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Mental health benefits of urban green space are shaped by green space attributes, visitor characteristics and the activities they undertake

Joseph Douglas[a,b], Simon Willcock[b,c], Fränze Kibowski[d], Tom Marshall[d] and Laurence Jones[a]

[a]UK Centre for Ecology & Hydrology, Bangor, UK; [b]School of Environmental and Natural Sciences, Bangor University, Bangor, UK; [c]Net Zero and Resilient Farming, Rothamsted Research, North Wyke, UK; [d]Natural England, York, UK

ABSTRACT

Access to green spaces is limited in urban areas and has proven benefits for the mental health and well-being of residents. However, there remains a paucity of evidence as to how these benefits vary based on a) the attributes of visited sites, b) the characteristics of visitors, and c) the activities undertaken during each visit. To address these evidence gaps, we analysed 10,749 responses to the Adults' People and Nature Survey (PaNS) for England, a national survey which gathers information on the location and self-reported mental health benefit of a recent green space visit. Our results suggest that women benefit more than men, and benefit varied between age groups – with those aged 40–54 years experiencing the greatest improvement. Larger green spaces and longer visits were associated with greater well-being. Our model also indicates significant positive relationships between reported mental health benefit and frequency of visits, living with a long-term illness, and the following visit activities: watching wildlife, picnicking, running/cycling, and walking. Seasonality was important, with spring visits more likely to result in strong benefit. We identified significant interactions between age and gender, and between visit duration and site area, which supports the conceptual framework that well-being benefits of green space access arise from a web of interrelating factors. Our findings highlight the need for policymakers and planners to ensure urban residents have access to many types of green area to meet their diverse use requirements and mental health needs.

KEY POLICY HIGHLIGHTS

- Policy that aims to promote well-being by the provision of green space in cities and towns should consider the role of site design alongside improving accessibility.
- Interventions that support wildlife in urban green spaces (e.g. habitat creation) can increase opportunities for users to experience the increased benefit associated with watching wildlife.
- Designing green spaces with attributes that facilitate walking, running, cycling and picnicking/eating can boost mental health outcomes.
- A larger site, with a greater selection of attributes that meet the diverse needs and preferences of visitors, is likely to provide greater well-being benefit to users compared to a smaller site.

1. Introduction

Global shifts in population distribution towards urban centres mean that a growing majority of people now live in places characterised by built infrastructure, in which vegetation cover and green spaces are often replaced with other land cover types in the course of development (United Nations Department of Economic and Social Affairs 2019; Richards and Belcher 2020). Green spaces are typically defined as open areas characterised by natural features, including parks, forests, gardens and waterbodies, in contrast to buildings and other hard infrastructure, such as roads (van den Berg et al. 2015; Nguyen et al. 2021).

Many studies provide evidence that spending time in green spaces is linked to multiple mental health benefits for visitors (White MP, Alcock I, et al. 2013; Hartig and Kahn 2016; Bratman et al. 2019), including reduced stress (Ewert and Chang 2018) and lower incidence of anxiety (Nutsford et al. 2013). Poor mental health and mental disorders constitute an important part of the global disease burden, with one in eight people globally having experienced a mental health disorder (World Health Organisation 2008; Steel et al. 2014). Decreasing access to green spaces therefore represents an important public health issue – a point that is reflected in the UN Sustainable Development Goal 11.7, which identifies the need to provide 'universal

access to safe, inclusive and accessible, green and public spaces' (United Nations Department of Economic and Social Affairs 2015).

Evidence to support a positive relationship between spending time in urban green spaces (UGS) and improved mental health outcomes is abundant. Relevant studies measure green space accessibility and usage using a variety of approaches, including the distance to the closest green space for surveyed residents (Bertram and Rehdanz 2015; Bijnens et al. 2022), the level of greenness in the local neighbourhood (Mavoa et al. 2019; Barboza et al. 2021; Holy-Hasted and Burchell 2022; Jeong et al. 2023), the frequency of recent visits (Lafortezza et al. 2009; Coldwell and Evans 2018; Hong et al. 2019; Mayen Huerta and Utomo 2021) and the health and well-being effects of individual green space visits (White MP, Pahl S, et al. 2013; Ekkel and de Vries 2017; Reeves et al. 2019). Such studies also assess psychological benefit using a range of metrics, from summary scales that describe overall well-being, including the Short Form Health Survey (Huo et al. 2018; Holy-Hasted and Burchell 2022) and the Warwick-Edinburgh Mental Well-being Scale (Tennant et al. 2007; Mayen Huerta and Utomo 2021), to indicators of specific psychological conditions – such as the Depression, Anxiety and Stress Scale (Lovibond and Lovibond 1995; Reeves et al. 2019) or metrics of attention restoration (Hartig et al. 1997; Berman et al. 2008).

The ability to access UGS, however, is not the only factor with bearing on the well-being benefits that these spaces provide to urban residents. The type and magnitude of benefit may also vary with the attributes of accessible sites, as well as the characteristics and needs of users – a point that must be considered as part of any intervention seeking to maximise well-being benefits that residents receive from UGS (Collins et al. 2020; Jones et al. 2022, 2025). Most of the research that considers this problem, focuses on the ecological differences between sites (Beute et al. 2023). Comparisons of different land types are common, for example, between urban and peri-urban green spaces (e.g. urban parks versus nature reserves; Carrus et al. 2015), forested and parkland areas (Ewert and Chang 2018), more or less 'domesticated' green spaces (Allard-Poesi et al. 2022) and forest sites with different management regimes (Martens et al. 2011). There are also many studies that compare well-being outcomes with continuous measures of site biodiversity (Fuller et al. 2007; Cameron et al. 2020; Fisher et al. 2021a) or with perceived ecological quality (Schebella et al. 2019; Fisher et al. 2021b).

Far less attention has been given to the role of factors besides natural site attributes as predictors of mental health outcomes from green space visits. Research that focuses on built features and amenities is more likely to address visitor use patterns and preferences (van Vliet et al. 2021; Palliwoda and Priess 2021; Grilli et al. 2020) than well-being (Wood et al. 2018; Ayala-Azcárraga et al. 2019). For visitor characteristics, there is evidence to suggest that socioeconomic background (Rigolon et al. 2021) and age group (Douglas et al. 2017) are related to the well-being benefit received from UGS, but further research is required to identify how other user characteristics are linked to outcomes. Likewise, few studies have considered how the activities and behaviours of UGS visitors relate to received benefits to mental health and well-being. Many studies look for relationships between green space access (Ord et al. 2013; Klompmaker et al. 2018; Shen et al. 2021) or attributes (Lindberg and Schipperijn 2015; Benton et al. 2021) and increases in physical activity, which can then lead to improvements in health and well-being, but there are few studies that directly consider how mental health and well-being benefits vary between visitors undertaking different activities – for example, between physical and non-physical activities (Holt et al. 2019), or walking versus conservation activities (Coventry et al. 2019).

To understand how these various factors relate to the mental health benefit of green space exposure, we must also consider the possible ways they interact with one another. Lennon et al. (2017) identify this need to consider a network of interacting factors and propose a framework of 'affordances' that 'dynamically interrelate' to shape the experiences and well-being benefits of people using UGS. They identify six interconnected dimensions that combine to describe the interaction of visitors with a green space – 'space', 'scale', 'time', 'objects', 'actions' and 'persons'. For example, larger green spaces (space) with more amenities (objects) may be more conducive to longer visits (actions). To promote ease of use for stakeholders and aligning with frameworks in Jones et al. (2022), which describe cultural ecosystem services in terms of the relationship between human capital, natural capital, and the needs and actions of users, this study consolidates the six dimensions into three broader categories: site attributes (space, scale, time and objects), visitor characteristics (persons) and visitor activities (actions). Studies that investigate a range of factors are better suited to apply the affordances framework to consider how visitor experiences and health outcomes emerge from the relationships between those factors. In a study of residents living

near a set of green spaces in Eindhoven and 's-Hertogenbosch, Netherlands, van Dinter et al. (2022) assess the relationship between resident characteristics, green space attributes, the activities commonly undertaken during visits and life satisfaction, an aspect of well-being. This approach allows researchers to explore the pathways by which visitors receive well-being benefit – for example, in their study, van Dinter et al. identified that older residents were more likely to visit a park to enjoy nature, an activity that was positively correlated with their sense of place, which itself was positively associated with life satisfaction.

A dataset in the UK with a large sample size and national coverage, collected as part of the Adults' People and Nature Survey (PaNS), provides an ideal opportunity to investigate the relationships between green space attributes, visitor characteristics, visit activities and the mental health benefit of green space. PaNS is a national stratified survey that provides data on the self-reported mental health benefit from thousands of visits to green spaces across England (Natural England 2023). The location of these visits is specified in each response, allowing us to obtain information on the built and natural features of each visited green space using other data sources. Using the PaNS dataset we were able to compare a) visitor characteristics, b) site features and c) visitor activity together with the well-being benefit of over 10,000 visits across nearly 4000 green spaces. Prior studies that have included factors from two (Wood et al. 2018; Ayala-Azcárraga et al. 2019) or all three of these categories (Ode Sang et al. 2016; van Dinter et al. 2022) have each been limited to a much smaller number of sites.

Here, we analysed responses to PaNS that describe the location and self-reported mental health benefit of a recent UGS visit to assess the relationships between respondent characteristics, site attributes and visitor behaviours as predictors of well-being outcomes. Through this analysis, we were able to assess the following research questions:

(1) Are the natural and built attributes of UGS linked to the mental health benefits of a visit to that space when controlling for visitor characteristics and activities undertaken?
(2) Are the characteristics of visitors linked to the mental health benefits of visiting UGS when controlling for the attributes of the visited site and the activities undertaken?
(3) Are the activities undertaken during a visit to UGS linked to mental health benefits from that visit when controlling for site attributes and visitor characteristics?

(4) Are interrelationships between factors related to UGS visits linked to the level of mental health benefit arising from the visit?

2. Methods

2.1. Self-reported mental health benefit from a recent UGS visit

The Adults' PaNS has been administered monthly since April 2020 to up to 25,000 respondents per year, aged 16 years or older, and provides official statistics on the relationship of residents of England to the natural environment (Natural England 2023, 2024). The survey uses a stratified random sampling method, grouping by age, gender, geographic region and education level (Natural England 2024). These data are published by Natural England, a public body sponsored by the UK Government Department for Environment, Food and Rural Affairs. The Adults' PaNS – along with the Children's PaNS, which we do not utilise in this study – acts as the successor to the Monitoring Engagement with the Natural Environment survey, with updated questions (Natural England 2020). One specified purpose of PaNS is to improve understanding of how passing time in natural settings can affect physical and mental health, asking respondents to recall details of their most recent visit to a green space. Participants first indicate whether they visited a green space in the preceding 14-day period and then respond to a series of questions about that visit, including the location of their visit and to report the health benefit they felt they received.

One question (M2A_Q9b) asks respondents to indicate their level of agreement ('1 – Strongly disagree', '2 – Disagree', '3 – Neither agree nor disagree', '4 – Agree' or '5 – Strongly agree) with the following statement about their green space visit – 'It was good for my mental health'. We use responses to this item as our metric of self-reported mental health benefit from a recent green space visit. The wording of the statement, however, makes it difficult to draw a meaningful distinction between participants who 'strongly disagree', 'disagree' or 'neither agree nor disagree', as all three answers could be given by respondents who either felt no change in their mental health or who felt a negative impact. As such, we treated these answers as equivalent, leaving three levels analogous to '0 – no benefit' '1 – some benefit' and '2 – strong benefit'. The decision to simplify the metric of mental health benefit is further justified by results from an additional analysis that uses the unmodified variable (Appendix A), which closely match the results from our final model.

2.2. Visited green spaces

PaNS asks respondents to indicate the location of their recent visit to a green space by searching an address in Google Maps and placing a pin on the site of that visit. Alternatively, they can provide a written address, from which a pin is automatically placed using Google Maps. In either case, each green space visit is ultimately associated with a single point coordinate. Using this coordinate, we were able to match each visit with a green space polygon, by intersecting these points with the Ordnance Survey Open Greenspace (OSOG) layer – a map of publicly accessible green spaces across the UK (Ordnance Survey 2023). To do this, we used the 'intersect' function from the terra package (Hijmans et al. 2024), a set of spatial data analysis tools in R, to remove any points that fall outside the OSOG polygons and pair each remaining point with its overlaid green space polygon. This process allowed us to find the size of each visited site and to determine which built and natural attributes are present within the boundaries of each site. To limit green space visits to urban sites, we first filtered out rural sites using the UK urban morphology layer developed by Jones et al. (2019), removing any green spaces that did not overlap with urban areas. The OSOG layer includes many small enclave green spaces, usually sports pitches, that are completely contained within a larger green space. We removed these enclaves, by dissolving any nested polygons, before matching the PaNS visits to their OSOG green spaces, to ensure that each visit was only matched to a single green space – e.g. with our data showing the larger green space which contained, amongst its other attributes, a sports pitch.

2.3. Natural UGS attributes

For information on the natural attributes of the UGS visited by our subset of PaNS respondents, we calculated land cover metrics from the 2018 Copernicus High Resolution Layers for tree cover density, blue cover, and grassland cover (Copernicus Land Monitoring Service 2020a, 2020b, 2020c) Table 1. These raster layers provide information on land cover type at 10 m resolution. We first intersected these layers with our UGS vector layer, so that every cell with its centre point covered by a green space polygon would be matched to the identification number of that UGS using the terra package (Hijmans et al. 2024). To calculate our land cover metrics, we then calculated the proportion of cells with each land cover type against the total number of cells within each green space boundary. For tree cover density, each raster cell has a value indicating the proportion of its area covered by tree canopy during satellite surveying, so we considered any value above zero to

contain tree canopy. For blue space, only cells designated as 'permanent water' – rather than 'temporary water', 'permanent wet', or 'temporary wet' – were included as blue cover, as this category covers all non-seasonal bodies of water such as rivers, ponds, and lakes. The grassland layer only distinguishes between cells with grassland cover and those without, and so required no initial formatting. To test whether there is an optimal coverage level for each of these natural land cover types, above and below which coverage is associated with lower reported benefit (i.e. a quadratic relationship), we calculated additional square terms for tree cover, blue space cover and grassland cover.

To account for seasonal and long-term changes to the condition of the UGS in our dataset, the date of visit provided by PaNS respondents was converted into two variables to be included in our final model – year and season. The latter was divided by month as follows: winter (December, January, February), spring (March, April, May), summer (June, July, August) and autumn (September, October, November).

2.4. Amenities and other built green space features

Spatial data on the built elements of green spaces were sourced from OpenStreetMap (OSM), an open geographic database maintained by volunteer contributors (OpenStreetMap contributors 2024). OSM includes data for a broad range of features and covers the entirety of England. We primarily selected built features that are connected to visitor activity for inclusion in our model, with the addition of public restrooms as a key amenity (Table 1). In most cases these features comprised a single category specified by OSM – e.g. cafés are mapped as a point with the tag 'amenity = café'. However, we created our own category for 'cultural centres', which combined the OSM tags for library, events venue, community centre, arts centre and social centre. We also used the overarching OSM group 'historic' as the basis of our 'historic feature' variable. The 'historic' category encompasses a list of sites and features of historic interest, such as monuments and historic buildings (OpenStreetMap Contributors 2024).

All built features were brought into R using the osmdata package (Padgham et al. 2017) for the entire extent of England, and then intersected with our layer of visited UGS using the terra package (Hijmans et al. 2024). Metrics for each feature were then calculated either as a binary 'present' or 'absent' categorical variable or as continuous variables calculated per kilometre squared of site area. The first method was applied to features that attract visitors and may therefore be associated with visitor experience and outcomes regardless of the number of each present –

Table 1. Descriptions of variables and results from cumulative link mixed model of self-reported mental health benefit, including parameter estimates, 95% confidence intervals and p values.

Variable	Description	Levels	Estimate (95% confidence interval)	p-value
Tree cover (linear)	Tree cover value calculated per UGS as proportion of total pixels with any tree cover (i.e. TCD value >0).		0.166 (−0.558, 0.891)	0.653
Tree cover (quadratic)			0.164 (−0.644, 0.972)	0.691
Blue space cover (linear)	Blue space cover value calculated per UGS as proportion of total pixels designated as 'permanent water'.		1.356 (−0.389, 3.1)	0.128
Blue space cover (quadratic)			−2.698 (−6.12, 0.724)	0.122
Grassland cover (linear)	Grassland cover value calculated per UGS as proportion of total pixels with grass cover.		−0.348 (−1.027, 0.332)	0.316
Grassland cover (quadratic)			0.269 (−0.486, 1.024)	0.485
Public toilet	Binary variable indicating whether or not UGS boundary contains at least one public toilet.	Present	−0.083 (−0.199, 0.032)	0.158
Café	Binary variable indicating whether or not UGS boundary contains at least one café.	Present	0.04 (−0.081, 0.162)	0.512
Playground	Binary variable indicating whether or not UGS boundary contains at least one playground.	Present	−0.008 (−0.114, 0.099)	0.888
Historic feature	Binary variable indicating whether or not UGS boundary contains at least one historic feature (any feature in OSM category 'historic').	Present	0.093 (−0.009, 0.195)	0.075
Cultural centre	Binary variable indicating whether or not UGS boundary contains at least one cultural centre (any of the following OSM features: library, events venue, community centre, arts centre, social centre).	Present	0.044 (−0.126, 0.215)	0.611
Fountain	Binary variable indicating whether or not UGS boundary contains at least one fountain.	Present	−0.145 (−0.293, 0.004)	0.056
Path network, by area	Total length of footways within UGS, per square kilometre UGS area.		−0.002 (−0.018, 0.015)	0.85
Seating, by area	Number of benches within UGS, per square kilometre UGS area.		−0.004 (−0.026, 0.018)	0.752
Sports pitches, by area	Number of sports pitches within UGS, per square kilometre UGS area.		−0.001 (−0.028, 0.027)	0.969
Area	Area of UGS, square kilometres.		**0.203 (0.142, 0.264)**	**<0.001**
Year	Year of visit: 2020, 2021, 2022 or 2023.	2021	−0.06 (−0.162, 0.042)	0.246
		2022	−0.055 (−0.159, 0.049)	0.301
		2023	−0.082 (−0.248, 0.084)	0.33
Season	Spring (March to May), summer (June to August), autumn (September to November) or winter (December to February).	**Spring**	**0.121 (0.01, 0.232)**	**0.032**
		Summer	−0.028 (−0.144, 0.088)	0.638
		Autumn	0.041 (−0.076, 0.157)	0.492
Gender	'Male' or 'female' (PaNS item Q64)	**Male**	**-0.281 (−0.492, −0.07)**	**0.009**
Age	'16–24', '25–39', '40–54', '55–64' or '65+' (PaNS item Q62)	**25–39**	**0.224 (0.019, 0.428)**	**0.032**
		40–54	**0.482 (0.272, 0.691)**	**<0.001**
		55–64	**0.321 (0.079, 0.563)**	**0.009**
		65+	−0.019 (−0.284, 0.246)	0.89
Education	'A university degree (or above)', 'any other qualifications (e.g. A Levels, O Levels, GCSEs, BTEC, Diplomas, Trade Apprenticeships)' or 'no qualifications' (PaNS item Q67).	Non-degree	0.026 (−0.062, 0.114)	0.562
		No qualifications	**0.334 (0.112, 0.555)**	**0.003**
Marital status	Respondent selected one from list: 'Single', 'Married or civil partnership', 'Co-habiting', 'Separated', 'Divorced', or 'Widowed' (PaNS item Q65). 'Separated' and 'Divorced' combined for analysis.	**Co-habiting**	**-0.153 (−0.284, −0.022)**	**0.022**
		Single	−0.045 (−0.158, 0.068)	0.435
		Divorced or separated	−0.027 (−0.181, 0.128)	0.735
		Widowed	0.176 (−0.061, 0.412)	0.145
Work status	Respondent selected one from list: 'Full-time employment', Part-time employment', 'Self-employed', 'Unemployed – short-term', 'Unemployed – long-term', 'Not working – retired', 'Not working – looking after house/children/other caring responsibilities', 'Not working – long-term sick or disabled', 'Student – full-time', or 'Student – Part-time' (PaNS item Q68). Simplified groupings as follows – unemployed ('Unemployed – long-term' and 'Unemployed – long-term'), student ('Student – full-time' and 'Student – Part-time') and self-employed/carer ('Self-employed' and 'Not working – looking after house/children/other caring responsibilities').	**Part-time**	**-0.164 (−0.293, −0.034)**	**0.013**
		Not working – long-term illness	0.011 (−0.239, 0.26)	0.934
		Not working – retired	**-0.177 (−0.352, −0.002)**	**0.047**
		Self-employed or carer	0.036 (−0.105, 0.176)	0.618
		Student	−0.03 (−0.235, 0.175)	0.776
		Unemployed	−0.151 (−0.35, 0.048)	0.136
Income	Annual household according to respondent: '£0– 14,999', '£15,000– 19,999', '£20,000– 29,999', '£30,000– 39,999', '£40,000– 49,999' or '£50,000 +' (PANS item Q69).	£15,000– 19,999	0.055 (−0.103, 0.213)	0.494
		£20,000– 29,999	−0.003 (−0.143, 0.138)	0.972
		£30,000– 39,999	0.033 (−0.119, 0.184)	0.672
		£40,000– 49,999	−0.017 (−0.181, 0.147)	0.842
		£50,000 +	−0.135 (−0.285, 0.015)	0.078
Ethnicity	Respondent indicated broad ethnic group (PaNS item Q70); divided between 'white' and 'non-white' ('Asian or Asian British, Black or Black British', 'Mixed', and 'Other').	'Asian or Asian British', 'Black or Black British', 'Mixed', or other ethnicity	0.108 (−0.01, 0.226)	0.072

(Continued)

Table 1. (Continued).

Variable	Description	Levels	Estimate (95% confidence interval)	p-value
Weekly exercise	Respondent indicated the number of days they did physical activity in the week prior to survey response (PaNS item Q76).	One day	−0.012 (−0.19, 0.166)	0.893
		Two days	0.007 (−0.153, 0.168)	0.927
		Three days	**0.207 (0.042, 0.371)**	**0.014**
		Four days	**0.274 (0.098, 0.451)**	**0.002**
		Five days	**0.258 (0.088, 0.428)**	**0.003**
		Six days	**0.373 (0.158, 0.588)**	**0.001**
		Seven days	**0.421 (0.249, 0.593)**	**<0.001**
Illness	Respondent indicated whether or not they have a physical or mental health condition lasting or expected to last over 12 months (PaNS item Q74).	**Yes**	**0.143 (0.048, 0.239)**	**0.003**
Visit frequency	Respondent indicated, on average, how often they spent in green spaces over the last year, from these options: 'every day', 'more than twice a week, but not every day', 'twice a week', 'once a week', 'once or twice a month', 'once every 2–3 months', 'less often', 'never'. Simplified to: 'every day', 'more than twice a week', 'once or twice a week' and 'less than once a week'.	**More than twice a week, but not every day**	**-0.614 (−0.76, −0.469)**	**<0.001**
		Once or twice a week	**-0.233 (−0.352, −0.115)**	**<0.001**
		Less than once a week	**-0.467 (−0.591, −0.343)**	**<0.001**
Children		One child	0.058 (−0.071, 0.188)	0.376
		Two or more children	−0.033 (−0.174, 0.107)	0.643
Dog	Respondent indicated whether or not they own a dog (PaNS item Q73).	**Own at least one**	**-0.232 (−0.327, −0.138)**	**<0.001**
Visit duration	Respondent selected one: 'Less than half an hour', 'half an hour to an hour', '1 to 2 hours', '2 to 3 hours', '3 to 5 hours' or 'over 5 hours' (PaNS item M2A_Q7). Answers of '2 to 3 hours', '3 to 5 hours' or 'over 5 hours' were combined to a single category, 'over 2 hours'.	Thirty minutes to one hour	0.111 (−0.005, 0.227)	0.06
		One hour to two hours	**0.341 (0.22, 0.462)**	**<0.001**
		Over two hours	**0.322 (0.175, 0.468)**	**<0.001**
Activity – Eating	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'eating or drinking out/picnicking' (PaNS item M2A_Q8A).	**Yes**	**0.224 (0.108, 0.34)**	**<0.001**
Activity – Play	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'playing with children' (PaNS item M2A_Q8A).	Yes	0.077 (−0.054, 0.207)	0.249
Activity – Walking	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'walking (including taking a dog out for a walk)' (PaNS item M2A_Q8A)	**Yes**	**0.355 (0.245, 0.465)**	**<0.001**
Activity – Run or cycle	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'cycling or running' (PaNS item M2A_Q8A)	**Yes**	**0.297 (0.139, 0.454)**	**<0.001**
Activity – Wildlife	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'wildlife watching' (PaNS item M2A_Q8A)	**Yes**	**0.641 (0.544, 0.739)**	**<0.001**
Activity – Attraction	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'visiting an attraction' (PaNS item M2A_Q8A)	Yes	−0.02 (−0.223, 0.182)	0.844
Activity – Sporting activity	Respondent indicated whether or not they engaged in one of the following activities during their recent UGS visit – 'sports and games', 'fishing', 'horse-riding', 'shooting/hunting', or 'boating, watersports or swimming outdoors' (PaNS item M2A_Q8A)	Yes	0.135 (−0.028, 0.299)	0.105
Activity – Car	Respondent indicated whether or not they engaged in the activity during their recent UGS visit – 'appreciating scenery from a car' (PaNS item M2A_Q8A)	Yes	−0.227 (−0.494, 0.04)	0.096
Area*Duration		**Thirty minutes to one hour**	**-0.119 (−0.186, −0.052)**	**0.001**
		One hour to two hours	**-0.188 (−0.257, −0.119)**	**<0.001**
		Over two hours	**-0.191 (−0.268, −0.115)**	**<0.001**
Gender*Age		Male, 25–39	0.165 (−0.098, 0.428)	0.218
		Male, 40–54	−0.134 (−0.395, 0.127)	0.314
		Male, 55–64	**-0.347 (−0.638, −0.056)**	**0.019**
		Male, 65+	−0.112 (−0.381, 0.157)	0.414

The reference levels for categorical variables are as follows: absent (public toilet, café, playground, historic feature, cultural centre, fountain), 'less than 30 minutes' (visit duration), no (all activities), 2020 (year), winter (season), female (gender), '16–24' (age), degree or above (education), married (marital status), full-time (work status), 'less than £15,000' (income), 'White' (ethnicity), none (children), own none (dog), no days (weekly exercise), no (illness) and every day (visit frequency). Results for categorical variables with more than two levels are described for each level. Significant results (p <0.05) are shown in bold. Results for nested random effect of green space location are reported in Appendix H.

these were public toilets, cafés, playgrounds, historic features, cultural features and fountains. The second group included features that might be linked to visitor experience based on their distribution/density throughout the UGS – these were footpaths, sports pitches, and seating. These three variables, in addition to site area itself, were natural log-transformed and mean centred.

2.5. Visitor characteristics and activities during visit

Each PaNS respondent is required to provide information on personal characteristics. We selected the following characteristics to describe the sociodemographic profile of visitors in our analytical sample: age, gender, education level, marital status, work status, income, ethnicity and long-term illness (Table 1). We also included dog ownership, number of children and recent frequency of physical activity as proxies for common motivations for green space visits – to go dog-walking, to visit with children and to exercise respectively (Meis-Harris et al. 2019). These proxies were necessary because specific information on visitor motivations was unavailable for the majority of our sample – there is a PaNS item (M2A_Q5) that asks respondents to identify motivations for their visit, but responses were collected from less than a third of the relevant respondents. Chi-squared tests using this subsample of 3288 responses show significant relationships between dog ownership and 'to walk a dog' being given as a motivation for a visit ($p < 0.001$), between having children and 'to look after children/other family members' as a motivation ($p < 0.001$), and between recent exercise frequency and the motivation 'for physical health and exercise' ($p < 0.001$), supporting the use of our proxy metrics. Lastly, we included the frequency of green space visits in the past year to test for a possible link between more regular visits and increased benefit from a single visit. Due to a limited sample size, we simplified several of these variables (marital status, work status, ethnicity, number of children, visit duration and frequency of green space visits in last year) by combining levels with small numbers of responses where reasonable – see Table 1 for details.

PaNS respondents who answered questions on their recent green space visit were also asked which activities they engaged in during their visit (M2A_Q8A), indicating whether they did or did not engage in each activity from the following list: 'eating or drinking out/picnicking', 'playing with children', 'walking (including taking a dog for a walk)', 'cycling or running', 'fishing', 'appreciating scenery from a car', 'horse-riding', 'shooting/hunting', 'sports and games', 'visiting an attraction', 'boating/watersports/ swimming outdoors', 'wildlife watching' or 'any other outdoor activity (specify)'. We formatted each activity

as its own binary variable – for example, one variable indicates whether respondents did or did not go for a walk during their visit. However, we combined 'fishing', 'horse-riding', 'shooting/hunting', and 'boating/watersports/swimming outdoors', which each received small numbers of affirmative responses, with 'sports and games' to create an overall sporting activity variable. Finally, we included the duration of visit, recorded categorically by a single PaNS item (M2A_Q7) with six levels from 'less than half an hour' up to 'over 5 hours', as a final aspect of visitor behaviour that is likely to relate to mental health benefit (White MP, Pahl S, et al. 2013; Table 1). As this question asks respondents to record the total time of their visit, including journey time, and there are no additional survey items that would allow the accurate separation of journey time and time spent on site, we were unable to separately investigate visit and journey length. Subsequent interpretation of results reflects this limitation. A full summary of the formatted dataset is available in Appendix B.

2.6. Model selection/construction

To develop our full model structure, we formed multiple *a priori* hypotheses, based on our initial research questions – i.e. whether natural and built site attributes, visitor characteristics and visitor activities affect the self-reported mental health benefit experienced by visitors to an UGS when controlling for all other factors (Appendix B). We modelled the self-reported mental health benefit of an UGS visit as a function of all these variables (listed in Table 1), with the addition of visited UGS as a random effect, using a cumulative link mixed model (*ordinal* package; Christensen 2024). The unique identification number for each UGS was included as a nested random effect to account for skew in the number of visits towards a minority of sites – around 200 sites received more than 10 visits, with one visited by 142 respondents in our sample. This addition prevented us from treating ordered variables in the model as ordinal, so all variables were either categorical or continuous (Table 1).

The included interaction terms were selected from a longer list of interactions based on *a priori* hypotheses related to possible interrelationships captured by the dimensions of the affordances framework (Lennon et al. 2017). Earlier versions of our model included all of these interactions, but those without a significant relationship to the output were excluded from the final model to reduce the risk of overfitting (Appendix C). In the cases of the remaining age*gender and duration*site interaction terms, these were initially proposed based on a) the link of both age and gender to perceptions of safety (Douglas et al. 2017)

and the potential for a subsequent link to perceived well-being effect and b) the potential for both site area and visit duration to modulate the dose received by visitors, for example, with regard to the restorative effect of the 'softly fascinating stimuli' provided by green spaces (Basu et al., 2019). Due to an extremely small number of responses (19) from our data subset that specified their gender identity as other than male or female, we removed these prior to analysis to prevent an error occurring as a result of age*gender interaction categories with zero returns.

The final model is described as follows: self-reported mental health benefit ~ tree cover + (tree cover)^2 + blue space cover + (blue space cover)^2 + grassland cover + (grassland cover)^2 + public toilet + café + playground + historic feature + cultural centre + fountain + path network by site area + seating by site area + sports pitches by site area + site area + gender + age + education + marital status + work status + income + ethnicity + illness + children + dog + weekly exercise + visit duration + eating + walking + play + run/cycle + wildlife watching + visiting attraction + sport + view from car + year + season + age*gender + area*visit duration + (1 | green space ID).

Additional models using blocks regressions were also created to provide insight into the existence of possible indirect relationships between visitor activities and site attributes (Appendix D). Tests of multicollinearity identify a number of collinear relationships between variables in the model (Appendix E). The final model was not simplified further as a) multicollinearity between variables is minimal (Spearman's coefficient between −0.6 and 0.6 for all correlations between continuous variables; Cramer's V less than 0.1 for 75% of categorical relationships; Akoglu 2018), and b) all remaining terms are of individual relevance to our research questions. Results from an alternative version of the final model, which treats the outcome variable as numeric and continuous, are shown in Appendix F. All data formatting and analysis was completed in R (version 4.4.0; R Core Team 2024).

3. Results

The formatted dataset that formed the basis of our model includes 10,727 visits to 3744 separate UGS taken by residents of England between April 2020 and March 2023. The sociodemographic profile of visitors was evenly split between men and women (50.9% men and 49.1% women), with 40–54 years old being the most common age group (16–24: 13.9%; 25–39: 24.3%; 40–54: 25.6%; 55–64: 14.9%; > 65: 21.2%). Additional information describing the sociodemographic profile of the sample can be found in Appendix B. Most respondents found their green space visit to be beneficial to their mental health – only 8.5% of respondents reported no benefit from their visit, while 50.8% experienced some benefit and 40.7% received a strong benefit.

Here, we highlight the key findings from our model comparing the relationships of site attributes, visitor characteristics, and visit activities with the self-reported mental health benefit of visitors to UGS. Differences reported in the text are calculated by comparing predicted values, i.e. accounting for other factors in the model. The full results of the model are presented in Table 1.

The size of the visited green space was positively associated with reported mental health benefit (B = 0.203, $p < 0.001$), with a clear relationship with natural log of green space area (Figure 1(a)), as was the duration of the visit (including journey time) – for example, visits lasting a total of one to two hours were 6.7% more likely to result in 'strong benefit' compared to a visit of under half an hour (B = 0.341, $p < 0.001$; (Figure 1(b)); untransformed graphs are available in Appendix G). There is a significant interaction between the size of the visited UGS and the total duration of the visit at all visit durations. However, this interaction appears to be stronger for shorter visits – e.g. a visit of less than 30 minutes to a 10 Ha site resulted in an 8.6% greater chance of a 'strong benefit' over a visit of the same duration to a 1 Ha site (B = −0.033, $p = 0.001$), but only a 0.8% increased chance for visits between one and two hours (B = −0.188, $p < 0.001$; Figure 1(c)). Another significant relationship to reported benefit is season, with spring visits 2.9% more likely to result in 'strong benefit' than winter visits (B = 0.121, $p = 0.032$) – although there was no significant difference between winter and either summer or autumn visits. Neither tree cover, grassland cover, nor blue space cover were significantly associated with benefit.

Gender was significantly associated with reported benefit (B = −0.281, $p = 0.009$), with women 8.9% more likely to report 'strong benefit' compared to men (Figure 2(a)). The age of visitors was also significantly associated with reported benefit, with the youngest group, aged 16–24, reporting least benefit and those aged 40–54 the most benefit. People aged 25–39 (B = 0.224, $p = 0.032$), 40–54 (B = 0.482, $p < 0.001$), and 55–64 (B = 0.321, $p = 0.009$), were 4.5%, 10.2% and 6.6% more likely to report 'strong benefit' respectively compared to younger visitors aged 16–24 years (Figure 2(b)). There was also a significant interaction between age and gender, with the gap in benefit between men and women significantly wider for those aged 55–64 years compared to that of the 16–24 age group (B = −0.347, $p = 0.019$; Figure 2(c)).

People with a long-term health condition lasting more than a year reported greater benefit compared to other respondents (B = 0.143, $p = 0.003$), while people who reported taking part in moderate exercise

on multiple days in the week prior to surveying reported greater benefit from their visit versus people who did not exercise (e.g. three days – B = 0.207, p = 0.014). Owning a dog corresponded to a 5.2% lower probability of 'strong benefit' from a recent UGS visit compared with non-dog owners (B = −0.232, p< 0.001), and married respondents gained greater benefit compared to co-habiting respondents (B = −0.153, p = 0.022). People who work full-time recorded greater benefit than people who work part-time (B = −0.164, p = 0.013) and retirees (B = −0.177, p = 0.047), while people with no formal qualifications were 8.0% more likely to report 'strong benefit' than people with a university degree (B = 0.334, p = 0.003). Respondents who visited green space every day over the last year were 5.6% more likely to report 'strong benefit' from their recent visit compared to people who visited more than twice a week (B = −0.614, p = 0.001), 10.8% more likely compared to those who visited once or twice a week (B = −0.233, p< 0.001), and 13.9% more likely compared to those who visited less than once a week (B = −0.467, p< 0.001).

Lastly, visitors who took part in certain activities during their visit reported greater mental health benefit than those who did not take part in each activity, with the greatest increase in benefit reported by those who spent time watching wildlife: walking (8.5% increase in probability of 'strong benefit'; B = 0.355, p < 0.001), watching wildlife (15.7% increase; B = 0.641, p< 0.001), picnicking/eating (5.3% increase; B = 0.224, p< 0.001), and running/cycle (7.1% increase; B = 0.297, p< 0.001; (Figure 3)).

4. Discussion

In this study we used data from PaNS, a large representative survey of adults living in England, to identify factors that are associated with the mental health benefit gained from a single visit to UGS. Our study provides new insights into the mental health benefit of actual exposure, rather than local greenness or UGS availability as a proxy (White MP, Pahl S, et al. 2013; Wyles et al. 2019; Beute et al. 2023). Results from our study suggest that the mental health benefits of visiting an UGS vary with differences in site attributes, visitor characteristics, and visit activities. We also identify interactions between some of the studied variables, which supports the conceptual framework that differences in mental health benefit arise from a network of interrelating socioecological factors (Lennon et al. 2017).

4.1. Site attributes and seasonal change

The positive relationship between green space size and mental well-being, which is reflected in prior research (Sharifi et al. 2021), could be explained as larger sites provide greater restorative effects to visitors by allowing for a greater sense of isolation from the visual and auditory stimuli of surrounding buildings, roads, and other hard infrastructure (Ebenberger and Arnberger 2019; Holy-Hasted and Burchell 2022). This explanation is supported by our observation that the increase in reported mental health benefit begins to plateau at greater UGS sizes, where visitors might feel almost entirely isolated from stressful urban stimuli and more fully experience the sense of 'being away' that characterises psychologically restorative environments (Kaplan and Kaplan 1989).

Spring visits corresponded with significantly higher benefit compared to winter visits, which could reflect a positive effect of green vegetation, spring-time flowers and warmer conditions. This trend might also be influenced by national lockdowns imposed in response to the COVID-19 pandemic, which largely fell in the spring for two of the response years in our sample. While there is some evidence that lockdowns were linked to changes in visitor behaviour (e.g. to the frequency of visits; Lemyre and Messina 2023), there is limited evidence to support a link between these periods of social restrictions and the well-being benefit obtained from green space experiences (Darcy et al. 2022). There was no evidence for a corresponding difference between either summer or autumn compared to winter visits, so it may be that the positive change between winter and spring is based on a comparative effect – i.e. the experience of greener and warmer conditions is more strongly related to reported mental health benefit due to the recent change from the colder and less green conditions of the winter months. There is some previous evidence that the amount of local green space is linked most strongly to mental health and well-being during spring, but the relationship between seasonal change and the well-being benefits of green space remain poorly understood (White et al. 2021).

Previous studies provide broad evidence that the natural attributes of UGS have an important link to the experiences and well-being outcomes of users (Reyes-Riveros et al. 2021). The lack of significant associations between specific components of natural quality – tree cover, grassland cover, or blue space cover – and benefit in our model suggest relationships between well-being and diversity or natural quality of UGS may be more complex. We selected this limited set of variables to balance describing the natural character of each site as fully as possible with limiting the risk of overfitting the model (Zhang 2014). It is possible, however, that these three indicators together do not capture enough information about the natural aspects of UGS that are most strongly related to mental health. For example, some
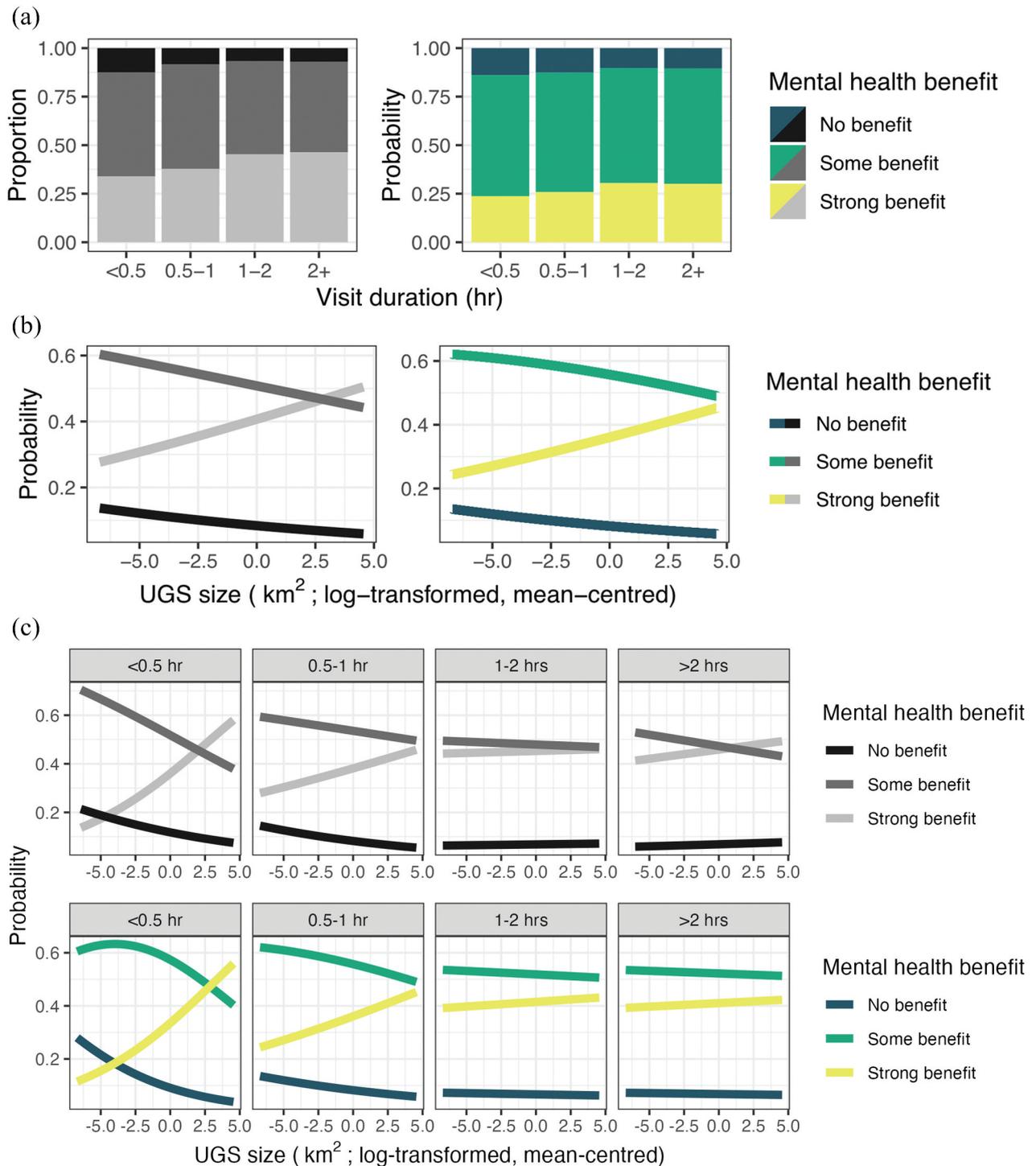
Figure 1. Self-reported mental health benefit from an urban green space visit compared with (a) visit duration (hours), (b) green space size (mean-centred, natural log scale), and (c) both green space area (mean-centred, natural log scale, x-axis) and visit duration (hours, panels). Grayscale plots show the proportion of responses for each benefit level (a) or results from binomial generalised linear models (UGS area against mental health benefit; (b and c). Colour plots show predicted probabilities for each benefit level based on the final model that accounts for other factors.

studies highlight the importance of vegetation structure and distribution (Schebella et al. 2019; Campagnaro et al. 2020), and our natural attribute metrics together do not sufficiently describe the vertical structure of vegetation or its spatial fragmentation across each site. There is therefore potential for further analysis that considers the natural attributes of UGS in greater detail and their role in the mental health outcomes of single visits.

As with natural site attributes, the results of the model do not reveal any significant associations between built attributes and the mental health benefits of UGS visitors. This may simply reflect the different role of built infrastructure in green space,
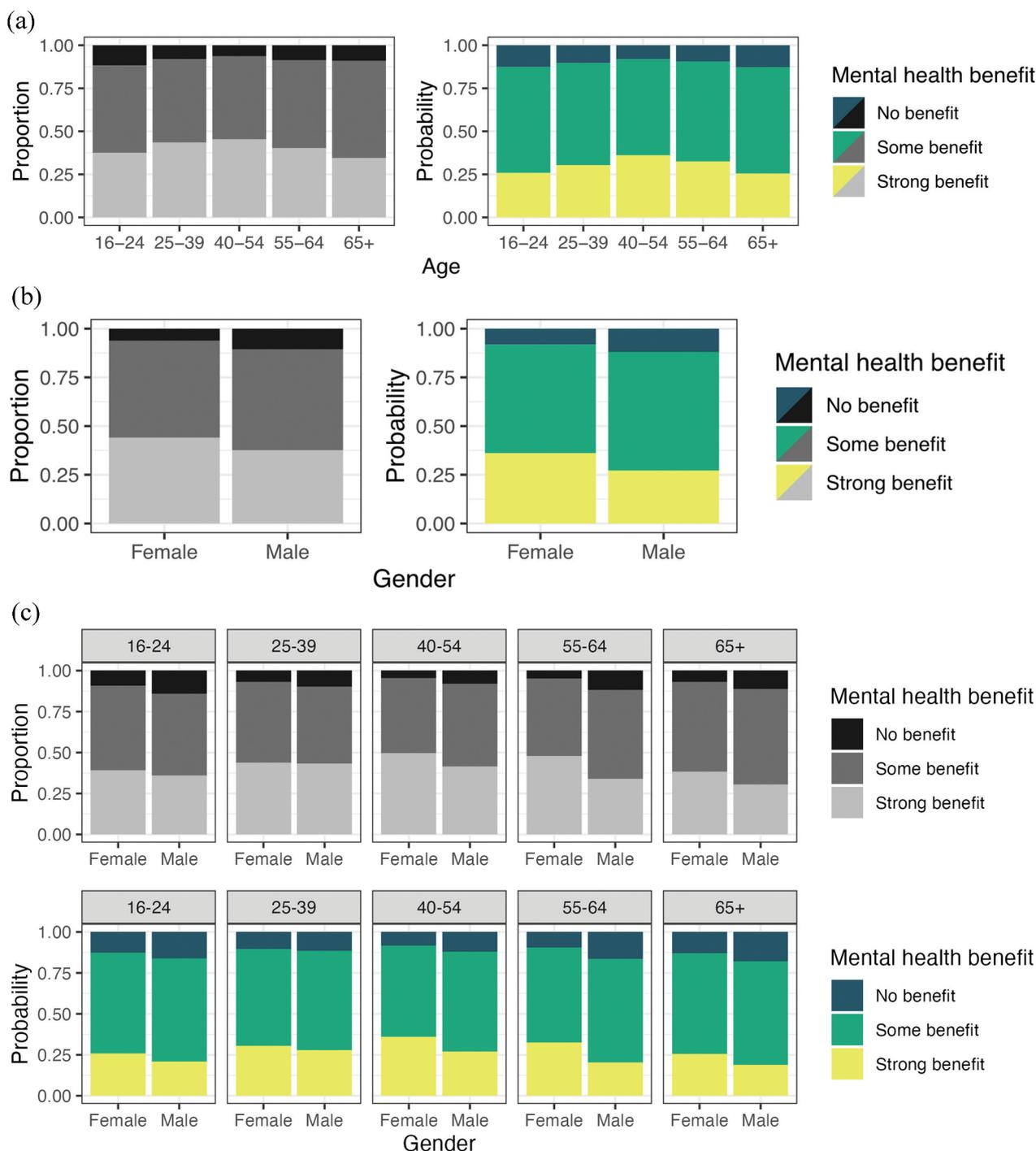
Figure 2. Self-reported mental health benefit from an urban green space visit compared with (a) age, (b) gender, and (c) both age and gender. Grayscale plots show the proportion of responses for each benefit level, calculated from the sample data. Colour plots show predicted probabilities for each benefit level based on the final model that accounts for other factors.

such as playgrounds and sports pitches, as factors that attract visitors and facilitate the activities that promote benefit. There are few previous studies that directly assess the relationship between built UGS attributes and well-being outcomes (e.g. Wood et al. 2018), but a greater number demonstrate links between built attributes and use patterns or preference (Lo and Jim 2012; Lindberg and Schipperijn 2015; Miralles-Guasch et al. 2019; van Vliet et al. 2021). Therefore, built attributes could be considered

to have indirect effects on the mental health benefits of visiting UGS, by influencing the activities undertaken during each visit – which our results suggest do significantly relate to visitor outcomes. Although our additional block regression did not provide any evidence for such indirect relationships (Appendix C), there is scope to investigate specific pathways linking site attributes to visitor activities and their mental health benefit. For example, a future study could assess whether species richness is positively linked
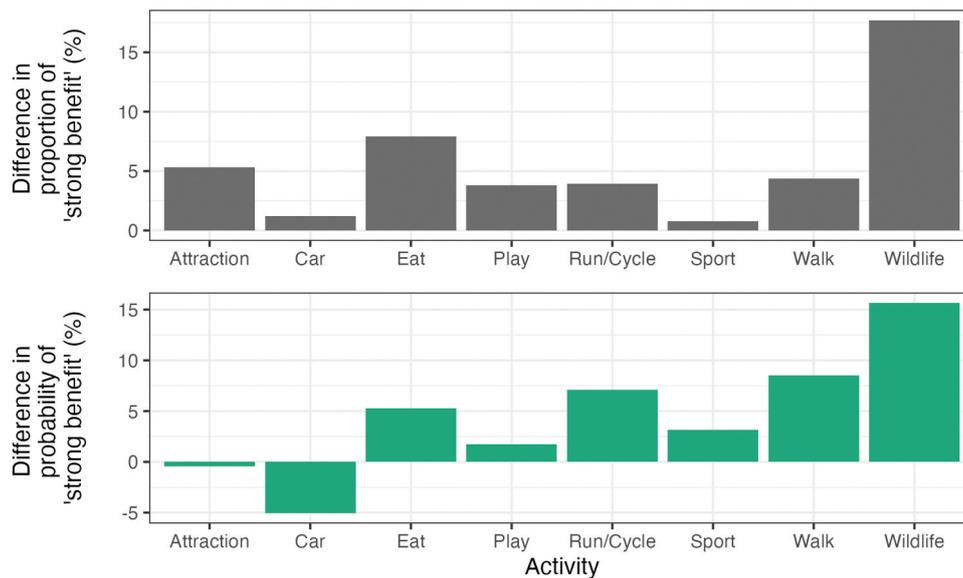
Figure 3. Percentage differences between the probability of a 'strong' mental health benefit of an urban green space visit for people who took part in each of the listed activities versus the probability of 'strong' benefit for those who did not take part in that activity. For descriptions of each activity, see Table 1. The top plot shows the difference between proportions calculated from the sample data. The bottom plot shows the difference between predicted probabilities calculated using the final model.

to the proportion of UGS visitors who watch wildlife, an activity which our analysis suggests is linked to increased mental health benefit.

4.2. Visitor traits

By controlling for the potential confounding effects of the attributes of visited UGS and the activities undertaken by visitors, we were able to investigate how self-reported mental health benefit varies between sociodemographic groups irrespective of the features of individual visits. Women reported significantly higher benefit than men, which reflects previous evidence that women benefit more from access to green space (Ode Sang et al. 2016; Fernández Núñez et al. 2022). This gender relationship may arise because women experience a greater burden of mental health problems compared to men (NHS England 2021; Fernández Núñez et al. 2022), and therefore have greater potential to benefit from restorative experiences like green space visits. Another possible explanation is that women assign greater aesthetic value to green spaces compared to men, which could influence the self-reported benefit from a visit (Ode Sang et al. 2016). Our analysis also provides evidence that green space outcomes vary over life course (Douglas et al. 2017). Middle-aged groups benefitted more than younger and older aged visitors, which could be linked to differing preferences for green space attributes between age groups. For example, Palliwoda and Priess (2021) show that younger visitors prefer sports facilities, middle-aged users prioritise seating and other built infrastructure, while older individuals are more likely to value

natural features. If UGS are more likely to appeal to the preferences of middle-aged visitors, this may explain age-specific trends in experience and well-being outcomes. For example, UGS may provide sufficient paved area for the physical activities preferred by middle-aged visitors, while providing fewer large, wooded areas for activities such as hiking or mountain-biking, preferred by younger people (Nguyen et al. 2021), or areas suited to nature-related activities, which are preferred by older age groups (Ode Sang et al. 2016). This explanation, however, relies on the assumption that visitors who are unable to access their preferred activities and green space features during a visit will report lower mental health and well-being benefit, even though they have selected that particular green space for their visit. Further research would help to illuminate the relationships between preference, use patterns, and mental health outcomes in the context of visitor age.

Another visitor characteristic that was significantly correlated with reported mental health benefit was the presence or absence of a long-term illness or disability. Prior research shows that green space exposure is associated with reduced incidence of several long-term mental health disorders, including depression, anxiety, and ADHD (Nutsford et al. 2013; Bratman et al. 2019; Engemann et al. 2019), while there is some evidence that 'green social prescribing' – non-medical support based in natural settings and prescribed by local medical practitioners – improves the well-being of people living with a mental illness (Thomas et al. 2022). Qualitative research further highlights the role of green space in improving well-being for people with long-term

health conditions through the alleviation of social isolation (Darcy et al. 2022). Our results reveal a new dimension in this area of research, suggesting that a single visit to an UGS is associated with a greater immediate mental health benefit for people with a long-term health condition than for people without one. This relationship may arise as visitors with a long-term illness have lower overall well-being, and therefore greater potential to experience improvement (Harvey et al. 2020). Given that this result from our model is based on a binary indicator of whether or not respondents have any type of long-term condition, there is potential for future research to investigate this relationship in more detail – for example, whether the mental health benefits of green space exposures vary significantly between people living with physical and mental health conditions.

4.3. Activities during visit

There are few previous studies that directly address the relationship between visitor activity and the health benefits of visiting UGS. Many observational studies are unable to do so because they use proxies for actual exposure, such as local green space availability, in place of surveying respondents about a specific green space visit (Beute et al. 2023). Such studies are therefore limited to asking respondents about their preferred green space experiences (Veitch et al. 2020) or drawing indirect conclusions from the results of site attributes linked to specific activities (Wood et al. 2018). Experimental studies that are also interested in site quality usually do not attempt to compare the effect of activity type on benefit due to the practical constraints of experimental design (Martens et al. 2011; Reeves et al. 2019). Our observational study provides a rare example where the link between visit behaviours and mental health outcomes are analysed directly by asking respondents to recall details of a recent visit to a green space (White MP, Pahl S, et al. 2013; Wyles et al. 2019).

Our results suggest that activities characterised by social interaction, aerobic exercise, or experiencing nature, were linked to greater reported mental health benefit. The positive associations of social connectedness and intense physical activity with mental health are well established (Kawachi and Berkman 2001; Mikkelsen et al. 2017), and there is some prior evidence that these relationships persist in the context of green space usage (Fan et al. 2011; Holt et al. 2019). Few studies have investigated the difference in well-being outcomes between green space users who report watching wildlife and those who do not. Our finding that watching wildlife corresponded with a large increase in the reported mental health benefit of an UGS visit could be

explained in terms of nature relatedness – a personal trait that describes both the frequency with which people interact with nature and how much value they place on those experiences (Nisbet et al. 2009). Prior research has shown a positive correlation between nature relatedness and various health and well-being indicators, which is partly reflected by our own finding that people who spent more time in green spaces in the last year – one key element of nature relatedness – received greater benefit from their most recent visit (Dean et al. 2018; Richardson and Hamlin 2021; Grabowska-Chenczke et al. 2022). It could be the case that people with higher nature relatedness are more inclined to watch wildlife (Richardson et al. 2022) and separately to report greater benefit from an UGS visit. It is likely, however, that watching wildlife is itself positively associated with reported benefit, aside from any indirect effect of nature relatedness – for example, by providing a 'softly fascinating' sensory experience that allows recovery from stress and cognitive fatigue (Berman et al. 2008; Basu et al. 2019).

The positive association between visit duration and mental health benefit could support a dose-response relationship (Southon et al. 2018). However, that the journey to and from the visited site is included in our visit duration variable complicates this interpretation. In fact, any combination of the following explanations could apply: i) people are willing to travel for longer to visit a site they know will provide them greater benefit, ii) visitors are more likely to stay longer in sites where they are experiencing greater benefit, or iii) longer green space visits produce greater benefit. Future research on the relationship between visit duration and well-being outcomes should ensure that these different possible effects are addressed separately using targeted survey questions.

4.4. Interrelationships between factors

Our model of the self-reported mental health benefit from UGS visits also includes two significant interaction terms – one between age and gender and another between the size of visited green space and the duration of visits. The results from the latter interaction show that the positive relationship between site area and mental health benefit are more pronounced for shorter visits, under an hour. This relationship could indicate a compensatory effect, whereby a longer visit could make up for any reduction in benefit from visiting a smaller site.

The significant interaction terms in the model together may support the notion that the mental health benefit from a green space experience emerges from the interrelationships between the attributes of

the green space and the behaviours and characteristics of visitors (Jones et al. 2016, 2022). This network of interacting factors forms the basis of the affordances concept, which in the context of green space usage emphasises the active participation of users in a space over the conceptualisation of visitors as passive observers and recipients of benefit (Lennon et al. 2017; Palmer et al. 2023). Our findings highlight the great diversity of needs found in urban communities with regard to UGS provision – i.e. use patterns and health outcomes vary not only between demographic groups and preferred activity, but also by the possible intersections of these factors. Therefore, urban areas that contain a wide range of green space settings will likely provide more mental health and well-being benefit to a wider pool of residents with differing needs and backgrounds.

4.5. Limitations and future opportunities

By analysing responses to PaNS we were able to investigate the self-reported mental health benefit of a recent UGS visit using a large sample of users. However, a limitation imposed by using this dataset was that our measure of benefit was based on a single available survey item, rather than a more robust measure of general mental health and well-being provided by an established and tested mental health scale used in other studies of green space, such as the Short Form Health Survey or Warwick-Edinburgh Mental Well-being Scale (Krefis et al. 2018; Nguyen et al. 2021). In-depth metrics such as these provide more accurate representations of well-being but increase the burden on respondents by requiring them to answer more questions. One advantage of the mental health metric implemented in this study is that it directly addresses the mental health benefit of individual green space visits, whereas most general mental health scales would need to be adapted to this targeted use. There are, however, some established measures of specific aspects of mental well-being that are directly concerned with the well-being potential of the green space visit, which, in addition to being validated metrics, can provide information on specific mental health outcomes – for example, the Perceived Restorativeness Scale (Hartig et al. 1997; Han 2018). Although this study relies on a previously unvalidated, single-item measure of mental health benefit, the large sample size and direct applicability of the survey item to our research questions help to mitigate the limitations of this outcome variable.

Another limitation in this study, common to other observational studies in this area of research, is the inability to identify causal effects, especially in relation to the characteristics of visitors. For example, our results indicate a difference in reported benefit between men and women, which we interpret as women receiving greater mental health benefit from UGS visits compared to men. However, another potential interpretation of this result is that women could be generally more effusive about mental health compared to men, potentially due to gendered differences in stigma around mental health in the UK (Bradbury 2020). It is worth noting that established metrics also experience some level of bias based on demographic groups – for example, answers from the Short Form Health Survey vary among age, education, and ethnic groups (Galenkamp et al. 2018). Experimental studies provide an important way to identify causal relationships, but can be limited in scope – for example, experimental designs related to green space and well-being typically focus on a single visit activity and so only provide insights on a limited set of UGS use scenarios (e.g. Martens et al. 2011; Reeves et al. 2019).

A third limitation of our method arises from respondents being asked to recall their most recent green space visit, up to two weeks before surveying, rather than immediately after their green space exposure (Bell et al. 2019). This problem has been considered in previous studies which similarly asked respondents to recall details of a recent green space visit (White MP, Pahl S, et al. 2013; Wyles et al. 2019). These studies agree that, while surveying green space users *in situ* would be the ideal method to ensure the greatest accuracy of responses, waiting a small number of days to record outcomes is unlikely to greatly impact results – in part, because respondents are asked to elaborate on the details of their visit before answering items on perceived benefit, thus aiding their recollection (White MP, Pahl S, et al. 2013; Wyles et al. 2019).

Further issues arise from the attributes of our selected secondary data sources and the need to compare data from multiple sources. For example, there is a temporal mismatch between the land cover datasets (Copernicus Land Monitoring Service 2020a, 2020b, 2020c), which are produced from measurements in 2018, and our PaNS sample, collected between 2020 and 2023. Any changes in land cover between 2018 and 2023 due to, for example, redevelopment or changes to land management regime, will cause discrepancies between the land cover profile as captured in these datasets and the profile experienced by PaNS respondents during their visit. The 10 m resolution of the CLMS land cover layers limits the precision of our land cover metrics and may fail to capture finer-scale natural attributes within green spaces that may impact visitor experience – for example, linear tree stands (Fang and Ling 2003). The nature of the OSM secondary dataset also introduces uncertainty to our analysis – as an open-source dataset, produced and updated by voluntary contributors, there are fewer

checks to ensure accuracy. This means that areas are irregularly updated and that smaller features (e.g. seating) may not be recorded as reliably. All of the issues introduced by the comparison of these multiple secondary data sources add additional statistical noise to our analysis, thus reducing the overall reliability of results.

Finally, while the data used in this analysis were drawn from a nationally representative sample, by necessarily excluding PaNS respondents who had not visited UGS in the two weeks before answering the survey, there is a bias in our analytical sample towards people who are more likely to spend time in green spaces and those who live in urban areas. This is a limitation inherent to any approach that involves asking respondents about a recent visit and could be mitigated in other studies through the use of experimental research methods.

5. Conclusion

We used a large dataset that describes recent visits to UGS to model self-reported mental health benefit against a) the natural and built attributes of the visited sites, b) the characteristics of visitors, and c) the activities performed during the course of each visit. We found significant relationships for variables from all three of these categories. Site area, gender, age, long-term illness, visit duration, watching wildlife, picnicking, running/cycling, and walking were all significantly related to reported mental health benefit. These results provide evidence to support UGS managers and designers in facilitating a wider range of visitor activities, and wildlife engagement in particular, to promote visitor well-being outcomes. Appropriate interventions might include promoting wildlife through habitat creation and prioritising green space size during the design and planning process. Significant interactions between age and gender, and between visit duration and site area suggest that the mental health benefit from green space visits is determined by the interrelationships between relevant factors. Future research should use targeted measures of the mental health outcomes from UGS exposure to better understand the network of relationships that determines benefit.

Data statement

All data used in this study are publicly available with permission from: Natural England (2023), the European Union's Copernicus Land Monitoring Service (2020a, 2020b, 2020c), OS data Crown Copyright (Ordnance Survey 2023), and OpenStreetMap contributors (2024).

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