did not affect the main results.

4. Discussion

4.1. Main findings

We found support for the idea that for people living alone in urban areas (as well as those living with a partner), recreational visits to green spaces were associated with better mental health via two related yet distinct pathways, relationship and community satisfaction, which may reflect relational and collective restoration processes, respectively (Hartig, 2021). The indirect association between just one green space visit over a two-week period and mental well-being was positive (0.19 on the 0–100 scale) and also detectable, although likewise very small (OR 0.994), for anxiety/depression medication use. The role of neighbourhood green space, on the other hand, was more mixed and sensitive to the choice of metric and buffer size.

Although, in line with expectations, people living alone had consistently less neighbourhood green space and they visited green spaces less often than those living with a partner (Boyd et al., 2018), contrary to predictions, there was no difference in the strength of the indirect associations with either metric of nature exposure and mental health between these two groups. Further subgroup comparisons within the living alone group showed few differences in the total indirect effects within people living alone based on gender, age, financial strain, and geographical location. Nevertheless, the indirect associations between neighbourhood green space and mental well-being were positive for males but not females, and residents of warmer climatic conditions but not in colder climates. More visits to green spaces were associated with mental well-being via community satisfaction in all subgroups, whereas the indirect pathway via relationship satisfaction varied more.

Our finding that the social restoration processes explaining residential exposure to green space and mental health were similar in strength among people living alone and those living with a partner is in line with Astell-Burt et al. (2022a). Nevertheless, it slightly differs from the results by Astell-Burt et al. (2022c) who found that people living alone benefit more from neighbourhood green space over time. In all these studies, however, green space exposure was associated with social restoration processes among people living alone and those not living alone, although differences in study populations (multi-country versus Australian), designs (cross-sectional versus longitudinal), and measures (mental health versus loneliness/availability of social contacts as the outcome) restrict their direct comparability. It seems, nevertheless, that more research efforts to understand these processes and how they develop over time are needed. For instance, the association between neighbourhood green space and green space visits among people living alone may be worthy of more detailed investigation. Although in our study this association was dependent on the choice of green space metric, it was evident that the coverage of neighbourhood green space was consistently lower in the group living alone. To what extent this poses an additional barrier to visit green space, or demonstrates a deliberate choice (e.g. a lack of interest in visiting green space; Boyd et al., 2018), deserves more detailed investigation.

For respondents living alone, specific subgroups showed some different patterns in the social restoration processes between green space exposure and mental well-being. To begin with, there were indicative gender differences. Having a greater coverage of neighbourhood green space was associated with more green space visits for males, but not for females. One explanation for this finding could be related to safety, which may be a more prevalent concern for females' use of nearby urban green space (Lapham et al., 2016). On the other hand, the observed gender differences might imply that having nearby green space is simply more important for the mental health of males. Although females have generally higher rates of depression and anxiety (World Health Organization, 2017), among people living alone, it is males that more commonly have issues with general and mental health (Joutsenniemi et al., 2006; Lindström and Rosvall, 2019). Therefore, it is possible that urban green space exposure could reduce some of the mental health disparities among people living alone.

Similar explanations might be plausible in explaining the few divergent patterns we found for age, showing that some indirect associations from visits to green space were positive for respondents between aged less than 60 but not those >60 years. Again, concerns with safety tend to be more common in older age (Lapham et al., 2016). Earlier studies have shown a peak in worse perceived health between ages 35–65 in people living alone (Henning-Smith and Gonzales, 2020). Although the age groups in our study were not directly comparable, our results could imply that visits to urban green space can mitigate some of

the adverse health conditions associated with living alone in mid-adulthood.

In terms of financial strain, there was no difference in the social restoration process between neighbourhood green space and mental health but some tentative differences in terms of visits to green space were found. Generally, those with lower socio-economic status have been found to benefit more from neighbourhood green space (Rigolon et al., 2021), but this was not the case among those living alone in this study. Yet, there might have been differences in the quality of neighbourhood green space that also affect the types of use and associated social processes (Astell-Burt et al., 2022b). For example, publicly open green space such as parks have been identified as particularly important for the health of those in lower socio-economic position, partly due to their provision of opportunities for socialising (Rigolon et al., 2021). This reasoning could apply to our study, if those with financial strain visited green areas that were less suitable for their social restoration needs than those with no such strain.

Finally, in terms of subgroup differences, we found some tentative between-country patterns showing the strongest indirect relationships in the southern countries with warmer climates. This might indicate an associated benefit of being able to engage in recreational green space use all year round, supporting Hartig's suggestion that collective restoration through nature-based activities is more likely under better weather conditions (Hartig et al., 2007), or different patterns of use (e.g. spending sedentary time vs. engaging in physical activity). Further, the social environment during outdoor recreation can be more solitary during the cold season in northern locations (Gatti et al., 2022). Our geographical comparisons were, however, exploratory and merit further investigation with larger country-specific samples.

4.2. Limitations

Our study has, nevertheless, several limitations. First, we had no specific information on the quality of green space that could be relevant in terms of relational or collective restoration or frequency of visits to green space. Some types of green spaces (such as allotment gardens) can be particularly conducive to social restoration processes (e.g. alleviating loneliness; Astell-Burt et al., 2022b; van den Berg et al., 2010) but assessing the presence of such locations near respondents' home was not feasible in the current study using secondary data. Nevertheless, our study can serve as a basis for more detailed investigations on green space quality that best foster relational and collective restoration.

Second, although we found that our operationalisations of relational and collective restoration resulted in two significant pathways operating in parallel, supporting the notion that the two processes may be connected but are not identical, we also recognise that these operationalisations were merely the best available proxies included in the BIS survey using two items from an existing well-being scale, the PWI (Cummins et al., 2003). We accept that satisfaction with one's close relationships is not equivalent to relational restoration, although it may in part arise from it. We would, therefore, encourage future studies to investigate and use items deliberatively developed to measure these constructs. For example, according to the theory, collective restoration is more likely to occur when whole communities are restoring from usual demands (Hartig et al., 2013) and ideally it would be measured at a community level (Hartig, 2021). More sophisticated testing of the theories in future will require further scale development and testing.

Third, the measure of anxiety/depression medication use has some limitations, as it says nothing about severity of condition, dosage, or length of use, creating considerable potential variance in responses among users (Tester-Jones et al., 2020).

Fourth, although the model was constructed in the causal order explicitly suggested by the theories (Astell-Burt et al., 2022b), our data were cross-sectional which means any implications of our study are merely correlational. Longitudinal analyses and interventions to promote green space use and community activities (e.g. van den Bogerd et al., 2021) can shed more light on how these social restoration processes develop over time.

Fifth, with respect to recent greenspace visits, we were not able to account for the activities or company during the visits, nor whether the visited locations were near home or further away. This information could have helped to investigate in detail the importance of neighbourhood green space for visit frequency (although previous evidence points to declining number of visits with increasing distance; Ekkel and de Vries, 2017), potential differences in patterns of green space use between people living alone and those living with a partner, and whether specific types of visits are more strongly associated with social restoration processes and mental health than others. Our study was, nevertheless, a first attempt to assess relational and collective restoration in relation to neighbourhood green space and visits to green space, and our results, supporting both theories, encourage more detailed investigations on the types of visits that particularly support social restoration.

Sixth, our categorisation of respondents was based on household size and marital status, which might not reflect actual relationship status of the respondents, nor whether living alone is by one's own choice or not. These factors, in turn, can affect one's restoration needs and how well they can be actualised. For example, we can speculate that the positive indirect effect of visits to green space on mental well-being via relationship satisfaction could partly result from visits by those living alone who are in a relationship and visit green spaces with partners with whom they do not currently live (by choice, or for other reason). Nevertheless, the RRT explicitly states that relational restoration can be experienced in many types of green space visits, including visiting alone (Hartig, 2021).

Finally, although the original samples were representative of each target area for gender, age and regional distributions, our focus here was on the urban respondents and their subcategories. Therefore, the sample used in our analyses might not have equally well represented the respective subpopulations in each country. We encourage replications with larger samples specific to urban areas, and among people living alone. Further, whether these associations differ in residents in rural areas or in terms of blue space exposure was outside the scope of this study but would be worthy of investigation.

4.3. Conclusions

We found that visits to green space were associated with better mental health via greater personal and community satisfaction to a similar degree for people living alone and those living with a partner, offering support for the role of both nature-based relational and collective restoration processes (Hartig, 2021). However, what distinguished people living alone was the lower quantity of both neighbourhood green space and green space visits. These could be due to various spatial (e.g. availability) and individual (e.g. personal preferences and availability of company) factors (Boyd et al., 2018). Thus, the relevant questions to address in research, urban planning and policy-making are, firstly, how to ensure adequate quantity of green space in growing cities (Haaland & Konijnendijk van den Bosch, 2015), especially in densely built locations where more and more people are living alone and, secondly, how to encourage the use of urban green areas among people living alone.

Collective restoration could also be promoted with different types of interventions (beyond the synchronisation of holiday periods; Hartig et al., 2013). These interventions could be (a) design-based, such as the inclusion of facilities that foster direct social interaction, including circular seating and infrastructure for organising events/gatherings (Hunter et al., 2019), providing opportunities for positive emotional contagion; and/or (b) behavioural, such as providing the context for normative nature-based behaviours (e.g. designated picnic areas), or more specific interventions to encourage people to interact with other community members such as conservation or gardening groups (Hsueh

et al., 2022).

Tentative evidence from this type of interventions has, indeed, shown a potential to enhance social restoration more broadly, indicated by a reduction in loneliness (Hsueh et al., 2022), and more are being actively developed and assessed (RECETAS, 2022). In line with these recent developments, our study supports the idea that spending time in urban green space is associated with greater satisfaction with interpersonal relationships and being part of a community, and that these experiences are associated with better mental health in multiple industrialised countries, for both single and partnered adults.

Credit author statement

TPP – Conceptualization, Formal analysis, Visualization, Investigation, Funding acquisition, Writing – original draft; MPW – Conceptualization, Data curation, Investigation, Writing – review & editing; LRE – Data curation, Writing – review & editing; MvdB, GNB, AO & LEF – Funding acquisition, Writing – review & editing; KK – Writing - reviewing and editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data from 11 countries is available from the UK data service (DOI: 10.5255/UKDA-SN-8874-2), and the rest upon request from authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envres.2023.116324.

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