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Associations between pro-environmental behaviour and neighbourhood nature, nature visit frequency and nature appreciation: Evidence from a nationally representative survey in England

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ABSTRACT

Progress on changing human behaviour to meet the challenges of regional and global sustainability has been slow. Building on theory as well as small-scale survey and experimental evidence that exposure to nature may be associated with greater pro-environmentalism, the aim of the current study was to quantify relationships between exposure to nature (operationalised as neighbourhood greenspace, coastal proximity, and recreational nature visits) as well as appreciation of the natural world, and self-reported pro-environmental behaviour for the adult population of England. Using data from a nationally representative sample (N = 24,204), and controlling for potential confounders, a structural equation model was used to estimate relationships. Indirect effects of neighbourhood exposures via nature visits and nature appreciation were accounted for. We found positive relationships between both recreational nature visits and nature appreciation and pro-environmental behaviour across both the whole sample and key socio-demographic groups. The more individuals visited nature for recreation and the more they appreciated the natural world, the more pro-environmental behaviour they reported. Although rural and coastal dwellers tended to also be more pro-environmental on average, patterns were complex, potentially reflecting situational constraints and opportunities. Importantly, positive associations between pro-environmental behaviours and high neighbourhood greenspace and coastal proximity were present for both high and low socio-economic status households. Improving access to, and contact with, nature, e.g., through better urban planning, may be one approach for meeting sustainability targets.

1. Introduction

Human actions are threatening the ability of global ecosystems to maintain planetary life-support systems (Steffen et al., 2015). The current research investigated whether urban living, and the associated detachment from the natural world, might be part of the problem (WHO, 2016; Martin and Czellar, 2017). Understanding and influencing the collective behaviours and choices of individuals and households are key for global aspirations embodied in the Paris Agreement on Climate Change and the UN's Sustainable Development Goals (Ostrom, 2012; IPCC, 2018; UNEP, 2011; DEFRA, 2018). In the United States, household energy-related behaviours such as home heating/cooling and cooking account for 18% of greenhouse gas emissions (U.S. Energy Information Administration, 2011). Including all household behaviours (e.g., personal travel), households directly account for 38% of US energy consumption (Gardner and Stern, 2008). The picture is similar in the UK, where household behaviours account for approximately 22% of consumption related CO_2 emissions, rising to 75% if indirect emissions from the production of consumer goods/services are included (Baiocchi et al., 2010). Consequently, there is increasing policy focus on the factors associated with the adoption of greener lifestyle choices (IPCC, 2018).

Sustainability challenges are exacerbated by rapid population growth and increasing urbanisation, and the United Nations predict that the current 55% of the world's population living in urban areas will rise to 68% by 2050. Although urbanisation has potential economic, social and health-related benefits, evidence is growing that a resulting disconnection from the natural world, leading to an 'extinction of experience' of nature (Miller, 2005), is part of the problem of unsustainable lifestyles. For instance, people who live in more urban areas report

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lower environmental concern (Weinstein et al., 2015), adults who had less contact with the natural world as children report fewer pro-environmental behaviours (Evans et al., 2018; Wells and Lekies, 2006), and spending even a short amount of time in an urban, compared to a natural setting, reduces feelings of connectedness to nature (Mayer et al., 2009), and willingness to behave sustainably (Zelenski et al., 2015).

Encouragingly, there are ways of increasing exposure to, contact with, and/or feelings of connectedness with, the natural world even among urban populations (Fuller and Gaston, 2009), and research suggests these processes can enhance pro-social values and behaviours (Guéguen and Stefan, 2016; Weinstein et al., 2009; Zhang et al., 2014), thought to reflect similar underlying values to pro-environmentalism (Schwartz, 1994). A personal connection with nature is held to have an important mediating role in relationships between exposures to nature and pro-environmentalism in individuals (Martin and Czellar, 2017). This 'personal connection' is variously conceived as an emotional affiliation to nature (Mayer and Frantz, 2004), or as part of a person's concept of self (Clayton, 2003), though measures of seemingly distinct concepts such as the "Connectedness to Nature Scale" (Mayer and Frantz, 2004) and the "Environmental Identity Scale" (Clayton, 2003) have substantial convergence and likely reflect a generic psychological phenomenon which is evidenced in evaluative responses to statements expressing appreciation of nature (Brügger et al., 2011).

While several studies also show a positive relationship between some forms of nature contact and/or emotional connectedness and some types of pro-environmental behaviour (PEB), these have generally been conducted with small and/or rural samples (Scannell and Gifford, 2010; Clayton, 2003; Hartig et al., 2001; Kals, et al., 1999; Gosling and Williams, 2010), which limits generalisability. It also remains unclear whether mere *neighbourhood* exposure, e.g., the presence of natural environments near one's home, is linked with people's propensity to act sustainably, or whether this link requires more direct, *intentional* exposure, e.g., recreational visits to natural settings (Keniger et al., 2013). While important advances have been made through experiments and small scale surveys which help us to understand the psychological processes involved (Mayer and Frantz, 2004; Beery and Wolf-Watz, 2014; Gosling and Williams, 2010; Martin and Czellar, 2017), larger scale studies with representative samples can examine additional research questions and increase the policy relevance of conclusions.

Larger scale studies allow for better analysis of how population relationships may be qualified by the socio-demographic factors (e.g., age, gender, social class, labour market status, household composition, disability, ethnicity) which are known to be related to nature exposure and/or PEB. Previous work has also tended to focus on aggregate measures of PEB (Mayer et al., 2009; Zelenski et al., 2015; Scannell and Gifford, 2010; Clayton, 2003; Hartig et al., 2001; Kals et al., 1999; Gosling and Williams, 2010), rather than also analysing how contact with nature may be differently related to the wide range of specific PEBs in both the private (e.g., household recycling) and public (e.g. belonging to an environmental group) spheres (Stern, 2000). Distinguishing such patterns will be invaluable when developing interventions to encourage specific PEBs (Cohen-Shacham et al., 2016; Akenji and Chen, 2016).

The current work makes several advances in our understanding of the link between nature exposure, nature appreciation and PEB. First, we examined the associations between a latent variable measure of general PEB, based on seven different behaviours, and two types of exposure: a) incidental neighbourhood exposure, operationalised as the amount of greenspace in one's neighbourhood, and as the proximity of the neighbourhood to the coast; and b) intentional exposure, operationalised as the frequency of recreational visits to natural environments. Visit frequency is often thought to be facilitated by living nearer to greenspaces (Jones et al., 2009) and the coast (White et al., 2014), and thus could be viewed as a mediator between any neighbourhood - PEB relationship. That is, if a positive relationship between neighbourhood greenspace and/or coastal proximity and PEB is found this might be due to spending more time intentionally visiting that proximal nature, rather than due to incidental exposure from proximity *per se*. By building a structural equation model (SEM) that places visit frequency on the pathway between neighbourhood exposure and PEB, this mediation hypothesis could be tested. Some researchers have suggested that a lack of neighbourhood greenspace (Maat and de Vries, 2006), or at least a lack of good quality local green space (Jones et al., 2009), might lead to compensatory behaviour such that people make intentional visits to nature to balance their lack of neighbourhood exposure (Sijtsma et al., 2012). This alternative mediation hypothesis could be tested in the same way.

Second, we examined a further potential mediating pathway from neighbourhood exposure to PEB, through Nature Appreciation (NA). This tested the hypothesis that living in a greener area/nearer the coast might increase PEB by increasing one's appreciation of the natural world. Although it is possible that NA might influence where one chooses to live, as suggested by a house price premium in greener areas (Gibbons et al., 2014), it is usually a relatively minor consideration compared to factors such as proximity to work, schools and transport links (Schirmer et al., 2014; Gehrke et al., 2019), and thus we assumed it would mainly act as a product of where one lived, rather than a cause. The relationships between the two mediators in our model are theoretically unclear. Does greater NA lead to more visits, or do more visits lead to greater NA? We believed the safest thing to do, especially using cross-sectional data, was assume that these relationships were iterative and bi-directional (although models testing directionality in both directions were also constructed for completeness).

Third, by using a large national dataset, we accounted for a wide set of socio-demographic covariates which are both important sources of individual level heterogeneity, and connected to both nature exposure and PEB, in order to derive population representative estimates of associations. Our large sample size also allowed us to stratify the data on key socio-demographic factors (e.g. gender, age and socio-economic status) to examine whether relationships between exposures to natural environments and PEB observed in the general population held across sub-population groups.

Finally, we re-specified the SEM with each separate self-reported PEB as the outcome variable (in contrast to the underlying latent measure of their commonality) in order to explore whether certain PEBs are more sensitive to nature exposure than others. Our basic approach for both the latent construct of general PEB, and individual PEBs used in

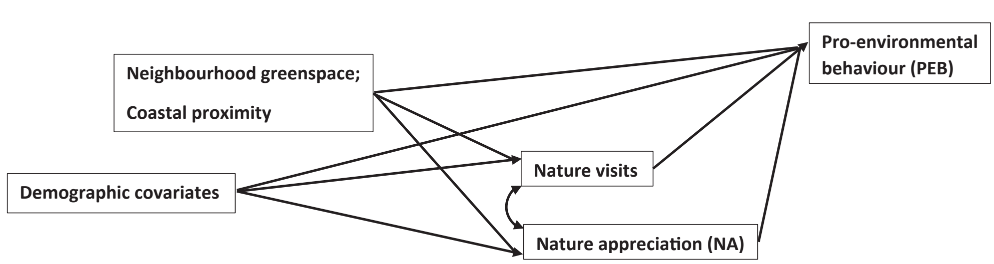

Fig. 1. Schematic representation of SEM to estimate relationships between exposures to natural environments and pro-environmental behaviour.

separate models, can be seen in Fig. 1.

2. Methods

2.1. Participants

Our data were drawn from waves 1–7 of the annual Monitor of Engagement with the Natural Environment (MENE) survey and collected between a twelve month period in 2009/10 (wave 1), and a twelve month period in 2015/6 (wave 7). The survey is part of the UK's official national statistics and representative of the adult population of England (Natural England, 2017). Although there was a potential estimation sample of 24,631, home location data was missing for 426 respondents (1.73%). Demographic characteristics of the resulting available estimation sample (n = 24,204) are presented in Table S1. Sample weights were used in our analyses to ensure full representativeness and generalisability.

2.2. Measures

2.2.1. Variables of Interest

Neighbourhood exposure: Details of the nature exposure variables are given in Table S2, and are summarised here in brief. Neighbourhood exposure defined neighbourhood as the Lower-layer Super Output Area (LSOA) in which respondents lived (ONS, 2012; population ≈ 1500; mean area ≈ 4 km^2). Based on earlier UK studies (Mitchell and Popham, 2008; Wheeler et al., 2012) we considered the amount of greenspace (including gardens) in an individual's neighbourhood, and neighbourhood proximity to the coast. Exposure data on LSOAs were extracted from other sources and applied to the MENE dataset. Greenspace was operationalised from urban-rural classification of LSOAs (Bibby and Shepherd, 2004) and from the Generalised Land Use Database (Office of the Deputy Prime Minister, 2005), and four categories of exposure were derived: Urban, low greenspace (< 50%); Urban, medium greenspace (≥50% to < 75%); Urban, high greenspace (≥75%); and Rural (i.e., 'village', 'hamlet' and 'isolated dwellings'). LSOA coastal proximity was operationalised as the linear distance of the LSOA population weighted centroid to the coast and categorised, as supported by previous research (Wheeler et al., 2012), as coastal (< 5km), intermediate (5–20 km) and inland (> 20 km). Estimation sample frequencies for neighbourhood greenspace and neighbourhood coastal proximity categories, disaggregated by participation in each of the 7 PEB recorded in MENE, are presented in Tables S3 and S4.

Nature visits: The nature visit frequency measure used ordinal categorical responses to the question '*thinking about the last 12 months, how often, on average, have you spent your leisure time out of doors (*e.g., *parks, woodlands, beaches) away from your home?*'. Response options were scored 1–6 and ranged from "Never or only once or twice" (1) to "Every day or more than once per day" (6). Estimation sample frequencies for the six nature visit frequency categories, disaggregated by participation in each of the 7 PEBs recorded in MENE, are presented in Table S5.

Nature appreciation: The nature appreciation variables from which a latent nature appreciation factor was derived were 5-point Likert scale items with responses ranging from *Strongly disagree* (0) to *Strongly agree* (4): (a) *Spending time out of doors (including in my own garden) is an important part of my life*; (b) *There are many natural places I may never visit but I am glad they exist*; (c) *Having open green spaces close to where I live is important*.

Pro-environmental behaviour: Self-reports on seven specific behaviours (with Yes/No responses) were included in the MENE (Table 1). Some of these were considered 'private' sphere (recycling; buying eco-friendly and seasonal/local products; and walking/cycling for short journeys), whereas others were considered 'public' sphere (encouraging others to be pro-environmental; environmental organisation membership; and environmental volunteering). Several behaviours, including green travel choices, recycling, and the purchase of eco-friendly and local/seasonal products, have been identified in strategy documents (DEFRA, 2008, 2011, 2017) as explicit targets of UK government behaviour change intervention. These seven variables were used to construct a latent general PEB factor in the SEM.

Factor analysis: The factor structure of the nature appreciation and behaviour items was explored with Exploratory Factor Analysis (EFA) using a WLSMV estimator and oblique (Geomin) factor rotation. EFA model fit was evaluated by the standards proposed by Hu and Bentler (1999) and Brown (2015) for good fit: RMSEA (≤0.06, 90% CI ≤ 0.06); SRMR (≤0.08); CFI (≥0.95; ≥0.9 adequate fit); TLI (≥0.95; ≥0.9 adequate fit). A two factor model had good fit: RMSEA = 0.033 (95% CI = 0.031–0.035); SRMR = 0.050; CFI = 0.991; TLI = 0.984. The rotated factor loadings for the seven PEB variables were positive and ranged from 0.487 to 0.772 on the first factor, and the rotated factor loadings for the three nature appreciation variables were positive and ranged from 0.705 to 0.886 on the second factor (detail in Table S6); factor correlation = 0.564. In other words, the two constructs were independent and showed good internal reliability. The measurement model of the SEM therefore derived latent factor scores for PEB and NA from the appropriate factor indicators, and these linear factor scores were used in the structural part of the SEM.

2.2.2. Control Variables

Details of the operationalisation of the covariate control variables are given in Table S7. Categorical measures of season and year were included to adjust for seasonal/secular trend in responses. Informed by previous research, we included measures of neighbourhood deprivation, and individual level labour market status (Alcock et al., 2017) and socio-economic status (Kemmelmeier et al., 2002; Gifford and Nilsson, 2014; Whitmarsh and O'Neill, 2010; Alcock et al., 2017) as measured by the social grade classification (National Readership Survey, n/d). We also adjusted for demographic characteristics which have been found to relate to pro-environmentalism: age (Gifford and Nilsson, 2014; Whitmarsh and O'Neill, 2010; Alcock et al., 2017), gender (Gifford and Nilsson, 2014; Whitmarsh and O'Neill, 2010; Alcock et al., 2017), ethnicity (Gifford and Nilsson, 2014), and marital and parenting status (Longhi, 2013; Diamantopoulos et al., 2003; Whitmarsh and O'Neill, 2010; Thøgersen and Ölander, 2006; Alcock et al., 2017). In addition, we accounted for disability, car ownership (Thøgersen and Ölander, 2006) and dog ownership (White et al., 2018), which may influence people's propensity to make nature visits and their pro-environmental behaviour.

2.3. Analysis

The SEM (schematically represented in Fig. 1) was estimated using Mplus V.8 software. The SEM used a mean and variance adjusted weighted least squares estimator and delta parameterisation. Two factors, NA and PEB were defined in the measurement model and then treated as latent mediating and outcome variables in the structural model. The observed variables neighbourhood greenspace, coastal proximity (and covariate control variables) were included in the model to predict the observed variable nature visit frequency and the latent variables NA and PEB. In addition, PEB was regressed on nature visit frequency and on NA.

In addition to a latent variable measure of general PEB derived from the seven binary variables recorded in MENE, each individual behaviour was also included in a separate SEM analysis as the outcome variable. Regression of the binary outcome (y) variables used the variance of the continuous latent variables underlying them (y^*), such that when the value of y^* falls below a threshold, $y = 0$ is observed, and when the value of y^* exceeds a threshold, $y = 1$ is observed; the latent response variable formulation is the same model as the probability curve formulation for probit or logistic regression of y (Muthén, Muthén and Asparouhov, 2016). Linear regressions of continuous latent

Table 1
Pro-environmental behaviour variables in the MENE dataset.

Measure	Label	Response raw N (weight adjusted %)	
Thinking about the last 12 months, which of the following environment-related activities did you do?		Yes	No
I usually recycle items rather than throw them away	Recycling	18,093 (76.0)	6,111 (24.0)
I usually buy eco-friendly products and brands	Eco-products	5,793 (25.3)	18,411 (74.7)
I usually buy seasonal or locally grown food	Seasonal/local	8,935 (38.2)	15,269 (61.8)
I choose to walk or cycle instead of using my car when I can	Green travel	9,827 (42.3)	14,377 (57.7)
I encourage other people to protect the environment	Encouragement	5,971 (25.6)	18,233 (74.4)
I am a member of an environmental or conservation organisation	Membership	1,611 (7.3)	22,593 (92.7)
I volunteer to help care for the environment	Volunteering	1,207 (5.1)	22,997 (94.9)

variables underlying the binary specific PEB outcomes were therefore specified, and the standardised coefficients reported in the results used the variances of those latent variables. Similarly, regression of the ordinal nature visit frequency variable used the variance of the continuous latent variable underlying the ordinal data, such that a significant positive coefficient on a predictor (associated with a higher estimated value on the underlying latent variable) is interpreted to mean that the probability of a higher visit frequency category increases and the probability of a lower visit frequency category decreases.

All analyses applied the sample weights issued with the MENE dataset to increase population representativeness. SEM estimates using bootstrap CIs and 1000 draws, which necessitated treating the MENE weights as if they were explicitly replicate weights (which is not supported by MENE survey documentation), produced non-symmetric CIs which were only negligibly different from the symmetric CIs reported in the results (including for indirect effects), and in no instance was the associated probability threshold different from that reported.

As discussed above we thought the most cautious approach to examining the relationship between nature visit frequency and nature appreciation was to assume a bi-directional relationship, and avoid the specification of a pathway between them whilst allowing their residual terms to covary. Nevertheless, we tested this assumption using exploratory models with the general PEB outcome, in which pathways between nature visit frequency and NA were specified in both directions. These models showed no evidence to support effect priority (results are presented in Table S8), and thus we continued to model them without specifying a pathway between them in our main models.

3. Results

We present the analyses of general PEB at the national population level first, then for sub-groups of the population. Then we present analyses of the specific PEBs in the national population.

3.1. SEM of general pro-environmental behaviour in the national population

Linear and standardised linear estimates for variables of interest in the three regression equations in our SEM are presented in Table 2 (parameter estimates for the measurement part of the model are presented in Table S9).

3.1.1. Visits on neighbourhood

Consistent with a ‘compensatory visits’ hypothesis, the regression of nature visit frequency on neighbourhood exposures to nature showed that people in medium greenspace urban areas made significantly fewer nature visits than those in low greenspace urban areas (equivalent to 8% of 1 SD in nature visit frequency). Contrary to a ‘facilitating’ hypothesis, there were no significant differences in the frequency of nature visits among those in high greenspace urban areas and rural areas, compared to low greenspace urban areas (though a marginally significant positive effect was observed for rural areas). Higher nature visit frequency was, however, associated with both intermediate and proximal coastal neighbourhoods compared to inland neighbourhoods (equivalent to 4% and 18% of 1 SD in nature visit frequency, respectively), suggesting that the proximity of coastal environments facilitated nature visits, consistent with previous findings (White et al., 2014). Approximately 16% of the variance in nature visit frequency was accounted for by the variables (including covariates) in our model.

3.1.2. Nature appreciation on neighbourhood

The regression of nature appreciation (NA) on neighbourhood exposure showed that those in medium greenspace urban areas had significantly lower NA (equivalent to 4% of 1 SD in NA) than those in low greenspace urban areas, which may be related to the higher frequency of nature visits observed among those in these low greenspace neighbourhoods. In contrast, and despite no significant difference in their nature visit frequency, those in high greenspace urban areas and rural areas had significantly higher NA than those in low greenspace urban areas (equivalent to 7% and 18% of 1 SD in NA, respectively). Whilst no difference was observed in NA among those with intermediate coastal proximity compared to those in inland neighbourhoods, those in coastal neighbourhoods also had significantly higher NA (equivalent to 5% of 1 SD in NA). Approximately 10% of the variance in nature appreciation was accounted for by the variables (including covariates) in our model.

3.1.3. PEB on visits, nature appreciation and neighbourhood

Supporting predictions, the regression of PEB found strong significant paths from both mediators (even after adjusting for any indirect effects of neighbourhood exposures via them). For nature visits a 1 SD increase was associated with an increase in PEB equivalent to 17% of 1 SD. For NA, a 1 SD increase was associated with an increase in PEB equivalent to 45% of 1 SD.

The regression of PEB also showed interesting relationships with neighbourhood exposures to greenspace both from indirect effects via the mediators and from direct effects. Taking medium vs. low greenspace urban areas first, although there was no significant total effect (people in low and medium greenspace urban areas reported similar levels of PEB), there were significantly negative indirect effects via both nature visit frequency and NA (though equivalent to only 1% and 2% of 1 SD in PEB, respectively). The lack of an overall total effect was due to a significant positive direct effect. Taken together, these findings suggest that the lower nature visit frequency and NA observed in medium compared to low greenspace urban areas does negatively affect PEB, but they are compensated for by greater generic neighbourhood exposure.

For high (vs. low) greenspace urban areas, the total effect was, this time, positive and significant with greater PEB in high vs. low greenspace areas equivalent to 6% of 1 SD in PEB. There was, however no significant direct effect or indirect effect via visits. A significant positive indirect effect via NA (equivalent to 3% of 1 SD in PEB) contributed to the positive total effect; residents of high green areas were more likely to have higher levels of nature appreciation, which in turn were associated with more PEBs.

Finally, living in a rural (vs. low urban greenspace) area was also

Table 2
SEM of general PEB, linear and standardised linear estimates for variables of interest only.

Outcome	Predictor	Effects Pathway	Estimate	(95% CI)	Stnd Y/XY	(95% CI)
Nature visits[a] (R^2 = 0.158)	Urban, low greenspace	(reference)	/	/	/	/
	Urban, medium greenspace		−0.089***	(−0.127, −0.051)	−0.082***	(−0.117, −0.047)
	Urban, high greenspace		−0.029	(−0.076, 0.017)	−0.027	(−0.070, 0.016)
	Rural		0.059†	(−0.008, 0.127)	0.054†	(−0.008, 0.116)
	Inland	(reference)	/	/	/	/
	Intermediate		0.048*	(0.009, 0.087)	0.044*	(0.009, 0.079)
	Coastal		0.200***	(0.162, 0.238)	0.183***	(0.149, 0.218)
Nature appreciation[a] (R^2 = 0.104)	Urban, low greenspace	(reference)	/	/	/	/
	Urban, medium greenspace		−0.024*	(−0.047, −0.001)	−0.041*	(−0.080, −0.001)
	Urban, high greenspace		0.041**	(0.012, 0.070)	0.070**	(0.020, 0.119)
	Rural		0.107***	(0.062, 0.152)	0.181***	(0.105, 0.257)
	Inland	(reference)	/	/	/	/
	Intermediate		0.005	(−0.020, 0.030)	0.008	(−0.035, 0.050)
	Coastal		0.032**	(0.008, 0.056)	0.054**	(0.014, 0.094)
General PEB[a] (R^2 = 0.443)	Urban, low greenspace	(reference)	/	/	/	/
	Urban, medium greenspace	direct	0.024*	(0.000, 0.047)	0.043*	(0.001, 0.085)
		indirect via visits	−0.008***	(−0.011, −0.004)	−0.014***	(−0.020, −0.008)
		indirect via NA	−0.010*	(−0.020, 0.000)	−0.018*	(−0.036, 0.000)
		total indirect	−0.018**	(−0.029, −0.007)	−0.032**	(−0.052, −0.012)
		total	0.006	(−0.019, 0.031)	0.011	(−0.035, 0.056)
	Urban, high greenspace	direct	0.018	(−0.011, 0.046)	0.032	(−0.019, 0.083)
		indirect via visits	−0.003	(−0.007, 0.002)	−0.005	(−0.012, 0.003)
		indirect via NA	0.018**	(0.005, 0.030)	0.031**	(0.009, 0.054)
		total indirect	0.015*	(0.001, 0.029)	0.027*	(0.002, 0.052)
		total	0.033*	(0.002, 0.063)	0.059*	(0.004, 0.113)
	Rural	direct	0.082***	(0.041, 0.124)	0.147***	(0.073, 0.220)
		indirect via visits	0.005†	(−0.001, 0.011)	0.009†	(−0.001, 0.020)
		indirect via NA	0.046***	(0.026, 0.065)	0.082***	(0.047, 0.116)
		total indirect	0.051***	(0.029, 0.072)	0.091***	(0.053, 0.129)
		total	0.133***	(0.089, 0.177)	0.237***	(0.160, 0.315)
	Inland	(reference)	/	/	/	/
	Intermediate	direct	0.004	(−0.020, 0.028)	0.006	(−0.036, 0.049)
		indirect via visits	0.004*	(0.001, 0.008)	0.007*	(0.001, 0.014)
		indirect via NA	0.002	(−0.009, 0.013)	0.004	(−0.016, 0.023)
		total indirect	0.006	(−0.006, 0.018)	0.011	(−0.010, 0.032)
		total	0.010	(−0.015, 0.035)	0.017	(−0.027, 0.062)
	Coastal	direct	0.050***	(0.026, 0.073)	0.089***	(0.047, 0.131)
		indirect via visits	0.017***	(0.014, 0.021)	0.031***	(0.024, 0.038)
		indirect via NA	0.014**	(0.004, 0.024)	0.024**	(0.006, 0.043)
		total indirect	0.031***	(0.020, 0.043)	0.056***	(0.035, 0.076)
		total	0.081***	(0.056, 0.106)	0.145***	(0.100, 0.189)
	Nature visits		0.087***	(0.077, 0.097)	0.170***	(0.152, 0.188)
	NA		0.425***	(0.401, 0.449)	0.450***	(0.432, 0.469)
NA with visits		covariance	0.148***	(0.140, 0.157)	0.264***	(0.250, 0.278)
Model Fit:	χ^2	(d.f. = 282) 3014.32***				
	RMSEA (95% CI)	0.020 (0.019, 0.021)				
	CFI	0.936				
	TLI	0.913				
	SRMR	0.042				

[a] Adjusted for residential area IMD quintile; age category; gender; ethnicity; labour market status; marital status; parenting status; disability status; car ownership; Social Grade; dog ownership; year; season.
† p < .1.
* p < .05.
** p < .01.
*** p < .001.

associated with greater PEB (total effect equivalent to 24% of 1 SD in PEB). Again, there was no mediation via visits, but a significant indirect effect via NA (equivalent to 8% of 1 SD in PEB). This time, however, there was also a significant direct effect (equivalent to 15% of 1 SD in PEB). Rural dwellers reported more PEBs, in part due to higher nature appreciation, but also directly, due to other characteristics of rural residence (and after accounting for covariates).

In terms of coastal proximity, and as with medium vs. low urban greenspace areas, residents of intermediate (vs. inland) neighbourhoods showed similar levels of PEB (i.e. no significant total effect). However, this time there was only a significant indirect effect via nature visits (equivalent to 1% of 1 SD in PEB), but not via NA. Those who lived 5–20 km from the coast (vs. > 20 km) tended to visit nature more and thus also tended to report higher levels of PEB. There was also no significant direct effect and the lack of a significant total effect reflects the very small indirect effect through visits alongside all other null effects.

Finally, PEBs were significantly higher among residents of coastal (< 5 km from the sea), vs. inland (> 20 km) neighbourhoods (total effect equivalent to 15% of 1 SD in PEB). Most of this large effect came from a significant positive direct effect (equivalent to 9% of 1 SD in PEB), though positive indirect effects via both nature visit frequency and NA were also significant (equivalent to 3% and 2% of 1 SD in PEB, respectively). Coastal dwellers visited nature more and had higher nature appreciation, but these effects alone did not account for the overall positive relationship, again a direct effect provides evidence that other characteristics of coastal residence were involved.

Of note, approximately 44% of the variance in PEB was accounted

Table 3
SEMs of general PEB in sub-populations; estimates for regression equation for PEB only, standardised estimates for variables of interest only. (National population estimates in final column for ease of comparison.)

	Gender categories		Age categories			Socio-economic status categories		Full sample
	Male N = 11,098 (R^2 = 0.442)	Female N = 13,106 (R^2 = 0.437)	Age 16–34 N = 7,482 (R^2 = 0.462)	Age 35–64 N = 10,776 (R^2 = 0.410)	Age ≥ 65 N = 5,946 (R^2 = 0.413)	Low SES N = 13,462 (R^2 = 0.401)	High SES N = 10,742 (R^2 = 0.397)	N = 24,204 (R^2 = 0.443)
Urban, low greenspace	/	/	/	/	/	/	/	/
Urban, medium greenspace, total effect	0.041	−0.021	−0.005	0.007	0.088†	0.047	−0.029	0.011
	(−0.027, 0.109)	(−0.082, 0.040)	(−0.082, 0.072)	(−0.063, 0.076)	(−0.016, 0.192)	(−0.014, 0.108)	(−0.098, 0.041)	(−0.035, 0.056)
Urban, high greenspace, total effect	0.089*	0.027	−0.020	0.098*	0.108†	0.083*	0.044	0.059*
	(0.007, 0.172)	(−0.046, 0.100)	(−0.123, 0.082)	(0.015, 0.181)	(−0.005, 0.222)	(0.008, 0.159)	(−0.038, 0.125)	(0.004, 0.113)
Rural, total effect	0.288***	0.187***	0.108	0.335***	0.192**	0.178**	0.280***	0.237***
	(0.170, 0.406)	(0.083, 0.291)	(−0.071, 0.287)	(0.220, 0.450)	(0.048, 0.335)	(0.059, 0.297)	(0.170, 0.390)	(0.160, 0.315)
Inland	/	/	/	/	/	/	/	
Intermediate, total effect	0.008	0.023	0.080†	0.051	−0.110**	0.027	0.012	0.017
	(−0.060, 0.076)	(−0.038, 0.083)	(−0.011, 0.171)	(−0.017, 0.118)	(−0.193, −0.028)	(−0.038, 0.092)	(−0.054, 0.077)	(−0.027, 0.062)
Coastal, total effect	0.121***	0.169***	0.179***	0.168***	0.075†	0.133***	0.158***	0.145***
	(0.053, 0.188)	(0.110, 0.229)	(0.088, 0.270)	(0.101, 0.235)	(−0.009, 0.159)	(0.070, 0.196)	(0.092, 0.225)	(0.100, 0.189)
Nature visits	0.146***	0.193***	0.091***	0.190***	0.215***	0.164***	0.189***	0.170***
	(0.119, 0.172)	(0.168, 0.218)	(0.058, 0.125)	(0.163, 0.217)	(0.179, 0.252)	(0.139, 0.190)	(0.162, 0.216)	(0.152, 0.188)
Nature appreciation	0.455***	0.450***	0.547***	0.430***	0.384***	0.459***	0.462***	0.450***
	(0.427, 0.482)	(0.426, 0.474)	(0.513, 0.581)	(0.405, 0.455)	(0.345, 0.423)	(0.434, 0.485)	(0.435, 0.488)	(0.432, 0.469)
Model fit statistics:								
χ^2	(d.f. = 274) 1435.65***	(d.f. = 274) 1740.50***	(d.f. = 266) 851.82***	(d.f. = 266) 1419.95***	(d.f. = 258) 1231.75***	(d.f. = 258) 1655.26***	(d.f. = 258) 1621.04***	(d.f. = 282) 3014.32***
RMSEA	0.020	0.020	0.017	0.020	0.025	0.020	0.022	0.020
(95% CI)	(0.019, 0.021)	(0.019, 0.021)	(0.016, 0.018)	(0.019, 0.021)	(0.024, 0.027)	(0.019, 0.021)	(0.021, 0.023)	(0.019, 0.021)
CFI	0.935	0.939	0.947	0.944	0.909	0.935	0.934	0.936
TLI	0.912	0.917	0.927	0.923	0.875	0.912	0.909	0.913
SRMR	0.043	0.042	0.041	0.040	0.044	0.043	0.045	0.042

for by the nature exposure and nature appreciation variables, plus covariates, in our model.

3.2. SEMs of general pro-environmental behaviour in sub-population groups

Standardised linear estimates for the SEM regression of PEB stratified on gender, age and socio-economic status (SES) sub-populations are presented in Table 3 (for ease of interpretation only total effects are given for neighbourhood exposure categories). Results for the full sample are repeated in the final column for ease of comparison.

Findings in the sub-population analyses were broadly similar to those in the overall sample analysis. In particular, the effects of nature visits and nature appreciation were consistently strong across all demographic groups. Relationships with neighbourhood exposure were also broadly similar with a few deviations. In terms of neighbourhood greenspace: (a) For all groups, total effects of medium vs. low greenspace urban neighbourhoods were not statistically significant, consistent with the population estimate; (b) Whilst high vs. low greenspace urban neighbourhoods were again positively associated with PEB, consistent with the population estimate, among males, those aged 35–64 and those in the low SES group, significant associations were not observed among females, those under 35 and over 64, and those in the high SES group; and (c) The total effects of rural vs. low green urban neighbourhoods were significant and positive for all sub-populations, consistent with the population estimate, except among those aged under 35, where positive total effects were not statistically significant. In terms of coastal proximity: (a) There were no significant total effects of intermediate coastal proximity vs. inland neighbourhoods, consistent with the population estimate, with the exception of the sub-population aged over 64, where a negative relationship was observed; and (b) The total effects of coastal vs. inland neighbourhoods were similarly positive across the sub-populations (though only marginally significant among those aged over 64), again consistent with the population estimate.

3.3. SEMs of specific pro-environmental behaviours in the national population

Standardised linear estimates for the SEM regressions of the continuous latent variables underlying each of the specific binary PEB variables (see Methods) are presented in Table 4 (again total effects only are given for neighbourhood exposure categories), where results for the latent general PEB variable underlying their commonality are repeated for ease of comparison in the final column. After adjusting for indirect effects of neighbourhood exposures via visit frequency and nature appreciation, the effects of visits and appreciation were uniformly positive and significant across all seven PEBs. The relationships were especially pronounced between: a) nature visits and green travel (equivalent to 22% of 1 SD); and (b) nature appreciation and encouragement of others (equivalent to 36% of 1 SD).

There were however differences in the sensitivity of different PEBs to effects from neighbourhood nature exposures, especially among the more 'private sphere' behaviours. For example, recycling showed significant positive total effects for all neighbourhood greenspace category contrasts above low urban greenspace and for both coastal proximity category contrasts with inland neighbourhoods. In contrast, buying eco-friendly products showed no significant relationships with neighbourhood nature exposures. Buying seasonal and local produce had significant positive total effects associated with both high urban greenspace and rural neighbourhoods vs. low urban greenspace neighbourhoods and for coastal vs. inland neighbourhoods. In the case of green travel, the direction of significant associations with neighbourhood greenspace was reversed: high greenspace urban and rural vs. low greenspace urban neighbourhoods were associated with reductions in green travel, though a positive relationship was observed for coastal vs. inland neighbourhoods.

By contrast, the 'public sphere' behaviours had a more consistent pattern of association with neighbourhood greenspace. Encouraging pro-environmentalism, membership of environmental organisations and environmental volunteering all had significant positive total effects

Table 4
SEMs of specific PEBs; estimates for regression equations for PEBs only, standardised estimates for variables of interest only. (General PEB estimates in final column for ease of comparison.)

	Recycling (R^2 = 0.209)	Eco-products (R^2 = 0.164)	Seasonal/local (R^2 = 0.259)	Green travel (R^2 = 0.199)	Encouragement (R^2 = 0.196)	Membership (R^2 = 0.243)	Volunteering (R^2 = 0.088)	General PEB (R^2 = 0.443)
Urban, low greenspace	/	/	/	/	/	/	/	/
Urban, medium greenspace, total effect	0.071** (0.025, 0.118)	−0.033 (−0.084, 0.018)	0.040† (−0.006, 0.086)	−0.029 (−0.075, 0.018)	−0.003 (−0.053, 0.048)	−0.023 (−0.102, 0.055)	−0.002 (−0.083, 0.079)	0.011 (−0.035, 0.056)
Urban, high greenspace, total effect	0.119*** (0.061, 0.178)	−0.036 (−0.096, 0.025)	0.143*** (0.089, 0.197)	−0.071* (−0.127, −0.015)	0.012 (−0.049, 0.073)	0.058 (−0.032, 0.148)	0.039 (−0.059, 0.137)	0.059* (0.004, 0.113)
Rural, total effect	0.157** (0.067, 0.247)	0.061 (−0.025, 0.147)	0.407*** (0.331, 0.484)	−0.171*** (−0.252, −0.091)	0.115** (0.029, 0.200)	0.282*** (0.172, 0.393)	0.257*** (0.130, 0.384)	0.237*** (0.160, 0.315)
Inland	/	/	/	/	/	/	/	
Intermediate, total effect	0.085** (0.035, 0.136)	−0.043† (−0.094, 0.007)	0.043† (−0.002, 0.088)	−0.032 (−0.078, 0.015)	0.016 (−0.034, 0.066)	0.008 (−0.060, 0.077)	0.006 (−0.074, 0.086)	0.017 (−0.027, 0.062)
Coastal, total effect	0.123*** (0.074, 0.173)	0.017 (−0.032, 0.066)	0.174*** (0.131, 0.218)	0.111*** (0.066, 0.156)	0.044† (−0.005, 0.093)	0.086* (0.020, 0.153)	0.038 (−0.041, 0.116)	0.145*** (0.100, 0.189)
Nature visits	0.083*** (0.064, 0.102)	0.080*** (0.059, 0.101)	0.089*** (0.071, 0.108)	0.225*** (0.206, 0.243)	0.067*** (0.046, 0.088)	0.077*** (0.047, 0.106)	0.097*** (0.064, 0.129)	0.170*** (0.152, 0.188)
Nature appreciation	0.244*** (0.224, 0.264)	0.294*** (0.273, 0.316)	0.274*** (0.256, 0.293)	0.249*** (0.229, 0.268)	0.358*** (0.338, 0.378)	0.274*** (0.242, 0.306)	0.214*** (0.177, 0.250)	0.450*** (0.432, 0.469)
Model fit statistics:								
χ^2	(d.f. = 64) 861.17***	(d.f. = 64) 857.39***	(d.f. = 64) 863.93***	(d.f. = 64) 910.4***	(d.f. = 64) 860.85***	(d.f. = 64) 854.98***	(d.f. = 64) 869.99***	(d.f. = 282) 3014.32***
RMSEA (95% CI)	0.023 (0.021, 0.024)	0.023 (0.021, 0.024)	0.023 (0.021, 0.024)	0.023 (0.022, 0.025)	0.023 (0.021, 0.024)	0.023 (0.021, 0.024)	0.023 (0.021, 0.024)	0.020 (0.019, 0.021)
CFI	0.964	0.964	0.965	0.963	0.965	0.963	0.961	0.936
TLI	0.909	0.910	0.912	0.906	0.912	0.907	0.903	0.913
SRMR	0.016	0.016	0.016	0.016	0.016	0.016	0.017	0.042

for (only) rural vs. low greenspace urban neighbourhoods. In the case of membership, coastal vs. inland neighbourhoods had a significant positive association; no significant associations were observed between coastal proximity and encouragement or volunteering.

4. Discussion

Protection of the world's natural resources and ecosystems requires individuals and households to adopt more pro-environmental lifestyles and behaviours (Steffen et al., 2015; UNEP, 2011; DEFRA, 2018; Ostrom, 2012; IPCC, 2018). Although fears have been expressed that growing urbanisation and the 'extinction' of nature experiences may be undermining people's connections to the natural world and desire to protect it by behaving pro-environmentally, the evidence for such associations has been limited to smaller-scale samples. The present research addressed this research gap by exploring the relationships between general PEB/specific PEBs, and people's neighbourhood exposure to nature (greenspace amount and proximity to coast), their intentional exposure (frequency of recreational visits per week), and their psychological appreciation of the natural world (e.g. "*There are many natural places I may never visit but I am glad they exist*") by analysing data from a large, nationally representative survey of the English adult population.

4.1. Appreciating nature, visiting nature and PEB

Our findings provide strong support for the argument that people who have greater appreciation of the natural environment, and spend more recreational time in it, also report more pro-environmental behaviours. These patterns were robust across both 'private' (e.g. recycling) and 'public' (e.g. conservation volunteering) sphere behaviours (Stern, 2000). The positive associations with PEBs and nature appreciation are consistent with a body of prior research concerning general environmental identities, attitudes and beliefs (e.g. Brügger, et al., 2011; Clayton, 2003; Kals et al., 1999; Thøgersen and Ölander, 2006; Whitmarsh and O'Neill, 2010). The robust relationships between PEBs and spending time in nature are also consistent with earlier studies (Scannell and Gifford, 2010; Hartig et al., 2001; Kals, et al., 1999; Gosling and Williams, 2010).

In both cases the large and nationally representative nature of the current sample extended earlier work by being able to make clearer statements about how widespread such relationships are even across gender, age and SES groups identified as key predictors of pro-environmentalism (Diamantopoulos et al., 2003; Gifford and Nilsson, 2014; Kemmelmeier et al., 2002; Alcock et al., 2017). Our analyses were also able to explore both processes, appreciation and recreational visits. That both emerged as consistent predictors of PEB suggests that both are involved in the explanation of PEB. Given the cross-sectional nature of our data it was perhaps unsurprising that exploratory path analyses to try and see whether nature appreciation mediated the visits-PEB relationship or *vice versa* produced no clear results either way; people who visited nature more often had a greater appreciation of nature and people with higher appreciations of nature tended to visit nature more often.

However, they are clearly not synonymous in terms of their effects on PEB, and this highlights potential approaches to improving individual level sustainability that require further research. One potential approach could/should target improving people's appreciation of the natural world (reflecting more cognitive/emotional processes); another might address people's direct experience and engagement with nature (reflecting a behavioural process).

4.2. Neighbourhood nature and PEB

Exploring the relationships between PEB and how much greenspace was in an individual's neighbourhood and how close they lived to the sea was a particularly novel aspect of the current research. After accounting for socio-demographic factors, those living in high greenspace urban or rural neighbourhoods reported more environmentally friendly behaviours than those in low greenspace urban neighbourhoods (i.e. significant total effects). For high greenspace urban areas the effect was wholly mediated through greater nature appreciation. The pattern for rural dwellers was similar except that a direct path also emerged (i.e. through other characteristics of rural residence in addition to its impact on NA). We found no evidence of a 'facilitating' effect of high/rural neighbourhood greenspace on nature visits as a mechanism for more pro-environmentalism because, after accounting for covariates, people who lived in these neighbourhoods did not visit nature more often than those in the lowest greenspace areas (Jones et al., 2009).

People in high (vs. low) green urban neighbourhoods seemed to be more pro-environmental due to greater cognitive and emotional connection to the natural world as opposed to simply spending more time in it (issues of causal direction notwithstanding). Whilst this effect via nature appreciation was also observed for people in rural vs. low greenspace neighbourhoods, other mechanisms were also involved in this case.

By contrast, those in medium greenspace urban areas reported visiting nature significantly less than those living in the least green areas, and the indirect pathway to PEB was also significantly negative. One interpretation of these findings is that those in the lowest greenspace urban areas are trying to 'compensate' for the lack of local greenspace by making more active visits (c.f. Sijtsma et al., 2012). Although possible, we have no details on the motives of these residents so this is speculative and it is unclear why such a compensatory mechanism is not operating when compared to the higher greenspace areas. Opponent processes may be at work for these locations such that opportunity and compensation cancel each other out for these high vs. low greenspace comparisons though further research would be needed to unpack this.

Even after controlling for area greenness, those living in coastal neighbourhoods (< 5km) reported more pro-environmental lifestyles than those living inland (> 20 km), with significant indirect effects via both nature visit frequency and nature appreciation; on average, coastal dwellers visited nature more often and had higher nature appreciation. A small indirect effect via visits was also found for intermediate coastal (5–20 km) vs inland (> 20 km) residents. However, the relationship between coastal residence and pro-environmental behaviour also involves factors beyond the impact of coastal proximity on visiting and appreciating nature.

Both our subpopulation and individual PEB analyses suggested that the relationships with neighbourhood exposure were more complex than for nature appreciation and visit frequency. The generally positive relationships for the greenest neighbourhoods held for both males and females and for those of lower and higher socio-economic status, as well as for adults over 35, but we found no evidence for them in younger adults. This may be accounted for by a selective migration effect such that younger adults are still resident in neighbourhoods they grew up in, irrespective of their attitudes towards the natural world, while older adults have deliberately chosen to move to greener areas out of greater appreciation for natural settings. As noted above however, we have no data on motives for locations of residence or any data on how long individuals have lived in their current location so further work would need to be carried out to explore this possibility.

The similarity of findings for those with high vs. low socio-economic status is especially encouraging given that there is good evidence that poorer people in England tend to live in areas with less greenspace (Allen and Balfour, 2014), in part because homes are more expensive in such areas (Gibbons et al., 2014). The high urban greenspace-PEB effect is not, at least in the current sample, simply a wealth issue.

The sometimes subtle relationships between neighbourhood exposure and individual PEBs highlighted why collapsing across multiple behaviours can lead to oversimplification (Larsen et al., 2015) although we should also note that more error variance is associated with responses to single items. The contrasts in specific PEB/neighbourhood greenspace associations speak to the varied constraints and opportunities which greenspace brings. For example, lower levels of green transport (walking/cycling) in high-green urban and rural neighbourhoods may be due to the distance to local amenities and availability of transport infrastructure (e.g. public transport, cycle paths and pavements; Jones et al., 2016). The strongest positive effects for greenspace were with buying local/seasonal produce, which may be due to greater availability of such produce in these areas (e.g. local farmers markets). This interpretation is in line with previous research that has argued behaviours vary in difficulty or cost, and such variation can explain the traditionally observed attitude-behaviour gap (Kaiser et al., 2010, Kaiser et al., 2013).

5. Limitations

Whilst our results are consistent with experimental work suggesting nature exposure can enhance pro-social (Weinstein et al., 2009; Zhang et al., 2014) and pro-environmental values (Martin and Czellar, 2017), we cannot, however, conclude that the effects observed in our SEM correspond to true causal effects, in particular because we cannot eliminate plausible alternative models. Despite evidence that people's prior residential neighbourhood choices are not, in general, governed by the availability of natural environments (Schirmer et al., 2014; Gehrke et al., 2019), we are unable to rule out the possibility that, for example, those with greater appreciation of nature (and already having more pro-environmental behaviour) chose to move to greener/coastal neighbourhoods for that reason. The interpretation that the effects observed in our SEM analyses indicate causality would be supported by replication across independent samples, and by corroborating evidence from empirical studies which manipulate nature exposures, such as intervention studies.

The self-report nature of our measures of both intentional exposure and PEBs is another limitation. Furthermore, the binary response options for the PEB items may also simplify complex realities. Nonetheless, our measure of neighbourhood exposure was relatively objective and many of the patterns with specific PEBs, such as walking/cycling for short journeys and buying local/seasonal produce did appear consistent with situational constraints and opportunities, which suggest the self-reports did, at least in part, genuinely reflect actual behaviour. Further work using more objective and nuanced measures of nature visits, such as geo-located and time logged visit data, and of PEBs, such as audited produce purchase data, would enrich the present findings.

Our findings are also limited to the adult population of England and similar research is needed in other countries, especially where the kind of household behaviours discussed here may be more (e.g., Sweden) or less (e.g., USA) widespread (OECD, 2015), and in countries with a still largely rural population such as China and India undergoing rapid urbanisation. Understanding the exposure-response relationships between nature exposure and pro-environmental behaviours in these societies will be especially critical in understanding the global implications of detachment from, versus maintaining some connectedness with, the natural world.

6. Conclusion

We found that people with higher appreciation of nature and those who spent more recreational time in natural settings were also more likely to report engaging in a range of pro-environmental behaviours in a large, nationally representative English sample. After accounting for the influences of neighbourhood factors on people's intentional contact, neighbourhood exposures were themselves important, with more neighbourhood exposure to green/blue space also being related to greater general PEB and greater participation in most specific PEBs. Efforts to increase contact through improving social participation and physical infrastructure, i.e., through both influencing perceptions to make people want to visit natural environments, and through developing neighbourhood design policies to improve access to natural spaces in urban settings, may thus play a part in encouraging more sustainable behaviours (c.f. WHO, 2016, where such a dual approach to urban green space interventions for health is recommended). National planning policies for climate change frequently encourage the creation and protection of urban green spaces as a way to *adapt* to flooding, urban heat island effects, and other environmental challenges (DEFRA, 2018). Given the impact of lifestyle choices on carbon emissions, our results imply a benign circle in which urban green spaces may also contribute to *mitigation* by helping urban individuals reconnect with the natural world and adopt more pro-environmental lifestyles.

Declaration of Competing Interest

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envint.2019.105441.

References

Akenji, L., Chen, H., 2016. A framework for shaping sustainable lifestyles: Determinants and strategies. United Nations Environment Programme, Nairobi, Kenya.
Alcock, I., White, M., Taylor, T., Coldwell, D., Gribble, M.O., Evans, K.L., Corner, A., Vardoulakis, S., Fleming, L.E., 2017. 'Green' on the ground but not in the air: Pro-environmental attitudes are related to household behaviours but not discretionary air travel. Global Environ. Change 42, 136–147.
Allen, J., Balfour, R., 2014. Natural solutions for tackling health inequalities. Report for the Institute of Health Equity and Natural England. Downloaded 28/09/19 from: http://www.instituteofhealthequity.org/resources-reports/natural-solutions-to-tackling-health-inequalities/natural-solutions-to-tackling-health-inequalities.pdf.
Baiocchi, G., Minx, J., Hubacek, K., 2010. The impact of social factors and consumer behavior on carbon dioxide emissions in the United Kingdom: a regression based on input-output and geodemographic consumer segmentation data. J. Ind. Ecol. 14, 50–72.
Beery, T.H., Wolf-Watz, D., 2014. Nature to place: Rethinking the environmental connectedness perspective. J. Environ. Psychol. 40, 198–205.
Bibby, P., Shepherd, J., 2004. Developing a new classification of urban and rural areas for policy purposes—the methodology. Department for Environment, Food and Rural Affairs, London, UK.
Brown, T.A., 2015. Confirmatory Factor Analysis for Applied Research, 2nd ed. Guilford Publications, New York, NY.
Brügger, A., Kaiser, F.G., Roczen, N., 2011. One for all? Connectedness to nature, inclusion of nature, environmental identity, and implicit association with nature. Eur. Psychol. 16, 324–333.
Clayton, S., 2003. Environmental identity: A conceptual and operational definition. In: Clayton, S., Opotow, S. (Eds.), Identity and the natural environment: The psychological significance of nature. MIT Press, Cambridge, MA, USA, pp. 45–65.
Cohen-Shacham, E., Walters, G., Janzen, C., Maginnis, S., 2016. Nature-based Solutions to address global societal challenges. International Union for Conservation of Nature, Gland, Switzerland.
DEFRA, 2008. A Framework for Proenvironmental Behaviours. Report January 2008. Department of Environment, Food and Rural Affairs, HM Government, London, UK.
DEFRA, 2011. The Sustainable Lifestyles Framework. Department of Environment, Food and Rural Affairs, HM Government, London, UK.
DEFRA, 2017. Defra Group Areas of Research Interest. March 2017. Department of Environment, Food and Rural Affairs, HM Government, London, UK.
DEFRA, 2018. The National Adaptation Programme and the Third Strategy for Climate Adaptation Reporting: Making the country resilient to a changing climate. Department of Environment, Food and Rural Affairs, HM Government, London, UK.
Diamantopoulos, A., Schlegelmilch, B.B., Sinkovics, R.R., Bohlen, G.M., 2003. Can socio-demographics still play a role in profiling green consumers? a review of the evidence and an empirical investigation. J. Business Res. 56, 465–480.
Evans, G.W., Otto, S., Kaiser, F.G., 2018. Childhood origins of young adult environmental behavior. Psychol. Sci. 29, 679–687.
Fuller, R.A., Gaston, K.J., 2009. The scaling of green space coverage in European cities. Biol. Lett. 5, 352–355.
Gardner, G.T., Stern, P.C., 2008. The short list: The most effective actions U.S. households can take to curb climate change. Environ.: Sci. Policy Sustain. Develop. 50, 12–24.
Gehrke, S.R., Singleton, P.A., Clifton, K.J., 2019. Understanding stated neighborhood preferences: the roles of lifecycle stage, mobility style, and lifestyle aspirations. Travel Behaviour Soc. 17, 62–71.
Gibbons, S., Mourato, S., Resende, G.M., 2014. The amenity value of English nature: a hedonic price approach. Environ. Resour. Econ. 57, 175–196.
Gifford, R., Nilsson, A., 2014. Personal and social factors that influence pro-environmental concern and behaviour: A review. Int. J. Psychol. 49, 141–157.
Gosling, E., Williams, K., 2010. Connectedness to nature, place attachment and conservation behaviour: Testing connectedness theory among farmers. J. Environ. Psychol. 30, 298–304.
Guéguen, N., Stefan, J., 2016. "Green Altruism": Short immersion in natural green environments and helping behavior. Environ. Behavior 48, 324–342.
Hartig, T., Kaisser, F.G., Bowler, P.A., 2001. Psychological restoration in nature as a positive motivation for ecological behaviour. Environ. Behavior 33, 590–607.
Hu, L., Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct. Equation Modeling 6, 1–55.
IPCC, 2018. Global Warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. IPCC, Geneva, Switzerland.
Jones, A., Hillsdon, M., Coombes, E., 2009. Greenspace access, use, and physical activity: understanding the effects of area deprivation. Prev. Med. 49, 500–505.
Jones, T., Horton, D., Mullen, C., Pooley, C., Scheldeman, G., Strano, E., Tight, M., 2016. The role of street network connectivity and access to everyday facilities in shaping everyday walking and cycling in English cities. In: Gerike, R., Hülsmann, F., Roller, K. (Eds.), Strategies for Sustainable Mobilities: Opportunities and Challenges. Routledge, Abingdon, UK and New York, USA, pp. 15–38.
Kaiser, F.G., Byrka, K., Hartig, T., 2010. Reviving Campbell's paradigm for attitude research. Personal. Soc. Psychol. Rev. 14, 351–367.
Kaiser, F.G., Hartig, T., Brügger, A., Duvier, C., 2013. Environmental protection and nature as distinct attitudinal objects: An application of the Campbell paradigm. Environ. Behavior 45, 369–398.
Kals, E., Schumacher, D., Montada, L., 1999. Emotional affinity toward nature as a motivational basis to protect nature. Environ. Behavior 31, 178–202.
Kemmelmeier, M., Kròl, G., Young, H.K., 2002. Values, economics, and proenvironmental attitudes in 22 societies. Cross-Cultural Res. 36, 256–285.
Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013. What are the benefits of interacting with nature? Int. J. Environ. Res. Public Health 10, 913–935.
Larsen, L.R., Stedman, R.C., Cooper, C.B., Decker, D.J., 2015. Understanding the multi-dimensional structure of pro-environmental behaviour. J. Environ. Psychol. 43, 112–124.
Longhi, S., 2013. Individual pro-environmental behaviour in the household context. ISER Working Paper No. 2013-21. Available online from https://www.iser.essex.ac.uk/research/publications/working-papers/iser/2013-21.pdf.
Maat, K., De Vries, P., 2006. The influence of the residential environment on green-space travel: testing the compensation hypothesis. Environ. Planning A 38, 2111–2127.
Martin, C., Czellar, S., 2017. Where do biospheric values come from? A connectedness to nature perspective. J. Environ. Psychol. 52, 56–68.
Mayer, F.S., Frantz, C.M., 2004. The connectedness to nature scale: a measure of individuals' feeling in community with nature. J. Environ. Psychol. 24, 503–515.
Mayer, S.F., Frantz, C.M., Bruehlman-Senecal, E., Dolliver, K., 2009. Why is nature beneficial? The role of connectedness to nature. Environ. Behavior 41, 607–643.
Miller, J.R., 2005. Biodiversity conservation and the extinction of experience. Trends Ecol. Evol. 20, 430–434.
Mitchell, R., Popham, F., 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372, 1655–1660.
Muthén, B.O., Muthén, L.K., Asparouhov, T., 2016. Regression and Mediation Analysis using Mplus. Muthén & Muthén, Los Angeles, CA.
Natural England. 2017. Monitor of Engagement with the Natural Environment: the national survey on people and the natural environment. Technical Report to the 2009-16 Surveys. Natural England Joint Report JP023.
National Readership Survey. n/d. Social Grade. Available online from http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/.
OECD, 2015. Environment at a Glance 2015: OECD Indicators. OECD Publishing, Paris, France.
Office of the Deputy Prime Minister, 2005. Generalised Land Use Database Statistics for

England. ODPM Publications, London, UK.
ONS, 2012. Changes to Output Areas and Super Output Areas in England and Wales, 2001 to 2011. Office for National Statistics, Newport, UK.
Ostrom, E., 2012. Nested externalities and polycentric institutions: must we wait for global solutions to climate change before taking actions at other scales? Econ. Theor. 49, 353–369.
Scannell, L., Gifford, R., 2010. The relations between natural and civic place attachment and pro-environmental behavior. J. Environ. Psychol. 30, 289–297.
Schirmer, P.M., van Eggermond, M.A.B., Axhausen, K.W., 2014. The role of location in residential location choice models: a review of literature. J. Transp. Land Use 7, 3–21.
Schwartz, S.H., 1994. Are there universal aspects in the structure and contents of human values? J. Soc. Iss. 50, 19–45.
Sijtsma, F.J., de Vries, S., van Hinsberg, A., Diederiks, J., 2012. Does 'grey' urban living lead to more 'green' holiday nights? A Netherlands case study. Landscape Urban Plann. 105, 250–257.
Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetze, I., Bennett, E.M., et al., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 347 (6223), 1259855.
Stern, P.C., 2000. New environmental theories: toward a coherent theory of environmentally significant behaviour. J. Soc. Iss. 56, 407–424.
Thøgersen, J., Ölander, F., 2006. To what degree are environmentally beneficial choices reflective of a general conservation stance? Environ. Behavior 38, 550–569.
UNEP, 2011. Vision for change: Recommendations for effective policies on sustainable lifestyles. United Nations Environment Programme, Paris, France.
U.S. Energy Information Administration. 2011. Emissions of Greenhouse Gases in the United States 2009. Available online from: https://www.eia.gov/environment/emissions/ghg_report/pdf/0573%282009%29.pdf.
Weinstein, N., Balmford, A., DeHaan, C.R., Gladwell, V., Bradbury, R.B., Amano, T., 2015. Seeing community for the trees: the links among contact with natural environments, community cohesion, and crime. Bioscience 65, 1141–1153.
Weinstein, N., Przybylski, A.K., Ryan, R.M., 2009. Can nature make us more caring? effects of immersion in nature on intrinsic aspirations and generosity. Pers. Soc. Psychol. Bull. 35, 1315–1329.
Wells, N.M., Lekies, K.S., 2006. Nature and the life course: Pathways from childhood nature experiences to adult environmentalism. Children, Youth Environ. 16, 1–24.
Wheeler, B.W., White, M.P., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and wellbeing? Health & Place 18, 1198–1201.
White, M.P., Wheeler, B.W., Herbert, S., Alcock, I., Depledge, M.H., 2014. Coastal proximity and physical activity. Is the coast an underappreciated public health resource? Prev. Med. 69, 135–140.
White, M.P., Elliott, L.R., Wheeler, B.W., Fleming, L.E., 2018. Neighbourhood greenspace is related to physical activity, but only for dog owners. Landscape Urban Plann. 174, 18–23.
Whitmarsh, L., O'Neill, S., 2010. Green identity, green living? The role of proenvironmental self-identity in determining consistency across diverse proenvironmental behaviours. J. Environ. Psychol. 30, 305–314.
WHO, 2016. Urban Green Spaces and Health. World Health Organization Regional Office for Europe, Copenhagen, Denmark.
Zelenski, J.M., Dopko, R.L., Capaldi, C.A., 2015. Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behaviour. J. Environ. Psychol. 42, 24–31.
Zhang, J.W., Piff, P.K., Iyer, R., Koleva, S., Keltner, D., 2014. An occasion for unselfing: beautiful nature leads to prosociality. J. Environ. Psychol. 37, 61–72.