

RESEARCH ARTICLE



Factors influencing nature interactions vary between cities and types of nature interactions

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Abstract

1. There is mounting concern that people living more urbanised, modern lifestyles have fewer and lower quality interactions with nature, and therefore have limited access to the associated health and well-being benefits. Yet, variation in the different types of nature interactions and the factors that influence these interactions across populations are poorly understood.
2. We compared four types of nature interactions by administering surveys across two cities that differ markedly in urbanisation pattern and population density—Singapore and Brisbane—: (a) indirect (viewing nature through a window at work or at home); (b) incidental (spending time in nature as part of work); (c) intentional interactions in gardens; and (d) intentional interactions in public urban greenspace.
3. Our results show that Singapore respondents spent about half as much time (25.8 hr/week) interacting with nature as Brisbane respondents (52.3 hr/week), and indirect interactions were the most prevalent across both cities.
4. Nature orientation, age, income and gender significantly predicted the duration of nature interactions in both cities, while self-reported health, education and ethnicity additionally predicted the duration of nature interactions only for Brisbane. Also, the relationship(s) between each factor and duration could differ in direction and effect size between the types of nature interactions.
5. As such, we conclude that there is much local variation in the dynamics of interactions between people and nature, and that focused studies are needed to develop effective interventions addressing declines in nature interactions in different locations.

KEYWORDS

experiences of nature, greenspace, health and well-being, nature interactions, nature relatedness, urban

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1 | INTRODUCTION

Exposure to natural environments has been associated with a range of health and well-being benefits for adults (e.g. Bratman et al., 2015; White et al., 2019) and children (e.g. Dadvand et al., 2015; Donovan et al., 2018), at least among populations living in high income, largely urbanised societies (Astell-Burt et al., 2014; Halonen et al., 2014; Hartig & Kahn, 2016; Kardan et al., 2015; Keniger et al., 2013; Mitchell et al., 2015; White et al., 2013). These beneficial outcomes are considered to arise from people simply being in natural environments (Haluzá et al., 2014), or engaging in behaviours associated with natural environments (e.g. encountering street trees while cycling to work; Lottrup et al., 2013). Nature spans individual living organisms to ecosystems, and an interaction between people and nature is where an individual person is present in the 'same space' as nature, or perceiving a stimulus from nature (through sight, sound, smell, taste or touch; Gaston et al., 2018). Such interactions with nature would include, but are not limited to, visiting urban greenspace or national parks, viewing trees through a window, listening to bird song and being bitten by mosquitoes (Gaston et al., 2018).

However, there is an increasing concern that urbanisation and the challenges of modern life are reducing the quantity and quality of opportunities for residents to interact with nature (Soga & Gaston, 2016). These challenges could stem from (a) less available nature; (b) spatial barriers to access nature; and (c) changes in human behaviour. Intensely urbanised areas generally have fewer and more degraded natural ecosystems (McKinney, 2008). This makes nature less accessible to residents, and the type and quality of natural environments that they do access is poor. People who live further away from natural areas, or who live near degraded natural areas, are known to interact less frequently with nature (Neuvonen et al., 2007; Soga et al., 2015; Zhang et al., 2014). Similarly, behavioural changes relating to a modern lifestyle, such as more time spent indoors and a stronger preference for indoor activities (Matz et al., 2014), could similarly reduce urban residents' interactions with nature. Given that a person's immediate surroundings are frequently the major arena where most nature interactions happen daily (Turner et al., 2004), this potential reduction in nature interactions is of substantial concern as it entails a decline in the breadth and magnitude of health and well-being benefits that urban residents could potentially receive from interacting with nature.

Yet, to incorporate the benefits of urban nature into the daily lives of city residents, it is crucial to understand how, where and what type of nature interactions are occurring among the residents of a city, and whether these differ among cities. Variations in nature interactions will have specific consequences for health and well-being benefits, since the delivery is mediated via various human sensory pathways (Franco et al., 2017). Nature interactions can be classified into three types: indirect, incidental and intentional (Keniger et al., 2013; but see Gaston, 2020, Gaston & Soga, 2020; Soga & Gaston, 2020 for discussion and more nuanced terminologies for the types of nature interactions; or Giusti et al., 2018 for an alternative framework). Indirect interactions do not require physical presence in

nature (e.g. viewing nature through a window) and have been associated with improved cognitive functioning (Lottrup et al., 2015) and greater life satisfaction (Chang et al., 2020). Incidental interactions occur when the individual is physically present in nature, but where the interaction is the unintended result of another activity (e.g. encountering trees while working outdoors) and has been shown to reduce stress levels (Lottrup et al., 2013). Intentional interactions entail interacting with nature through direct intent (e.g. hiking or gardening), and deliver a broad range of physical (Cox et al., 2017; Cox, Shanahan, et al., 2017; Soga et al., 2017) and mental well-being benefits (Marselle et al., 2014), positive social outcomes (Soga et al., 2017; Weinstein et al., 2015) and potentially also strengthen environmentally protective behaviours (Whitburn et al., 2019).

The inter-relationships between the various types of nature interactions, urban form and social-cultural factors are likely to be complex, given that factors influencing the frequency and type of interactions might vary between individuals and across cities. For example, some people use greenspace because of a strong nature orientation (Lin et al., 2014), while others use them because they are accessible places for exercise or recreation (opportunity; Soga et al., 2015). Factors that influence orientation and opportunity are varied, and include location of residence, age, gender, ethnicity, income and education, and potentially complex interactions among these factors (Lin et al., 2014; McCormack et al., 2010). In relation to the accessibility of nature, greenspace in cities are differentially distributed across the urban landscape because of historical patterns of land development, along with socio-economic and ethno-racial inequalities, philosophy of park design and evolving ideas and governmental priorities about leisure and recreation (Byrne, 2012; Byrne & Wolch, 2009). A lower availability of urban greenery such as parks and street trees in lower income or minority neighbourhoods was reported in the United States (Landry & Chakraborty, 2009; Wolch et al., 2005), although this pattern is not necessarily ubiquitous (Timperio et al., 2007). Such differences, when aggregated across both individual and spatial levels, are likely to influence the amount and type of a person's daily nature interactions. As such, shedding light on these inter-relationships is important to improve the design of cities and programs for the delivery of human-nature interactions (Mitchell & Popham, 2008). This is particularly important for specific populations such as the low socio-economic and minority groups, who have traditionally been marginalised in their accessibility to urban greenspace (Rigolon, 2016) but who are also disproportionately exposed to greater negative environmental pollution (Wolch et al., 2014).

In this current study, we assess how residents of two contrasting cities differ in their types of nature interactions, and investigate whether the social-cultural factors that are associated with these interactions vary between the cities. We chose two cities that exhibit considerable differences in history, culture, urbanisation pattern and population density—Singapore and Brisbane. We administered surveys within each city to quantify four types of daily nature interactions between people and nature, distinguishing between: indirect interactions (viewing nearby nature through a window at work

and at home); incidental interactions (time spent in nature as part of one's work); intentional interactions in gardens (time spent in private and community gardens); and intentional interactions in parks (time spent in public urban greenspace). We then identified the factors that best predict the duration of nature interactions, and examined the differences in direction and effect for the relationship between each factor and each type of nature interaction.

We chose to focus on these four types of nature interactions as they form the predominant ways that people interact with nature in urban environments, and there exists evidence that such interactions deliver health and well-being benefits (Kuo, 2015). We further distinguished between intentional interactions in gardens and parks because they differ fundamentally in structure and management, and the type of activities conducted within them. Parks are generally larger, exist for public use and are managed by government agencies, while gardens are smaller, and usually privately owned and managed by individual households (Goddard et al., 2010). Parks are also where people undertake physical activity through active recreation (Leslie et al., 2010) while gardens are places to relax (Head et al., 2004) and express creativity (Kirkpatrick et al., 2009). These differences could therefore have an impact on the frequency of visits and duration of time spent within each type of greenspace.

2 | MATERIALS AND METHODS

2.1 | Study sites

We conducted our study in Singapore and Brisbane (Queensland, Australia), which differ markedly in urbanisation pattern and population density (Figure 1). Singapore is a highly urbanised, densely populated tropical city with a total land area of 725 km² (Government of Singapore, 2020), a population of 5.7 million residents and a population density of 7,804 individuals/km² (Singapore Department of Statistics, 2019a). Brisbane is a subtropical city, covering 1,342 km² of urban, peri-urban and agricultural land, with a population of 1.25 million residents and a population density of 934 individuals/km² (Australian Bureau of Statistics, 2020).

Both Singapore and Brisbane have strong urban greening policies, evident in their conservation of vegetation cover and provision of urban greenspace. Singapore has an urban greenspace provision target of 0.8 ha per 1,000 residents, and has formally designated 10% of land area as publicly accessible greenspace, with 5% protected as nature reserves (Tan et al., 2013). Similarly in Brisbane, the city council maintains a tree cover target of 40% of the total land area (Brisbane City Council, 2020) and the provision of public greenspace remains a key priority. The city council works to provide nature-based opportunities for residents through a large and well-connected greenspace network (Brisbane City Council, 2014a). The public park network covers approximately 10% of Brisbane (148 km²) and comprises local parks with playgrounds through to large natural areas of regional and state significance (Brisbane City Council, 2014b).

This said, the cities exhibit considerable differences in their urban development and ethno-racial composition. Singapore represents a highly compact urban development with high-density residential neighbourhoods localised along the perimeter of the island, two large water catchment areas situated in the centre and west of the mainland, and a network of interstitial publicly accessible and private greenspace. Overall, 95% of Singaporean households reside in high-rise apartments (Singapore Department of Statistics, 2019b), and thus have no access to private gardens or yards. In contrast, Brisbane has undergone a sprawling pattern of urban development with lower density residential neighbourhoods spread across a larger area with some interstitial greenspace; 78.5% of Queensland residents live in free-standing houses (Australian Bureau of Statistics, 2019). In terms of ethno-racial differences, 70% of Singapore's citizens are of Chinese ethnicity, alongside ethnic minorities such as Indians, Malays and Eurasians, whereas 70% of the Brisbane population is of European descent with ethnic minorities primarily of Chinese and Vietnamese descent (Australian Bureau of Statistics, 2016, 2019; Singapore Department of Statistics, 2019a).

2.2 | Participants and survey procedure

We delivered one urban lifestyle survey in Brisbane in 2012 and another in Singapore in 2019. To ensure that the two surveys were comparable, both were delivered in English, and the questions were identical. The Brisbane survey was delivered to 1,584 respondents in late spring, in accordance with the Institutional Human Research Ethics Approval of the Behavioural and Social Sciences Ethical Review Committee, University of Queensland (project number 2012000869). It was delivered online over a 2-week period through a market research company. The Singapore survey was delivered to 1,513 respondents in accordance with both the University of Queensland Institutional Human Research Ethics Approval (project number 2018001775) and the Institutional Review Board at the National University of Singapore (project reference S-18-344). It was deployed across a 1-month window through a market research company. Both surveys were delivered to a stratified subset of adults (18 years and above) voluntarily enrolled in the survey databases of the market research companies. All respondents indicated their agreement to participate by providing consent at the beginning of the online survey.

Respondents from both cities were stratified by several nested criteria to ensure that the final sample reflected a broad socio-economic spread with an even spatial distribution across each city. The stratification criteria were as follows: (a) gender (50% males and 50% females); (b) age (50% aged 18 to <45 years and 50% aged 45–75 years); (c) income; and (d) greenery surrounding current residence (four quartiles). For the Singapore survey, we further ensured that the ethnic composition of the respondents approximated that of the national population (i.e. 70% Chinese, 15% Malay, 7% Indian and 8% Others).

2.3 | Measures of nature orientation and four types of nature interactions

To measure respondents' nature orientation, we used the Nature Relatedness Scale (Nisbet et al., 2009). The scale effectively differentiates between groups of individuals who are nature enthusiasts, and those who engage to a lesser extent with nature (Nisbet et al., 2009). Respondents were invited to rate a set of 21 statements using a 5-point Likert scale ranging from 1 (disagree strongly) to 5 (agree strongly; full survey in Appendix B). An aggregation of the responses (as per Nisbet et al., 2009) provides a measure of an individual's affective, cognitive and experiential relationship with nature, with a higher score indicating a stronger connection with nature.

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

1. *Indirect interactions*: these referred to the time spent at home and at work in a room with a view of nearby (within 500 m) nature (trees, parks, rooftop gardens, bushland/nature reserves and sea, reservoir, rivers or canals). Respondents from Brisbane selected from seven duration intervals (see supporting information for the full survey) while those from Singapore stated the number of hours spent. To compute this variable, respondents were first asked how many days a week they worked. They were then asked how much time they spent in a room with a view of nature at home on average workday and an average non-workday, and at work on average working day. Indirect interactions were deemed zero hours if the respondent chose the option 'I have no good view'. The total duration of indirect interactions per week was given by: $(\text{Number of hours in a room with a nature view on a work day} \times \text{number of days worked}) + (\text{Number of hours in a room with a nature view on a non-work day} \times \text{number of days with no work})$.

All respondents further indicated the elements of nature that they can see from their windows corresponding to five categories: trees, parks, bushland/nature reserve, water or 'I have no good view'. We assumed that respondents were able to distinguish between different elements of nature.

2. *Incidental interactions*: these were measured by asking respondents how much time they spend in outdoor greenspace as part of their work in an average week. Respondents from Brisbane selected from 11 duration intervals (Supporting Information) while those from Singapore stated the number of hours spent.
3. *Intentional interactions in gardens*: these referred to the time spent in a garden. 'Garden' was defined as private garden, community garden or potted plants along one's corridor in the Singapore survey, and as private yard or deck for the Brisbane survey. Respondents from Brisbane selected from seven duration intervals (see Supporting Information) while those from Singapore

stated the number of hours spent. For both sets of respondents, those who have not spent any time, or for whom this question was not applicable (because they do not own a garden, potted plants or a space at the community garden) were deemed to have zero hours, since both circumstances indicate no nature interactions in gardens.

4. *Intentional interactions in outdoor greenspace*: these were measured by time spent in public parks in the past week. Respondents from Brisbane selected from six duration intervals (see Supporting Information) while those from Singapore stated the number of hours spent. The total time was calculated by summing the time spent across all public parks visited.

We also collected several socio-demographic covariates that could influence nature interactions, including age (Sanesi & Chiarello, 2006; Schipperijn et al., 2010), gender (Fermino et al., 2013; Schipperijn et al., 2010), ethnicity (Peters et al., 2010; Rigolon, 2016), personal monthly income (Mitchell & Popham, 2007; Scopelliti et al., 2016), highest formal educational qualification (Mayer & Frantz, 2004) and self-assessment of personal health (Russell et al., 2013). Tables S1 and S2 summarise the variables and distribution of respondents across each variable for the Singapore and Brisbane population respectively.

2.4 | Statistical analyses

All analyses were conducted in the statistical programming environment R version 3.6.2 (R Development Core Team, 2019). We assessed variations in the duration of time spent across four types of nature interaction, and identified factors associated with these variations by building two linear mixed-effects models (one for each city). The response variable was the duration (of time) spent experiencing each type of nature interaction, and was transformed (via a log then square root) to better achieve normality of residuals (Crawley, 2012). All duration responses from Singapore were converted to the categories used in the Brisbane survey for comparability. We then treated duration as a numeric response by using the mid-points of the selected categories, with the last category representing the maximum possible duration (e.g. the category of 71 or more hours was treated as '71').

We used the LME4 package (Bates et al., 2018), and specified the fixed effect factors as: the type of nature interaction, nature orientation, self-assessment of personal health, age, personal income, gender, highest formal educational qualification and ethnicity. We further specified the type of nature interaction to interact with all fixed effect factors, and as a random slope (Dworkin & Bolker, 2019). This allowed the relationship between the duration (of time) spent on experiencing each type of nature interaction to vary (independent of other types of nature interactions) in relation to each factor. Each respondent was also specified as a random intercept.

For both models, nature orientation, age and personal income were scaled, continuous variables while self-assessment of personal

health was treated as an ordinal variable with three levels (i.e. poor, average and good). All other variables were treated as categorical. Prior to analyses, we used the *vif()* function from the *car* package (Fox et al., 2012) to assess multicollinearity in the models, and found no problems ($VIF < 3$). Quantile plots, histograms of residuals and plots of residuals against fitted values were also examined for non-normality, heteroscedasticity or presence of outliers. Significant variables were identified ($p < 0.05$) using the *ANOVA()* function from the *LMERTEST* package (Kuznetsova et al., 2015).

3 | RESULTS

On average, individuals living in Singapore spent a shorter duration interacting with nature compared to those living in Brisbane. Summing the number of hours across all four types of nature interactions, the Singapore population spent an average of 25.8 hr/week experiencing nature, whereas the Brisbane population spent on average 52.3 hr/week. In both cities, indirect nature interactions accounted for the longest duration of time spent interacting with nature, with respondents from Singapore spending on average half as much time ($20.5 \text{ hr} \pm 0.64 \text{ SE}$) on indirect interactions compared to Brisbane respondents ($44.2 \text{ hr} \pm 0.70 \text{ SE}$; Figure 2). The average duration of indirect interactions at home and at work for the Singapore population ($11.5 \text{ hr} \pm 0.42 \text{ SE}$; $8.44 \text{ hr} \pm 0.38 \text{ SE}$) was half that of the Brisbane population ($26.6 \text{ hr} \pm 0.54 \text{ SE}$; $17.6 \text{ hr} \pm 0.47 \text{ SE}$). The duration of incidental nature interactions in Singapore ($1.5 \text{ hr} \pm 0.11 \text{ SE}$) was less than that in Brisbane ($2.4 \text{ hr} \pm 0.12 \text{ SE}$; Figure 2). However, the Singapore population spent more time on intentional park interactions ($2.3 \text{ hr} \pm 0.18 \text{ SE}$) than the Brisbane population ($1.6 \text{ hr} \pm 0.07 \text{ SE}$; Figure 2), whereas the Brisbane

population spent more time on intentional garden interactions ($3.1 \text{ hr} \pm 0.08 \text{ SE}$) than the Singapore population ($1.6 \text{ hr} \pm 0.06 \text{ SE}$; Figure 2).

When at home and at work, street and residential trees in both Brisbane and Singapore provided the greatest share of indirect nature interactions. However, a larger proportion of the Brisbane population had views of natural areas (bushland) compared to the Singapore population (nature reserves; Figure 2b,c), while views of urban parks were comparable across both cities. The working Brisbane population, however, was more likely to have no good view of nature from their office compared to the working population in Singapore (Figure 2b,c).

For both cities, the interaction terms between the type of nature interaction and four other factors (connection to nature, age, income and gender) were significant ($p < 0.05$; Table S3). However, the relationship between the factors and duration sometimes differed depending on the type of nature interaction. Figure 3 reports the effect size of each factor (on the duration) for each type of nature interaction, while Figure 4 displays the direction and magnitude of the relationship between each (statistically significant) factor and duration of nature interaction (for each type of nature interaction). Across both Brisbane and Singapore, people with a stronger connection to nature spent longer interacting with nature (Figures 3 and 4). However, the positive relationships between connection to nature and durations spent on intentional interactions in parks and gardens was stronger than that of incidental and indirect nature interactions (Figure 4).

The relationship between age and duration of nature interactions across both cities were weakly negative or unclear (Figure 4). An exception, however, was the positive relationship between age and duration spent on intentional interactions in gardens in Brisbane.

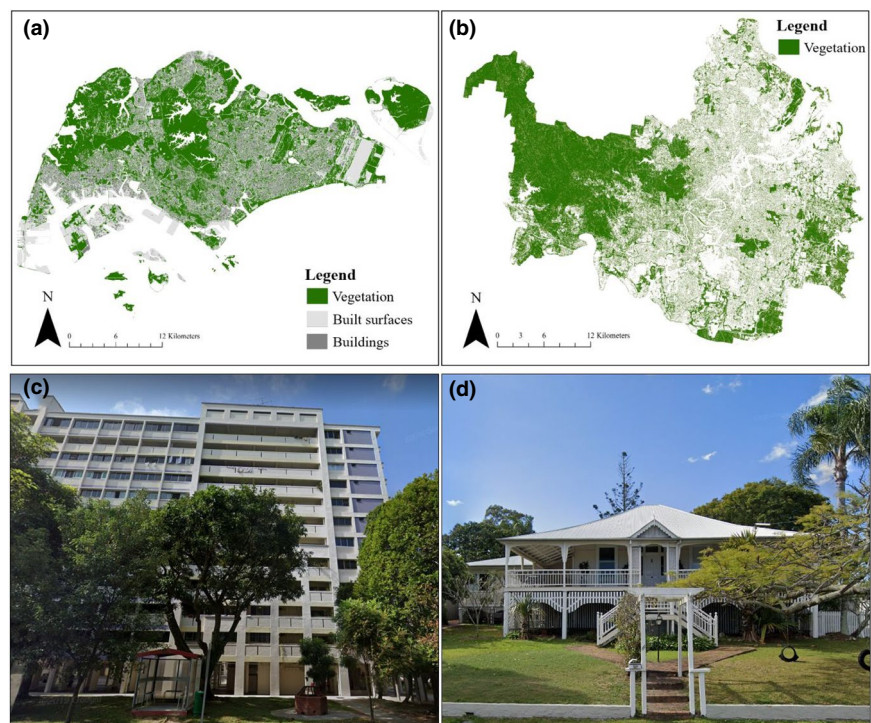


FIGURE 1 The distribution of urban greenspace across (a) Singapore (adapted from Gaw et al., 2019) and (b) Brisbane (adapted from Caynes et al., 2016); and the predominant housing type in (c) Singapore and (d) Brisbane (extracted from Google Street View)

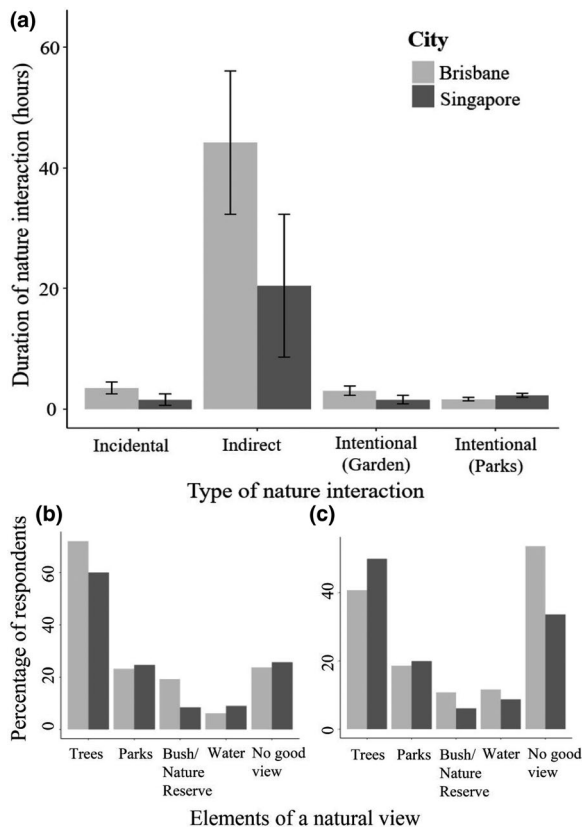


FIGURE 2 (a) The duration of time spent in a week on each of the four types of nature interaction for the Singapore and Brisbane population. Error bars represent standard errors. Breakdown of the percentage of respondents who spent time interacting (indirectly) with different elements of natural views when (b) at home and (c) at work

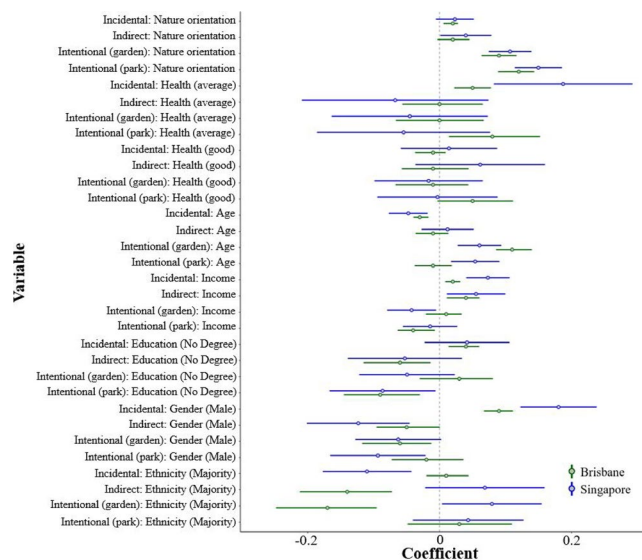


FIGURE 3 The model outputs for Brisbane and Singapore, showing the effect size and confidence intervals of each factor (on the duration) for each type of nature interaction. The effect size and confidence intervals for categorical factors are presented relative to a comparative base factor level [Health: Poor; Education: Degree; Gender: Female; Ethnicity: Non-Chinese (Singapore) or English is not the first language (Brisbane)]

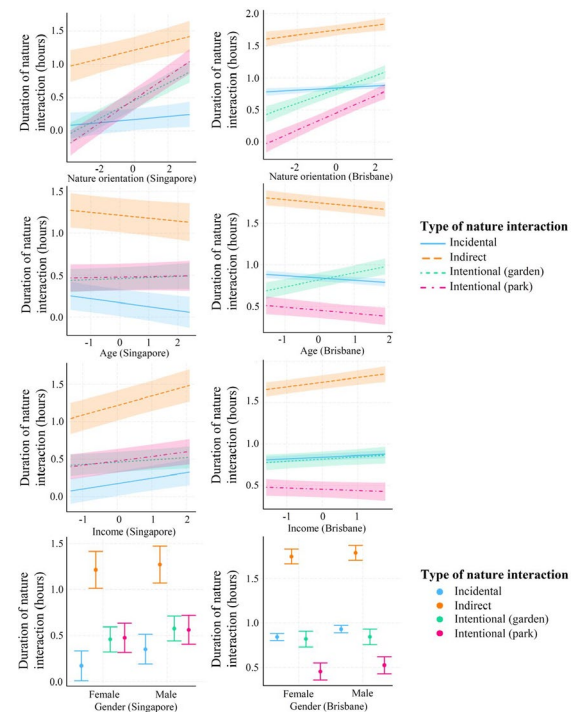


FIGURE 4 Interaction plots from the mixed-effects model showing the relationship between each (statistically significant) factor and the duration of nature interaction, for each type of nature interaction within Brisbane and Singapore: type of nature interaction: nature orientation; type of nature interaction: age; type of nature interaction: income; and type of nature interaction: gender. Fitted lines are used for continuous factors (i.e. nature orientation, age and income), with shaded areas representing confidence intervals. The effect size is plotted for categorical factor (i.e. gender), and error bars represent confidence intervals

This suggests that older people in Brisbane spent more time on intentional interactions in gardens (but less time for all other types of nature interactions; Figure 4).

There were also some weakly positive relationships between income and duration spent on nature interactions for both Brisbane and Singapore (Figures 3 and 4). However, the positive effect of income on indirect nature interactions was the strongest for both cities (Figure 4), indicating that people with higher income spent longer interacting indirectly with nature. For the Brisbane population only, there was a slight negative correlation between income and intentional interactions in parks. Males in both Brisbane and Singapore spent longer interacting with nature compared to females (Figures 3 and 4).

For Brisbane only, the interaction terms between type of nature interaction and three other factors (health, education and ethnicity) were significant ($p < 0.05$; Table S3). In the Brisbane analysis, people reporting better health spent longer interacting with nature through intentional interactions in parks (Figure 5). The relationships between education and ethnicity, and the duration spent on each type of nature interaction were less consistent (Figure 5). People reporting lower qualifications (no Bachelor's or Postgraduate Degrees) generally spent shorter durations

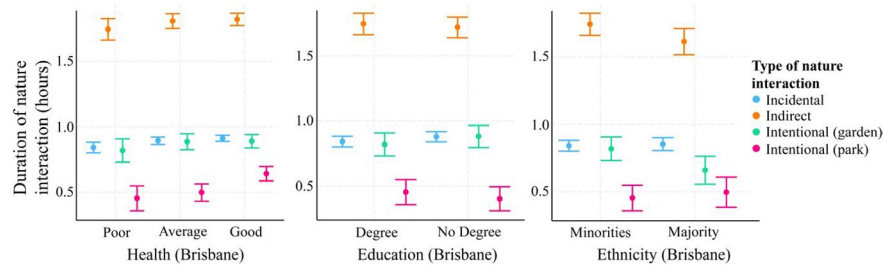


FIGURE 5 Interaction plots from the mixed-effects model showing the relationship between each (statistically significant) factor and duration of nature interaction, for each type of nature interaction within Brisbane only: type of nature interaction: health; type of nature interaction: education; and type of nature interaction: ethnicity. The effect size is plotted for categorical factors (i.e. health, education and ethnicity), and error bars represent confidence intervals

interacting with nature. Compared to the ethnic minorities, the ethnic majority in Brisbane spent longer on intentional interactions in parks but shorter durations on indirect interactions and intentional interactions in gardens.

4 | DISCUSSION

We found that, on average, the Singapore population spent only half as much time interacting with nature, and considerably less time engaging in indirect nature interactions (i.e. window views of nature), compared to the Brisbane population. Differences in city design, such as the dominant housing type and spatial distribution of greenspace, could influence the opportunity to interact indirectly with nature. Despite both cities having similar proportion of green cover, Brisbane residents reported longer durations of indirect nature interactions, perhaps because most residents live in low-density housing with access to a yard or deck, and the bulk of vegetative cover in Brisbane occurs within private residential yards (Shanahan et al., 2014). In contrast, the Singapore population primarily resides in high-rise apartments (Yuen, 2009), and working adults in Singapore also spend more time in offices (Chia et al., 2015), and longer waking hours being seated and sedentary (De Cocker et al., 2014; Müller-Riemenschneider et al., 2016). Further, urban greenspace in Brisbane are more evenly distributed across the city (Brisbane City Council, 2014a) than in Singapore (Urban Redevelopment Authority, 2017). Our finding where indirect interactions were the most common means of interacting with nature daily in both cities mirror findings from a study conducted in the United Kingdom (Cox, Hudson, et al., 2017), and could be an outcome of a modern urban lifestyle where people are spending more of their time indoors (Leech et al., 1996; Matz et al., 2014). Such quantifiable differences in time–activity patterns are consistent with broader global and societal trends such as more time spent on sedentary behaviours (Ding et al., 2020; Guthold et al., 2018; Kohl et al., 2012), increased time spent working from home (Turcotte, 2010) and extended screen time in adolescents (Cui et al., 2011; Leatherdale & Ahmed, 2011).

Opportunities to access greenspace seem to be important for the intentional use of gardens and parks (Oh et al., 2020). We found that the Brisbane population spent more time in gardens than in

parks (in an average week) while respondents from Singapore spent more time in parks than gardens. This could stem from differences in opportunities to access different types of greenspace—the Brisbane respondents reported greater access to a yard or deck compared to those from Singapore. Conversely, there are twice as many parks in a 500 m buffer around residences in Singapore compared to Brisbane (Lin et al., 2014; T.P.L. Nghiem, Y. Zhang, R.R.Y. Oh, C. Chang, C.L.Y. Tan, D. Shanahan, B. Lin, K. Gaston, R.A. Fuller, & R. Carrasco, unpublished data). These results provide evidence that both gardens and parks are essential urban greenspace that provide immediate and readily accessible means for people to interact with nature directly (Shanahan et al., 2017).

Our findings suggest that several socio-cultural factors are associated with how much respondents interact with nature. The interaction terms between nature orientation, age, income and gender, and type of nature interaction significantly predicted the duration of nature interactions for both Brisbane and Singapore. However, the way in which these factors relate to each type of nature interaction sometimes differed in direction and effect size. For example, a person's nature orientation (connection to nature) positively predicted the duration of all four types of nature interactions in both cities. However, these associations differed in effect size—nature orientation was more strongly and positively associated with intentional nature interactions in parks and gardens, compared to that of indirect and incidental nature interactions.

The finding that people who are more strongly connected to nature spend more time in nature aligns with previous research—they interact with greenspace more frequently and for longer (Lin et al., 2014, 2017), and are more likely to receive greater health and well-being benefits from these interactions (Giusti & Samuelsson, 2020). In fact, while nature orientation has been found to be associated with improved psychological well-being (Martyn & Brymer, 2016) and self-reported general health (Dean et al., 2018), a combination of nature orientation (i.e. feeling connected to, and being comfortable in, nature) and intentional nature interactions (i.e. regular physical activities outdoors) could deliver greater well-being benefits than either factor alone (Lawton et al., 2017). Indeed, appreciation of nature is a significant motivation for people to spend more time in nature (Clayton, 2007). However, given the correlational

nature of our study, we were unable to ascertain the presence or direction of any causal relationship between nature orientation and nature interactions; it is also possible that more nature interactions might strengthen a person's nature orientation.

We further found that age, income and gender vary in their associations with different types of nature interactions across cities. Across both cities, age was generally and weakly negatively associated with duration, indicating that older people tend to spend less time interacting with nature. The exception was that, within Brisbane, there was a positive relationship between age and intentional interactions in gardens. One explanation for this is that the means by which people in Brisbane interact with nature could change over their lifetime. As people get older, they may develop a preference to interact with nature through their private gardens rather than public parks, and this preference is a possibility since most Brisbane residents have access to a private garden. While this could potentially reflect increasing immobility, it may also reflect an increase in leisure time for older people (Gauthier & Smeeding, 2003), a developed preference for gardening as one of their favourite leisure time physical activities (Afonso et al., 2001; Rowinski et al., 2015) or the strengthening of people's relationship with nature as they age (Shanahan et al., 2014).

Personal income generally positively predicted the duration of nature interactions across both cities. However, the positive effect of income was the greatest for indirect nature interactions across both cities. This relationship could reflect the influence of vegetation on property value (Belcher & Chisholm, 2018; Pandit et al., 2013; Tapsuwan et al., 2009). Wealthier individuals can afford properties with more greenery, thereby providing people on higher incomes with greater opportunities to view nature through their window. However, for the Brisbane population, there was a slight negative correlation between personal income and intentional nature interactions in parks. While this was plausible, given that individuals with higher incomes are constrained in their use of greenspace by a lack of time and a preference for other activities in other places (Mowen et al., 2005), it runs contrary to some studies reporting that individuals with lower income spend less time in greenspace (Scott & Munson, 1994). We also found that males tend to interact with nature for longer compared to females. Indeed, females are under-represented in their use of greenspace (i.e. intentional park interactions; Cohen et al., 2007). It is also likely that life stage and family circumstances will impact how females interact with nature, perhaps more than men. For example, leisure time exercise behaviour in females is more severely attenuated by having children than for males (Popham & Mitchell, 2006), and time-activity studies have reported gender differences in time spent in different microenvironments. Males tend to spend more time outdoors (Matz et al., 2014) or in public parks while females spend more time in school and at food stores (Wu et al., 2011).

Self-reported health, education and ethnicity were three additional factors that significantly predicted the duration of nature interactions in Brisbane (but not Singapore). Individuals who reported better health spent longer on intentional interactions in parks.

However, the cross-sectional design of the present study renders us unable to ascertain whether people were healthier because they interacted for longer with nature, or that healthier people were able to access nature for longer. When compared to the ethnic minorities (of Chinese and Vietnamese descent), the ethnic majority in Brisbane spend longer on intentional interactions in parks but shorter durations on indirect interactions and intentional interactions in gardens. This finding is both similar (e.g. Peters et al., 2010) and different (e.g. Hamstead et al., 2018) to previous studies. For example, the ethnic minority (Moroccans) in the Netherlands used urban parks more frequently than the Dutch majority because they valued parks as a place to strengthen their social network (Peters et al., 2010). In contrast, ethnic minorities (of Hispanic or Latino descent) in New York visited urban parks less because of lowered accessibility (Hamstead et al., 2018). These inconclusive findings could be attributed to the differences in the ethnicities studied, the values they place on urban greenspace and the type of park visitation measures used (Rigolon, 2016).

4.1 | Designing cities to promote nature interactions

Our findings have implications for the design and implementation of interventions targeted at increasing nature interactions in people. First, the design and implementation of interventions by local authorities and practitioners must reflect city-specific variation in factors that are associated with differences in nature interactions, and consider these factors within the wider context of how local communities use, and need urban greenspace. However, on a broader scale, there is clearly a strong need to enhance the extent and quality of natural spaces that have health improvement as a key primary outcome. In an urbanising world where human well-being is not improved despite substantial increases in investments for better health care (Jorm et al., 2017), incorporating funds to enhance natural spaces into health care budgets could deliver substantial and cost-effective health gains while improving urban biodiversity (Dean et al., 2011).

5 | LIMITATIONS AND FUTURE RESEARCH

The major strength of this study is the direct comparison between two very different cities from different countries, which allows the exploration of the cultural and setting-based component of nature interactions. Given that most studies were conducted in temperate countries, we contribute knowledge from tropical countries.

However, this study was unable to measure every possible variation of indirect and incidental nature interactions. For example, some have included the viewing of images or videos of nature as indirect nature interactions (e.g. Nadkarni et al., 2017; Wolf et al., 2016; but see Gaston & Soga, 2020), which were not measured here. Our approach aimed to minimise respondent fatigue

(where respondents give less thoughtful answer to survey questions; Hochheimer et al., 2016) by constraining the length of the survey, and purposefully focused on places and daily activities that an average individual would spend the most time on, such as work (Tudor-Locke et al., 2011). A time budget study could be useful to track daily fluctuations in durations spent across a diverse range of indirect and incidental nature interactions. Lastly, both our surveys were biased towards capturing only responses from English-speaking individuals. This would preclude older respondents in Singapore who speak only a non-English language (approximately 16.5%; Singapore Department of Statistics, 2015), and more recent immigrants in Brisbane (approximately 20% in Greater Brisbane; Australian Bureau of Statistics, 2016).

Our study broadly distinguished between four types of daily nature interactions, on the premise that prior studies have shown that such interactions are associated with beneficial health and well-being outcomes. Yet, our approach did not quantify variation in biodiversity across nature interactions despite emerging evidence that people's perceptions of nature can differ (Southon et al., 2018), and more biodiverse landscapes deliver greater well-being benefits (e.g. Giusti & Samuelsson, 2020; Wolf et al., 2016; Wood et al., 2018). Future studies could consider measuring specific biological quantities such as species diversity, vegetation complexity and acoustic stimuli (differentiating between actual and perceived measures; sensu Fuller et al., 2007; Dallimer et al., 2012), to better understand whether interacting with a more biodiverse landscape is related to receiving greater health and well-being benefits (Craig et al., 2016).

6 | CONCLUSIONS

Our study showed that while the total duration of the nature interactions measured in Brisbane was twice that of Singapore, indirect interactions were the most prevalent means of experiencing nature daily in both cities. We further demonstrated that factors predicting the duration of nature interactions varied between cities and different types of nature interactions. Nature orientation, age, income and gender significantly predicted the duration of nature interactions in both Singapore and Brisbane. However, the relationship between each factor and each type of nature interaction could differ in direction and effect. As such, local studies will be essential to enable the design of locally relevant interventions to enhance interactions with nature.

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CONFLICT OF INTEREST

Kevin Gaston is Editor-in-Chief of *People and Nature*, but took no part in the peer review and decision-making processes for this paper.

AUTHORS' CONTRIBUTIONS

R.R.Y.O., K.S.F., R.A.F., D.F.S., K.J.G. and R.L.C. conceived the ideas and designed the methods; R.R.Y.O. and D.F.S. collected the data; R.R.Y.O. analysed the data and led the writing of the manuscript. All the authors contributed critically to the drafts and gave final approval for publication.

DATA AVAILABILITY STATEMENT

The data used for this study have been made publicly available on Dryad Digital Repository <https://doi.org/10.5061/dryad.z612jm6b9> (Oh et al., 2021).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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