

## **The rarity of direct experiences of nature in an urban population**

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## Highlights

- The most common form of nature experience involves not being present in nature
- Accumulatively 75% of time in nature was experienced by just 32% of the population
- People who experience nature regularly are the exception as opposed to the norm
- Connectedness to nature was positively correlated with spending time in nature
- Deconstructing nature dose will allow the development of targeted health outcomes

1 **Abstract**

2 As people live more urbanised lifestyles there is potential to lose daily contact with nature,  
3 diminishing access to the wide range of associated health benefits of interacting with nature.  
4 Experiences of nature vary widely across populations, but this variation is poorly understood.  
5 We surveyed 1,023 residents of an urban population in the UK to measure four distinctly  
6 different nature interactions: indirect (viewing nature through a window at work and at home),  
7 incidental (spending time outside at work), intentional (time spent in private gardens) and  
8 intentional (time spent in public parks). Scaled-up to the whole study population, accumulation  
9 curves of the total number of hours per week that people were exposed to each type of nature  
10 interaction showed that 75% of nature interactions were experienced by half the population.  
11 Moreover, 75% of the interactions of a type where people were actually present in nature were  
12 experienced by just 32% of the population. The average hours each individual experienced  
13 nature per week varied across interactions: indirect ( $46.0 \pm 27.3$  SD), incidental ( $6.4 \pm 12.7$  SD),  
14 intentional-gardens ( $2.5 \pm 2.9$  SD) and intentional-parks ( $2.3 \pm 2.7$  SD). Experiencing nature  
15 regularly appears to be the exception rather than the norm, with a person's connection to nature  
16 being positively associated with incidental and intentional experiences. This novel study  
17 provides baseline information regarding how an urban population experiences different types of  
18 nature. Deconstructing nature experience will pave the way for developing recommendations for  
19 targeted health outcomes.

20

21 **1. Introduction**

22 With over 70% of the global human population predicted to live in cities within 30 years (WHO,  
23 2016a), urbanisation is considered one of the most significant health issues of the 21<sup>st</sup> century

24 (WHO, 2016b), tied as it is to growing levels of chronic, non-communicable and mental health  
25 conditions (Dye, 2008; Sundquist, Frank, & Sundquist, 2004). Urban nature has the potential to  
26 help mitigate many of these health issues (Keniger, Gaston, Irvine, & Fuller, 2013; Shanahan et  
27 al., 2015b), with demonstrable links between exposure to nature and health and well-being  
28 benefits (Hough, 2014; Keniger et al., 2013; Shanahan, Fuller, Bush, Lin, & Gaston, 2015a).  
29 These benefits span a remarkable range of health outcomes, with evidence for reduced all-cause  
30 mortality and mortality from cardiovascular disease (Donovan et al., 2013; Mitchell & Popham,  
31 2008), reduced allergies (Hanski et al., 2012), enhanced general and self-reported health (e.g.  
32 Groenewegen, van den Berg, Mass, Verheij, & de Vries, 2012; Maas, Verheij, Groenewegen, de  
33 Vries, & Spreeuwenberg, 2006), improved self-reported wellbeing and a reduced risk of poor  
34 mental health (e.g. Bratman, Hamilton, & Daily, 2012; Bratman, Hamilton, Hahn, Daily, &  
35 Gross, 2015; Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007; White, Alcock, Wheeler,  
36 & Depledge, 2013) and improved cognitive ability (Berman, Jonides, & Kaplan, 2008; Han,  
37 2009).

38

39 Within the urban environment, exposure to nature is more complex and versatile than often  
40 portrayed; to a greater or lesser extent many people are exposed to components of nature  
41 throughout their daily lives. Keniger et al., (2013) identified three types of nature interactions.  
42 First, there is robust evidence for the benefits from ‘indirect interactions’ with nature while not  
43 being present in it (e.g. having a view of nature from home or work), including increased  
44 psychological well-being (Kaplan, 2001) and reduced stress at work (Kaplan, 1993). Second,  
45 people benefit from ‘incidental interactions’ with nature while carrying out another activity (e.g.  
46 walking past street trees during daily activities), which can lead to decreased levels of stress

47 (Kaplan, 1993; Lottrup, Grahn, & Stigsdotter, 2013). Third, there is a broad range of benefits  
48 provided by ‘intentional interactions’ (e.g. where someone intends to interact with nature through  
49 visiting parks or gardens), including reduced mortality from cardiovascular disease (Mitchell &  
50 Popham, 2008) and improved mental health (Fuller et al., 2007).

51  
52 Plainly, different people receive different levels of each kind of nature experience. This variation  
53 likely results from a combination of orientation and opportunity (Lin, Fuller, Bush, Gaston, &  
54 Shanahan, 2014; Soga & Gaston, 2015). Some people are more inclined towards interacting with  
55 nature (orientation), and some have greater access to those interactions (opportunity). Orientation  
56 and opportunity are themselves shaped by a wide array of factors including location, age, gender,  
57 ethnicity, income and education, and potentially complex interactions between them (Lin et al.,  
58 2014; McCormack, Rock, Toohey, & Hignell, 2010). The net outcome, combined with the  
59 composition of an urban population, will determine the extent to which nature interactions are  
60 distributed across that population in a more or less equitable fashion (with interactions being  
61 roughly equally distributed or disproportionately experienced by a small number of people). To  
62 date, this outcome is poorly understood.

63  
64 Deconstructing people’s daily nature experience is the first step towards better integrating  
65 science with planning and policy for improved health outcomes (Shanahan et al., 2015b).  
66 Modelling how, where and what type of nature people experience will allow a clearer  
67 understanding of how targeted green planning can be better incorporated into the daily lives of  
68 urban dwellers. For example, what kind of environments encourage walking (Middleton, 2010),

69 with the implications for behavioural change, advocacy, design and policy to create better urban  
70 environments.

71

72 In an urban population we examine four common nature interactions for which there is tangible  
73 evidence for pathways of benefit delivery: indirect interactions (time spent at home and at work  
74 in a room with a view of nearby nature); incidental interactions (time spent outside as part of  
75 job); intentional interactions (time spent in private gardens) and intentional interactions (time  
76 spent in public parks). We explore three questions: 1) How are experiences of nature distributed  
77 across different nature interactions? 2) How does this vary across the population? 3) How are  
78 these experiences distributed across socio-demographic groups?

79

## 80 **2. Material and methods**

81 This study was conducted within the urban limits of the ‘Cranfield triangle’ (52°07’N, 0°61’W),  
82 a region in southern England, U.K., comprising three adjacent towns of Milton Keynes, Luton  
83 and Bedford. These have a human population of c. 609,501 (2011 Census, UK), and occupy 166  
84 km<sup>2</sup>. An urban lifestyle survey, delivered online through a market research company (Shape the  
85 Future Ltd), was completed in May 2014 by 1,023 adults enrolled in their survey database.

86 Participants were self-selecting and were compensated with a nominal fee. Within the  
87 questionnaire, we collected several socio-demographic covariates that could influence nature  
88 interactions including age, gender, the primary language spoken at home, personal annual  
89 income, highest formal qualification, self-assessment of health and nature orientation (Table S1  
90 shows the variables and classifications for analysis purposes).

91

92 Respondents provided self-reported information on four types of common nature interaction that  
93 they experience in an average week:

94 (i) *Indirect interactions*: Time spent at home and at work in a room with a view of nearby nature  
95 (within 500m; defined as no view, trees, parks, countryside, lake, canal or river). Respondents  
96 were asked how many days a week they worked, before selecting how much time they spent in a  
97 room with a view of nature at home on an average workday and an average non-workday, and at  
98 work on an average working day. In each case respondents selected from the categories: Less  
99 than an hour; 1-2 hours; >2-4 hours; >4-6 hours; >6-8 hours; >8-10 hours; >10-12 hours; >12  
100 hours. The mid-points of the selected categories were chosen (where 12 or more hours was  
101 treated as '12') and then the total time per week was calculated by summing the number of hours  
102 on a work day by the number of days worked, and adding the sum of the number of hours on a  
103 non-work day by the number of days not worked.

104 (ii) *Incidental interactions*: Time spent working outdoors in an average week. Respondents  
105 selected from the categories: No time; 5 hours or less; 6-10 hours; 11-20 hours; 21-30 hours; 31-  
106 40 hours; 41-50 hours; 51-60 hours; 61-70 hours; 71 or more hours; Most of the time (in a  
107 separate question respondents were asked how many hours they spend at work). The mid-points  
108 of selected categories were chosen (where 71 or more hours was treated as '71').

109 (iii) *Intentional interactions (gardens)*: Time spent in private gardens. Respondents selected the  
110 total time spent in their private gardens in the last week from the categories; I don't have a  
111 garden / no time (these answers were combined, because both responses indicate no experiences  
112 of nature in private gardens), 1-30 minutes, 31 minutes to 1 hour, >1-3 hours, >3-5 hours; >5-7  
113 hours, >7-9 hours, >9 hours. The mid-points of the selected categories were used for analysis  
114 purposes (where 9 or more hours was treated as '9').

115 (iv) *Intentional interactions (parks)*: Time spent in up to seven public parks. Respondents  
116 selected from the categories; 1-29 minutes; 30 minutes -1 hour; >1-2 hours, >2-3 hours, >3-4  
117 hours, >4 hours. The mid-points of the selected categories were identified (where 4 or more  
118 hours was treated as '4') and then the total time was summed across all public parks visited.

119

## 120 2.1. Statistical analysis

121 We built a generalised linear mixed model with a Gaussian error distribution to model the total  
122 time spent experiencing each type of nature interaction (dependent variable), with each  
123 respondent as a random effect, against the type of nature interaction, nature orientation, self-  
124 assessment of health, age, income, gender, education and ethnicity. We log-transformed the  
125 dependent variable so that it was approximately normally distributed, before testing for the  
126 effects of covariates and paired interactions (nature interaction\*nature orientation, nature  
127 interaction\*age, nature interaction\*income). We used the 'MuMIn' package (Bartoń, 2015) to  
128 produce all subsets of models based on the global model and rank them based on AICc.  
129 Following Richards (2005) we retained all models where  $\Delta AIC_c < 6$ . We then used model-  
130 averaging to produce the coefficients with standard errors and 95% confidence intervals, of each  
131 retained parameter and interaction (Burnham & Anderson, 2002).

132

133 We scaled-up the total hours per week that survey respondents spent experiencing each type of  
134 nature interaction to the population of the Cranfield triangle. Based on the proportions indicated  
135 by the 2011 Census data we stratified by age (four level factor) to correct the survey population  
136 sample to that of the actual population (Appendix S1). We plotted accumulation curves for the  
137 total number of hours per week that both the survey respondents and the population of the



138 Cranfield triangle were exposed to each type of nature interaction, and for total time across  
139 interactions. We started with respondents who spent the greatest time experiencing nature, and  
140 then accumulatively added each respondent to the total population hours in the order of  
141 decreasing time spent experiencing nature.

142

### 143 **3. Results**

144 The average number of hours during which each individual experienced nature per week varied  
145 across interactions: indirect ( $46.0 \pm 27.3$  SD), incidental ( $6.4 \pm 12.7$  SD), intentional-gardens ( $2.5$   
146  $\pm 2.9$  SD) and intentional-parks ( $2.3 \pm 2.7$  SD; Fig. 1a-d). Across all four nature interactions  
147 people spent on average  $57.3 \pm 31.9$  SD hours per week (Fig.1e).

148

149 Accumulation curves were almost identical for survey respondents and when scaled up to the  
150 whole population for indirect interactions, which were experienced by the majority of people  
151 (Fig. 1a). For other kinds of nature experiences, scaling up led to somewhat slower rates of  
152 accumulation than for the survey respondents alone (Fig. 1). A small proportion of the survey  
153 population (13%) experienced 75% of the incidental interactions (Fig. 1b). The distribution of  
154 intentional experiences was similar for both private gardens and public parks, with 28% and 27%  
155 of the survey population, respectively, experiencing 75% of the total time (Fig. 1c and 1d). We  
156 found that 75% of all nature interactions were experienced by just 50% of the survey respondents  
157 and of the population.

158

159 Experiences of indirect and intentional (in gardens) interactions increased with age, while people  
160 over 60 had more intentional interactions in parks (Table 1). Respondents who experienced all

161 four types of nature interaction had better self-reported health (Table 1), while those who  
162 incidentally and intentionally interacted with nature had a higher nature orientation than those  
163 experiencing it indirectly (Table 1). Gender, education and ethnicity were not important  
164 predictors of time spent experiencing nature.

165

#### 166 **4. Discussion**

167 We demonstrate that, across four common types of nature interaction, accumulatively 75% of  
168 nature experiences were experienced by just 50% of the population. However, accumulatively  
169 75% of interactions where people were actually present in nature were experienced by just 32%  
170 of the population. Indeed, people who directly experience nature regularly in any given week are  
171 clearly the exception rather than the norm. This novel study provides baseline information  
172 regarding how experiences of nature vary across an urban population. This is a first step towards  
173 linking urban design and policy towards maximising the health benefits from urban nature.

174

##### 175 4.1. Indirect interactions

176 For the majority of people, the most common method of experiencing nature is while not actually  
177 being present in it, but by viewing natural scenes through a window.

178 Importantly, having a room with a view of nature does not necessarily mean that people are  
179 continuously experiencing that view. Instead, at work and in the home most people spend a  
180 significant amount of time with their attention directed towards specific tasks, and the presence  
181 of a window with a natural scene allows micro-restorative experiences (Kaplan, 1993, 2001),  
182 with scenes that are more fascinating being likely to be more restorative (Kaplan & Kaplan,  
183 1989). Here we show that there is great variation in the type of nature people can see from their

184 windows and this varies between work and home (Fig. S1). We show that street and residential  
185 trees are providing the lion's share of indirect nature experiences. An important contribution of  
186 future research would be to unpick how trees are distributed across the landscape in relation to  
187 the flow of people experiencing them. This would allow architects and planners to exploit key  
188 areas where the greatest number of people would interact with trees.

189

190 Despite research showing the benefits of nature views, such as office workers having perceived  
191 lower levels of job stress and higher job satisfaction (Kaplan & Kaplan, 1989), and residents of  
192 greener neighbourhoods reporting increased neighbourhood satisfaction and well-being (e.g.  
193 Kaplan, 2001), a significant number of people in this study had no good view of nature at work  
194 (33.8%) or at home (18.1%; Fig. S1). Neither nature orientation, age nor income were significant  
195 predictors of indirect interactions with nature, suggesting these experiences are more a  
196 consequence of opportunity, rather than orientation towards nature (i.e. you either live or work in  
197 a room with a view of nature, or you do not). Considering the benefits that visual access to nature  
198 provides there is considerable significant potential through innovative urban greening to further  
199 increase people's indirect exposure.

200

#### 201 4.2. Incidental interactions

202 Half of all workers spent some time outside at work, although the steep accumulation curve  
203 shows that a large proportion of people spend most of their work hours outdoors, rather than  
204 many people spending a small proportion of time outdoors. Nature orientation showed a  
205 significant positive relationship with incidental time spent in nature, suggesting that either people  
206 with an increased orientation towards nature are more likely to choose jobs where they spend

207 time outside, and/or that daily nature experiences increase nature orientation (Soga & Gaston,  
208 2015). A large proportion of the population spends a substantial amount of time in the  
209 workplace. Short work breaks are a common part of office culture and offer an important and  
210 largely untapped opportunity to promote healthy contact with nature. Indeed, attention  
211 restoration and self-esteem have been found to increase in as little as five minutes spent outside  
212 (Barton & Pretty, 2010), suggesting that access to nature at work can promote significant gains  
213 towards improving office health and productivity (Largo-Wight, Chen, Dodd, & Weiler, 2011).

214

215 Further research needs to explore daily incidental experiences of nature as people travel around  
216 the landscape. Unfortunately, this is not easily done and requires rather different approaches that  
217 are likely to be challenging to extrapolate to the entire population in the way that was done in  
218 this study. In future studies it will be important to unpick these experiences and the relative  
219 health benefits they provide, both from the nature people interact with, and how this varies  
220 across different activities people are engaged in during these interactions.

221

#### 222 4.3. Intentional interactions

223 Private gardens provide an immediate and readily accessible way for people to experience  
224 nature. Considering that 92% of the survey respondents claimed access to a private green space,  
225 it is somewhat surprising that 75% of the time spent in gardens was experienced by merely 28%  
226 of the population. Clearly opportunity was not the driving force behind use, instead we found  
227 orientation to be a strong predictor. Such results are supported by previous research showing that  
228 people with a higher orientation towards nature have the potential to receive high levels of  
229 garden vegetation benefits through active and passive means (Lin, Gaston, Fuller, Wu, Bush, &

230 Shanahan, 2017), and spend more time in private gardens and public parks, while living in areas  
231 with more vegetation (Lin et al., 2014). Literature from the environmental psychology field also  
232 shows that appreciation of nature is a significant motivation for people to spend time in nature  
233 (Clayton, 2007).

234

235 The ten-fold increase in hours spent in private gardens over public parks probably reflects  
236 differences in ease of access and the fundamentally different roles that they play in people's  
237 lives. Time spent in parks increased with income possibly because wealthier neighbourhoods  
238 often have increased access to higher quality green space encouraging use (Shanahan, Lin,  
239 Gaston, Bush & Fuller, 2014; Soga, Yamaura, Aikoh, Shoji, Kubo, & Gaston, 2015). We did not  
240 find that income affected time in gardens, which supports the results of previous studies (Lin et  
241 al., 2017). We did find that both time in parks and in gardens increased with age, probably  
242 because people's relationship to nature changes as they get older (Shanahan et al., 2017) or  
243 simply because older people have more leisure time (Gauthier & Smeeding, 2003).

244

## 245 **5. Conclusions**

246 Within an urban population variation in daily nature experiences is driven by both opportunity  
247 and orientation. To reverse the trend of declining nature experiences, research and public policy  
248 need to address both of these components. Arguably the simplest approach is to increase the  
249 quantity of green infrastructure (Shanahan et al., 2015b; Soga et al., 2015), thereby increasing  
250 both indirect and incidental interactions. However, as shown here and by Lin et al. (2014)  
251 opportunity is not sufficient to encourage use. It is critical to design public health interventions  
252 that increase people's orientation toward nature. Both theory and evidence suggest that

253 orientation is influenced by regular outdoor play during childhood (Bixler, Floyd, & Hammitt,  
254 2002; Thompson, Aspinall, & Montarzino, 2008). However, there is also enormous scope to  
255 increase orientation in adults through participation in nature-based activities (Scott, Amel, &  
256 Manning, 2014). Those who do not interact with nature may lose the substantial benefits  
257 associated with health and well-being (Keniger et al., 2013; Shanahan et al., 2015a). The health  
258 and well-being benefits of experiencing nature are now well established. The challenge is  
259 encouraging a greater proportion of the population to engage with the natural world around them.  
260 However, care needs to be taken, as a rise in the number of people accessing green spaces for  
261 health benefits might threaten urban ecosystems and the very health benefits that people seek  
262 (Stanley et al., 2015). Deconstructing types of nature experiences, as done here, is critical for  
263 guiding recommendations and policy to ensure that across the population the most people can  
264 benefit from interactions with nature.

265

#### 266 **Data accessibility**

267 Due to third party restrictions, the data are available on request from the corresponding author.  
268 The dataset will be available from the NERC Environmental Data Information Centre from mid  
269 2017.

## References

- Bartoń K. (2015). MuMIn: Multi-model inference. R package version 1.13.4. Retrieved August 15, 2015 from- <http://CRAN.R-project.org/package=MuMIn>.
- Barton, J., & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health? A multistudy analysis. *Environmental Science and Technology*, *44*, 3947-3955. doi - 10.1021/es903183r.
- Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, *19*, 1207-1212. doi - 10.1111/j.1467-9280.2008.02225.x.
- Bixler, R. D., Floyd, M. F., & Hammitt, W. E. (2002). Environmental socialization - Quantitative tests of the childhood play hypothesis. *Environment and Behavior*, *34*, 795-818. doi - 10.1177/1001391602237248.
- Bratman, G. N., Hamilton, J. P., & Daily, G. C. (2012). The impacts of nature experience on human cognitive function and mental health. *Annals of the New York Academy of Sciences*, *1249*, 118-136. doi - 10.1111/j.1749-6632.2011.06400.x.
- Bratman, G. N., Hamilton, J. P., Hahn, K. S., Daily, G. C., & Gross, J. J. (2015). Nature experience reduces rumination and subgenual prefrontal cortex activation. *Proceedings of the National Academy of Sciences*, *112*, 8567–8572. doi - 10.1073/pnas.1510459112.
- Burnham, K. P., & Anderson, D. R. (2002). *Model selection and multimodel inference: A practical information-theoretic approach*. (2nd ed.). New York: Springer Science and Business Media.
- Clayton, S. (2007). Domesticated nature: Motivations for gardening and perceptions of environmental impact. *Journal of Environmental Psychology*, *27*, 215-224. doi-10.1016/j.jenvp.2007.06.001.

- Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatzliolis, D., *et al.* (2013). The relationship between trees and human health evidence from the spread of the emerald ash borer. *American Journal of Preventive Medicine*, *44*, 139-145. doi - 10.1016/j.amepre.2012.09.066.
- Dye, C. (2008). Health and urban living. *Science*, *319*, 766-769. doi - 10.1126/science.1150198.
- Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K.J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, *3*, 390-394. doi - 10.1098/rsbl.2007.0149.
- Gauthier, A. H., & Smeeding, T. M. (2003). Time use at older ages: Cross-national differences. *Research on Aging*, *25*(3), 247-274. doi - 10.1177/0164027503025003003.
- Groenewegen, P. P., van den Berg, A. E., Maas, J., Verheij, R. A., & de Vries, S. (2012). Is a green residential environment better for health? If so, why? *Annals of the Association of American Geographers*, *102*, 996-1003. doi - 10.1080/00045608.2012.674899.
- Han, K. T. (2009). Influence of limitedly visible leafy indoor plants on the psychology, behavior, and health of students at a junior high school in Taiwan. *Environment and Behavior*, *41*, 658-692. doi - 10.1177/0013916508314476.
- Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., *et al.* (2012). Environmental biodiversity, human microbiota, and allergy are interrelated. *Proceedings of the National Academy of Sciences USA*, *109*, 8334-8339. doi - 10.1073/pnas.1205624109.
- Hough, R. (2014). Biodiversity and human health: Evidence for causality? *Biodiversity and Conservation*, *23*, 267-288. doi - 10.1007/s10531-013-0614-1.
- Kaplan, R. (1993). The role of nature in the context of the workplace. *Landscape and Urban Planning*, *26*, 193-201. doi - 10.1016/0169-2046(93)90016-7.



- Kaplan, R. (2001). The nature of the view from home - psychological benefits. *Environment and Behaviour*, 33, 507-542. doi - 10.1177/00139160121973115.
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge: Cambridge University Press.
- Keniger, L. E., Gaston, K. J., Irvine, K. N., & Fuller, R. A. (2013). What are the benefits of interacting with nature? *International Journal of Environmental Research and Public Health*, 10, 913-935. doi - 10.3390/ijerph10030913.
- Largo-Wight, E., Chen, W. W., Dodd, V., & Weiler, R. (2011). Healthy workplaces: The effects of nature contact at work on employee stress and health. *Public Health Reports*, 126, 124-130. PMID: PMC3072911.
- Lin, B. B., Fuller, R. A., Bush, R., Gaston, K. J., & Shanahan, D. F. (2014). Opportunity or orientation? Who uses urban parks and why. *PLoS ONE*, 9, e89422. doi - 10.1371/journal.pone.0087422.
- Lin, B. B., Gaston, K. J., Fuller, R. A., Wu, D., Bush, R., & Shanahan, D. F. (2017). How green is your garden?: Urban form and socio-demographic factors influence yard vegetation, visitation, and ecosystem service benefits. *Landscape and Urban Planning*, 157, 239-246. doi.org - /10.1016/j.landurbplan.2016.07.007.
- Lottrup, L., Grahn, P., & Stigsdotter, U. K. (2013). Workplace greenery and perceived level of stress: Benefits of access to a green outdoor environment at the workplace. *Landscape and Urban Planning*, 110, 5-11. doi - 10.1016/j.landurbplan.2012.09.002.
- Maas, J., Verheij, R. A., Groenewegen, P. P., de Vries, S., & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology and Community Health*, 60, 587-592. doi - 10.1136/jech.2005.043125.

- McCormack, G. R., Rock, M., Toohey, A. M., & Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: A review of qualitative research. *Health & Place, 16*, 712-726. doi - 10.1016/j.healthplace.2010.03.003.
- Middleton, J. (2010). Sense and the city: Exploring the embodied geographies of urban walking. *Social & Cultural Geography, 11*(6), 575-596. doi - 10.1080/14649365.2010.497913
- Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: An observational population study. *The Lancet, 372*, 1655-1660. doi - 10.1016/s0140-6736(08)61689-x.
- Richards, S. A. (2005). Testing ecological theory using the information-theoretic approach: Examples and cautionary results. *Ecology, 86*, 2805-2814. doi - 10.1890/05-0074.
- Scott, B. A., Amel, E. L., & Manning, C. M. (2014). In and of the wilderness: Ecological connection through participation in nature. *Ecopsychology, 6*, 81-91. doi - 10.1089/eco.2013.0104.
- Shanahan, D. F., Lin, B. B., Gaston, K. J., Bush, R., & Fuller, R. A. (2014). Socio-economic inequalities in access to nature on public and private lands: A case study from Brisbane, Australia. *Landscape and Urban Planning, 130*, 14-23. doi - 10.1016/j.landurbplan.2014.06.005
- Shanahan, D. F., Fuller, R. A., Bush, R., Lin, B. B., & Gaston, K. J. (2015a). The health benefits of urban nature: How much do we need? *BioScience, 65*, 476-485. doi - 10.1093/biosci/biv032.
- Shanahan, D. F., Lin, B. B., Bush, R., Gaston, K. J., Dean, J. H., Barber, E., *et al.* (2015b). Toward improved public health outcomes from urban nature. *American Journal of Public Health, 105*, 470-477. doi - 10.2105/AJPH.2014.302324.

- Shanahan, D. F., Cox, D. T. C., Fuller, R. A., Hancock, S., Lin, B.B., Anderson, K., *et al.* (2017). Variation in experiences of nature across a gradient of tree cover in compact and sprawling cities. *Landscape and Urban Planning*, *157*, 231-238. doi - 10.1016/j.landurbplan.2016.07.004.
- Soga, M., & Gaston, K. J. (2015). Extinction of experience: Evidence, consequences and challenges of loss of human-nature interactions. *Frontiers in Ecology and Environment*. doi - 10.1002/fee.1225.
- Soga, M., Yamaura, Y., Aikoh, T., Shoji, Y., Kubo, T., & Gaston, K. J. (2015). Reducing the extinction of experience: Association between urban form and recreational use of public greenspace. *Landscape and Urban Planning*, *143*, 69-75. doi - 10.1016/j.landurbplan.2015.06.003.
- Stanley, M. C., Beggs, J. R., Bassett, I. E., Burns, B. R., Dirks, K. N., Jones, D .N., *et al.* (2015). Emerging threats in urban ecosystems: A horizon scanning exercise. *Frontiers in Ecology and the Environment*, *13*(10), 553-560. doi - 10.1890/150229.
- Sundquist, K., Frank, G., & Sundquist, J. (2004). Urbanisation and incidence of psychosis and depression- Follow up study of 4.4 million women and men in Sweden. *British Journal of Psychiatry*, *184*, 293-298. Doi - 10.1192/bjp.184.4.293.
- Thompson, C. W., Aspinall, P., & Montarzino, A. (2008). The childhood factor - adult visits to green places and the significance of childhood experience. *Environment and Behaviour*, *40*, 111-143. doi - 10.1177/0013916507300119.
- White, M. P., Alcock, I., Wheeler, B. W., & Depledge, M. H. (2013). Would you be happier living in a greener urban area? A fixed-effects analysis of panel data. *Psychological Science*, *24*, 920-928. doi - 10.1177/0956797612464659.

World Health Organisation. (2016a). Urban health. Global health Observatory data. Retrieved April 26, 2016 from- [http://www.who.int/gho/urban\\_health/en/](http://www.who.int/gho/urban_health/en/).

World Health Organisation. (2016b). Urban population growth, Global Health Observatory data. Retrieved April 26, 2016 from- [http://www.who.int/gho/urban\\_health/situation\\_trends/urban\\_population\\_growth\\_text/en/](http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/).

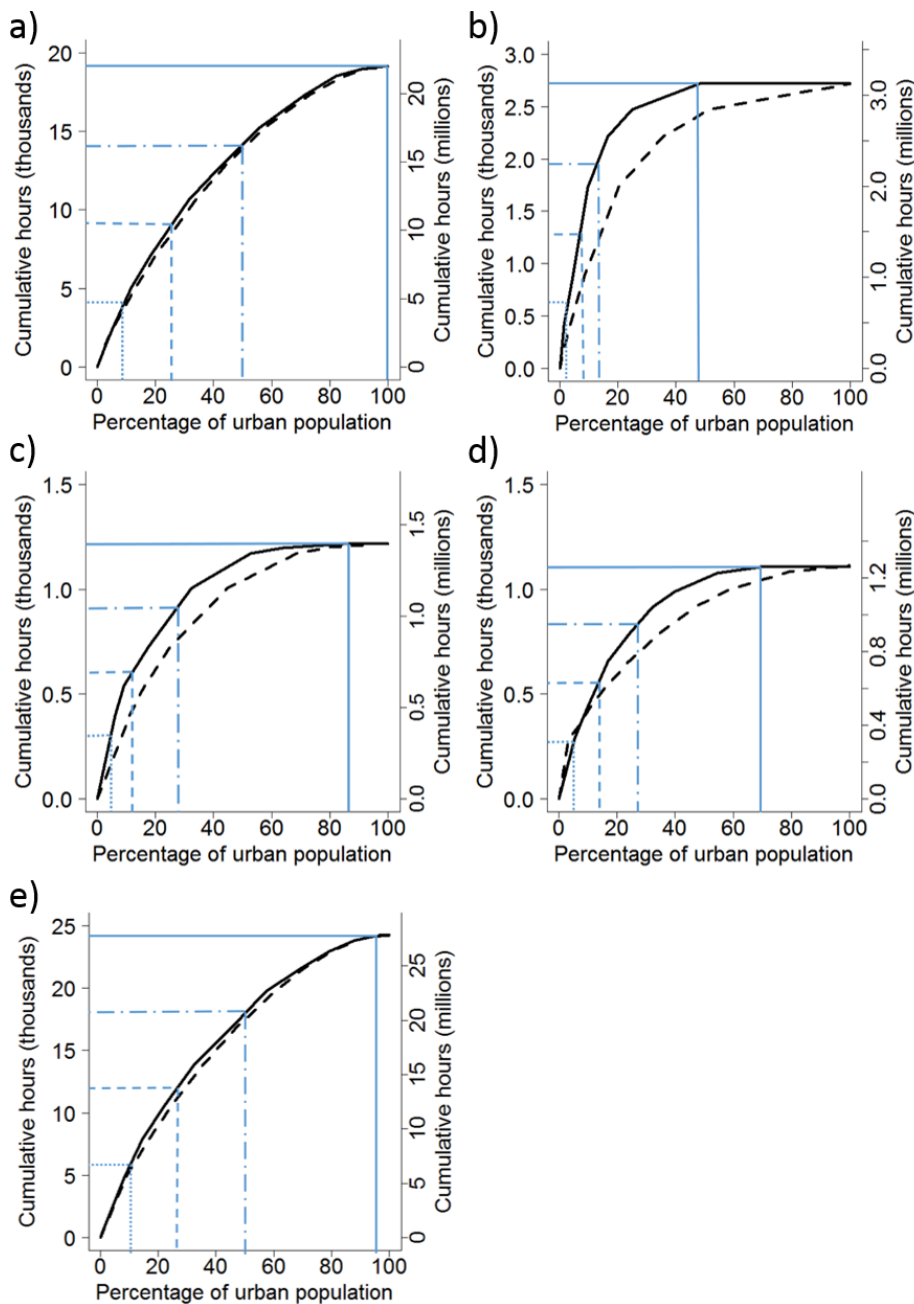
**Table 1:** The relationship between the total time spent experiencing each type of nature interaction (log-transformed) for each respondent and covariates. Respondent is a random effect, and model averaged parameter estimates and confidence intervals are given for factor levels relative to a comparative base factor level (Health, very poor; Nature interaction type, Indirect). Significant variables and factor levels are shown as  $*P < 0.05$ ;  $**P < 0.01$ ;  $***P < 0.001$ .

**Table 1:** The relationship between the total time spent experiencing each type of nature interaction (log-transformed) for each respondent and covariates. Respondent is a random effect, and model averaged parameter estimates and confidence intervals are given for factor levels relative to a comparative base factor level (Health, very poor; Nature interaction type, Indirect). Significant variables and factor levels are shown as \* $P < 0.05$ ; \*\* $P < 0.01$ ; \*\*\* $P < 0.001$ .

Variable	Estimate (SE)	95% Confidence intervals
Intercept	1.97 (0.3)***	1.39; 2.55
Income	0.06 (0.03)	-0.01; 0.12
Nature orientation	0.09 (0.9)	-0.09; 0.27
Age	0.00 (0.01)	-0.02; 0.03
Ethnicity	0.04 (0.04)	-0.05; 0.12
<i>Health</i>		
Poor	0.04 (0.11)	-0.18; 0.26
Average	0.22 (0.10)*	0.02; 0.42
Good	0.24 (0.10)*	0.05; 0.44
Very good	0.28 (0.10)**	0.08; 0.48
<i>Nature interaction</i>		
Incidental	-2.14 (0.33)***	-2.79; -1.50
Intentional (garden)	-2.65 (0.44)***	-3.51; -1.79
Intentional (park)	-2.78 (0.42)***	-3.60; -1.95
<i>Nature orientation: Nature interaction</i>		
Nature orientation: Incidental	0.18 (0.08)*	0.01; 0.34
Nature orientation: Intentional (garden)	0.33 (0.09)***	0.16; 0.50
Nature orientation: Intentional (park)	0.31 (0.08)***	0.15; 0.48
<i>Age: Nature interaction</i>		
Age: Incidental	0.00 (0.02)	-0.03; 0.03
Age: Intentional (garden)	0.07 (0.02)***	0.04; 0.10
Age: Intentional (park)	0.04 (0.02)*	0.01; 0.07
<i>Income: Nature interaction</i>		
Income: Incidental	0.15 (0.04)***	0.07; 0.24
Income: Intentional (garden)	-0.05 (0.04)	-0.13; 0.04
Income: Intentional (park)	0.09 (0.04)*	0.01; 0.18
Conditional R <sup>2</sup>	0.42	

**List of figures**

**Figure 1.** Cumulative hours spent per week experiencing different nature interactions by survey respondents (left y axis; solid curve) and scaled up to the whole population of the Cranfield triangle (right y axis; dashed curve): a) indirect interactions (in a room with a view of nearby nature); b) incidental interactions (working outside); c) intentional interactions (private gardens); d) intentional interactions (public parks); e) the total time across interactions. We show the percentage of the population that account for 25% (dotted line), 50% (dashed line), 75% (dash/dot line) and 100% (solid line) of the total nature experienced.



**Figure 1.** Cumulative hours spent per week experiencing different nature interactions by survey respondents (left y axis; solid curve) and scaled up to the whole population of the Cranfield triangle (right y axis; dashed curve): a) indirect interactions (in a room with a view of nearby nature); b) incidental interactions (working outside); c) intentional interactions (private gardens); d) intentional interactions (public parks); e) the total time across all interactions. We show the



percentage of the population that account for 25% (dotted line), 50% (dashed line), 75% (dash/dot line) and 100% (solid line) of the total nature experienced.

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### **Ethical clearance**

This research was conducted with approval from the Bioscience ethics committee of the University of Exeter (project number 2013/319). Participants provided written consent at the beginning of the online survey.

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