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ORIGINAL PAPER

Linking green space to health: a comparative study of two urban neighbourhoods in Ghent, Belgium

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Abstract This paper investigates the nature of the relationship between the greenness of the local environment and the health and well-being of its inhabitants by looking at a number of possible mediators within the same study: physical activity, perceived stress, ability to concentrate, social cohesion and neighbourhood satisfaction. Data were collected through a survey of residents in two neighbourhoods that differ objectively in green space provision, but which are largely similar in demographics, socio-economic factors, housing conditions and other environmental characteristics, apart from green space. Of the three dependent variables of interest: self-reported general health, bodily functioning and general well-being (happiness), it was self-reported happiness that differed significantly between the two neighbourhoods, with greater happiness in the greener neighbourhood. Amongst the possible mediators, people's satisfaction with their neighbourhood differed significantly: those living in the greener neighbourhood were more satisfied. Mediation analysis indicated that neighbourhood satisfaction fully mediates the relationship between neighbourhood greenness and happiness. Among the specific (environmental and social) neighbourhood qualities asked about, perception of neighbourhood greenness was found to be the most important predictor of neighbourhood satisfaction. Additional analysis showed that the view from the living room—green or not green—fully mediates the relationship between neighbourhood

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greenness and neighbourhood satisfaction. This study underscores the importance of nearby green space for people's overall well-being and suggests the need for green space to be evaluated in terms of visual proximity, that is, whether and how it is experienced from the street and the home.

Keywords Urban environment · Nearby nature · Happiness · Neighbourhood satisfaction · Green view

Introduction

Today there is a growing recognition that natural or 'green' environments can benefit the health of urban populations and so have a vital role to play in healthy city planning (e.g. Maller et al. 2005; Nilsson et al. 2007; Dawe and Millward 2008). This view fits well with the current emphasis on urban liveability and quality of life and is increasingly supported by scientific evidence. Specifically, beneficial associations have been reported between neighbourhood access to or availability of green space and indicators of health and well-being such as perceived general health (De Vries et al. 2003; Maas et al. 2006, 2009a; Mitchell and Popham 2007; Sugiyama et al. 2008), mortality (Takano et al. 2002; Mitchell and Popham 2008), morbidity (Maas et al. 2009b), health-related complaints and risk of psychiatric morbidity (De Vries et al. 2003; Maas et al. 2009a), stress (Grahn and Stigsdotter 2003; Nielsen and Hansen 2007), obesity (Ellaway et al. 2005; Nielsen and Hansen 2007) and life satisfaction in later life (Sugiyama et al. 2009). Furthermore, it was also found that populations living in greener environments show lower levels of income-related health inequality (Mitchell and Popham 2008).

Despite established links between nearby green space and the health of populations, research is not conclusive as to the mechanisms or processes underlying these relationships (Maas et al. 2008, 2009a; Sugiyama et al. 2008). Thus, important questions remain as to how and why such beneficial effects occur. For these reasons, it is of interest to examine not only the strength of the relationship, but also the variables that may mediate it. The aim of this article is to address this gap in research by examining plausible mediators of the relationship between green space and health.

Possible mediators of the relation between green space and health

Encouragement of physical activity

Certain environments may stimulate physical exercise (walking, cycling, etc.), which in turn is likely to benefit health (for reviews, see Humpel et al. 2002; Owen et al. 2004; Kaczynski and Henderson 2007). Green space may be associated with an increased likelihood of being physically active in at least two ways: green areas (e.g. a park nearby) provide a suitable environment for physical activity and natural features contribute to an aesthetically attractive environment that people like to

visit. However, the evidence currently available is ambiguous. A study in Perth, Australia (Giles-Corti et al. 2005), associated proximity to public parks, recreation and sports areas with increased levels of walking (but not with overall physical activity). Studies in Portland, Oregon (Fisher et al. 2004; Li et al. 2005), reported a positive relationship between the number of parks and the total area of green space and walking activity by senior residents. Evidence from eight European cities (Ellaway et al. 2005) associated increasing levels of greenery in the residential environment with an increased likelihood of being physically active. Work in Ontario (Kaczynski 2009) found that total physical activity was associated with park surface area, while physical activity within a neighbourhood was associated with the number of nearby parks. However, some studies have not found any association between the availability of green space and physical activity at all. Research in the city of Norwich, UK (Hillsdon et al. 2006), reported no evidence of a relationship between access to green areas and levels of recreational activity in middle-aged adults, and in Rockhampton, Queensland (Duncan and Mummery 2005), no relationship was found between proximity to parkland and walking for recreation. In fact, an inverse relationship was reported for overall physical activity. Finally, a study in the Netherlands (Maas et al. 2008) concluded that the amount of green space in the residential environment—percentage of green areas, including parks, farmland, forests and nature conservation areas—is only marginally related to the level of physical activity and that in more rural areas the relationship is stronger than in urban areas. This study also indicated that the level of physical activity does not explain the relationship between the amount of green space and perceived general health. The ambiguity of the evidence may partly be due to the wide variety of measures used for green space as well as physical activity (De Vries et al. 2011).

Restorative effects: stress reduction and attention restoration

A few cross-sectional studies have examined the restorative effects of contact with nature, particularly in connection with chronically high stress levels. It is assumed that those better able to cope with stress will have a lower risk of developing stress-related illnesses. In Swedish towns, Grahn and Stigsdotter (2003) found that the more time people spend outdoors in nearby green areas, the less they suffer from stress. Also, people with access to a garden did not suffer from stress to the same degree as those without such access. These findings were confirmed in a Danish study (Nielsen and Hansen 2007), which concluded that access to a garden or green areas close to home is associated with lower perceived stress. Some other studies examined nature's restorative effects on cognitive functioning or ability to concentrate. A study by Kuo (2001) showed that residents living in public housing buildings with nearby trees and grass reported greater effectiveness in managing major life issues than those without nature nearby. This relationship was mediated by the reduction in mental fatigue. Wells (2000) conducted a premove/postmove longitudinal study among low-income urban children. Her results indicate that children whose homes improved the most in terms of greenness following relocation, also tended to have the highest levels of cognitive functioning following the move. Furthermore, there are quite a number of experimental studies showing

restorative effects of brief experiences of contact with nature, with passive viewing and with physical activities such as walking (Hartig et al. 2011). One may assume that repeated experiences of this type have a cumulative effect (Hartig 2007).

Facilitation of social interaction and cohesion

Neighbourhood social ties are a key factor in the development of social cohesion, which may in turn give rise to beneficial health effects (Kawachi and Berkman 2000; Ellaway et al. 2001; Kim and Kawachi 2006; Echeverria et al. 2008). A few studies suggest that the availability of green public areas may facilitate informal social interaction with neighbourhood members. Kuo et al. (1998) and Kweon et al. (1998) found that in inner-city neighbourhoods of Chicago, where common spaces are often a barren no-man's land, levels of vegetation—in particular the presence of trees and grass—predict both the use of common spaces and neighbourhood social ties. Mediation tests indicated that the use of common spaces explains this link (Kuo et al. 1998; see also Sullivan et al. 2004). Furthermore, in Zürich, Switzerland, urban green areas (parks, playgrounds, forests) were found to play an important role for children and youths in making cross-cultural contacts and friendships (Seeland et al. 2009). Maas et al. (2009a) showed that in the Netherlands, people living in an environment with a greater percentage of green areas (including parks, farmland, forests and nature conservation areas) feel less lonely, although they do not have more contact with neighbours or friends in the neighbourhood.

Contribution to neighbourhood satisfaction

In a study by Fried (1982), easy access to nature—a two-item indicator composed of ease of access to the outdoors in the neighbourhood and the closeness of larger open spaces—proved to be the single strongest predictor of neighbourhood satisfaction. A positive relationship between the amount of tree cover and neighbourhood satisfaction was reported in several other American studies (Kaplan 1985; Ellis et al. 2006; Lee et al. 2008). Kearney (2006) showed that opportunities to visit natural areas and having a view of nature from home have a greater impact on neighbourhood satisfaction than residential density and proximity to nature areas. Similarly, Kaplan (2001) found that having natural elements or settings in the view from a window contributes to residents' satisfaction with their neighbourhood and benefits various aspects of their sense of wellbeing. A small body of research suggests that a negative perception of one's own neighbourhood is likely to increase the risk of poor health. This relationship between neighbourhood satisfaction and health has most commonly been assessed in relation to satisfaction with a list of specific environmental aspects. A study in the city of Hamilton, Canada (Wilson et al. 2004), found that people who dislike aspects of their neighbourhood's physical environment—lack of green space was one of these—are more likely to report poor mental health than those who like these aspects. In Amsterdam, the Netherlands (Agyemang et al. 2007), it was found that fair to poor self-rated health was associated with neighbourhood-level psychosocial stressors (nuisance from neighbours, youngsters hanging around, rubbish on the streets, feeling unsafe and

dissatisfaction with green space). In Adelaide, Australia (Leslie and Cerin 2008), it was also concluded that perceptions of environmental characteristics relating to the local neighbourhood—aesthetics and greenery, crime and traffic load and safety—may be important contributors to mental health. It was suggested that neighbourhood satisfaction mediates the relationship between (perceived) environmental characteristics and (self-rated) mental health.

Interrelationships between mechanisms

Finally, synergistic health effects may also exist between the different mechanisms. For example, neighbourhood appreciation, in particular the perception of aesthetic quality, was significantly associated with walking for exercise or recreation in several studies (e.g. Owen et al. 2004; Bergman et al. 2009). Conversely, it is possible that increased levels of physical activity influence people's perception of the environment (Humpel et al. 2004). Further, people living in walkable neighbourhoods are more likely to engage in informal contacts (Gehl 1987) and to know their neighbours (Leyden 2003). People living in less socially cohesive neighbourhoods are less likely to walk for exercise (Echeverria et al. 2008). Stress reduction and other restorative effects are also commonly linked to physical activity. In this respect, the restoration achieved through physical activity performed in a green environment might be higher than in a less green environment (Bodin and Hartig 2003; Hartig 2007). Thus, the different mechanisms may be interrelated and reinforce each other.

As can be seen from the above literature review, the use of green space concepts and measures vary according to the mechanisms under investigation. In this respect, most of these studies have employed a very specific (and perhaps somewhat narrow) definition of green space (see also Jorgensen and Gobster 2010), which may be less suitable when looking at more than one mechanism (and eventual interrelationships between them). What is also important to note is that the existing studies often ignore conditions in the local environment other than green space provision that may influence health outcomes. Macintyre et al. (2002), for example, have listed a variety of features of local areas which might influence human health. However, in current research into green space and health, the multiplicity of 'place effects' remains mostly unconsidered, and where such factors (e.g. residential density) are considered, they are often treated as independent background variables. Incorporating the potential health effects of multiple features of the local socio-physical environment, and moving beyond treating them as exerting an effect that is independent of other environmental features, remains a major challenge (see Macintyre et al. 2002; Cummins et al. 2007, for a general critique).

Study design and research questions

The overall aim of the present study is to investigate the nature of the relationship between the greenness of the local environment and the health and well-being of its inhabitants by looking at a number of possible mediators within the same study. This allows for the possibility of looking at the interrelationships of the mediators, but also

obtaining an indication of their relative strength, at least in terms of predictive validity. The focus is on urban neighbourhoods, as it is assumed that effects will be greater at the lower end of the greenness spectrum (see also Sullivan et al. 2004). Conceptually, greenness was considered at the level of the neighbourhood and encompassed two dimensions. The first is the availability of nearby green areas (parks, grass areas, etc.) that provide possibilities for walking. The second is the presence of streetscape greenery (lines of trees, front gardens, green facades, etc.).

The study uses a quasi-experimental cross-sectional design, focusing on two contrasting urban neighbourhoods. These neighbourhoods differ objectively in green space provision, but they are largely similar in demographics, socio-economic factors and other environmental characteristics, apart from green space. Consequently, a wide range of neighbourhood characteristics (including their possible interrelationships) which might influence human health or any of the mediators under consideration is kept (relatively) constant.

The research questions are:

1. Do the two urban neighbourhoods, differing in terms of greenness, also differ in terms of the health and/or well-being of their inhabitants?
2. If so, to what extent can the observed relationship be shown to be mediated by each of the following five variables: physical activity, perceived stress, ability to concentrate, social cohesion and neighbourhood satisfaction?

Methods

Neighbourhood selection

The study was conducted in Ghent (Belgium). With a population of over 200,000. Ghent is the second largest city in Flanders (northern Belgium). 'Neighbourhood' was defined by the spatial entity of a statistical sector, which represents a more or less homogeneous area in respect of social make-up (Pelfrene et al. 1998). Ghent contains 204 such neighbourhoods. An average neighbourhood has 1,102 inhabitants. The selection was made in three steps:

Firstly, those neighbourhoods were identified that contrast strongly in nearby green areas. For this purpose, the 'green space monitoring tool' developed by Van Herzele and Wiedemann (2003) was applied (Van Herzele et al. 2004a, for a more detailed description of methodology). This GIS application allows for a comparison of the provision of accessible green areas between and within cities at different functional scales (from the neighbourhood to the peri-urban level). The method is based on a calculation of 'catchment areas', taking into account the size of the respective areas and the eventual effect of barriers (e.g. major roads with pedestrian crossings located far apart from one another). For the purpose of the present study, two types of neighbourhoods were identified: those having green areas within a walking distance of both 400 m (min 1 ha) and 800 m (min 5 ha) and those lacking these facilities. They were labelled 'green' and 'non-green' neighbourhoods, respectively.

Secondly, the neighbourhood typology elaborated in a study by Vanneste (2004) was used to identify neighbourhoods with similar demographics (population density, age structure, ethnicity and household structure), socio-economic status (unemployment, working hours, income and car ownership) and housing characteristics (basic comfort, surface area, garden, type and age of dwellings, building density and proportion of rented accommodation). In that study—following Ward's method of hierarchical clustering (Vanneste et al. 2007, for a description of methodology)—five types of neighbourhoods were identified. Within the same neighbourhood type, pairs of green and non-green neighbourhoods that scored most similarly for these characteristics were identified. This procedure resulted in only three neighbourhood pairs.

Thirdly, these neighbourhoods were checked and compared to find similar scores for a number of environmental attributes. The Immission Frequency Dispersion Model developed by the Flemish Institute for Technological Research (VITO) was used to estimate health-related air pollution (SO_2, NO_2, particulate matter and lead). Additionally, fieldwork was carried out using a checklist for each street. This allowed for the characterising of the neighbourhood pairs for visible green attributes in the streets (trees, front gardens, etc.). Also, non-green elements of the environment associated with both physical activity (Saelens et al. 2003; Leslie et al. 2005) and general environmental quality (Bonaiuto et al. 2003) were compared. These include the quality of footpaths, land-use mix, public and commercial services (all field observations), noise disturbance, safety from crime and traffic (data from city administrations) and street connectivity (GIS calculations).

This three-step approach ultimately led to the selection of two inner-city neighbourhoods: Dierentuin (32.7 ha) and Sint-Jacobs (29.8 ha). According to the mentioned neighbourhood typology, inner-city neighbourhoods combine a high population density (in our case 81 and 77.6 inhabitants per ha, respectively) with a mixture of dwelling types. Compared to the city as a whole, the surface area of dwellings is typically small (<55 m^2). There is also more rented accommodation and there are few gardens. Small and single person households, residents aged over 60 and the unemployed are more common.

Based on the observations made in the present study, the two neighbourhoods can be described as follows. Both neighbourhoods contain a mix of functions and have a so-called traditional or complete design (Leyden 2003) where all daily facilities are within walking distance (although Sint-Jacobs has more shops and schools). They have a concentration of nightlife in one location: a square with small cafés in Sint-Jacobs and a large cinema complex with adjacent cafés in Dierentuin. Similar levels of air pollution, noise disturbance and safety from crime and traffic were found. Traffic density is unevenly spread with busy roads located at the periphery (Dierentuin) and crossing the neighbourhood (Sint-Jacobs). All of the streets have pavements but these are typically narrow and not always convenient. A notable difference is that the streets of Sint-Jacobs are often narrower and sometimes winding (showing their medieval origin), and street connectivity—measured by intersection density—is higher than in Dierentuin (2.3 and 1.5 intersections per ha, respectively). Although Dierentuin is also located in the old medieval part of the town, it was only built in the 19th and early 20th centuries (mainly on the site of a former zoo), which has resulted in a more regular street pattern.

Table 1 presents data on visible green elements and accessible green areas at different spatial levels, from the street to the wider environment (up to 1,600 m away). Sint-Jacobs has few small green elements. There is one public park of nearly 1 ha, which is split in two by a road. There is no larger city park within reach. The streets of Dierentuin have more trees and there are small front gardens in some cases. There is a public park (1.3 ha) located at the centre of the neighbourhood. Two city parks are within easy reach. The smallest (5 ha) is adjacent to the neighbourhood—although separated from it by a busy road—and the other (11 ha) is located some 700 m from the centre of the neighbourhood.

Sample and survey

Three hundred residential households per neighbourhood were randomly selected to participate in the study. A self-completion questionnaire was distributed in June 2004. The questionnaire was piloted to ensure readability, question clarity and acceptability. A prepaid and preaddressed envelope was provided to return the completed questionnaire, as well as a minor incentive for participation (chance to win a bookshop gift voucher). Hundred and ninety completed questionnaires were returned. The response rates were about the same for the two neighbourhoods: 32% for Dierentuin ($n = 97$) and 31% for Sint-Jacobs ($n = 93$).

The questionnaire was designed to provide information on the health and well-being of respondents, as well as on five possible mediators (indicators of physical activity, perceived stress, ability to concentrate, social cohesion, neighbourhood satisfaction). The questions on self-reported health and main control variables (such as health-related habits) were derived from the Belgian Health Interview Survey (Scientific Institute of Public Health 2001), a validated multi-purpose instrument aimed at supporting public health policy in Belgium. Other measures were derived from previously published studies (see further below).

Table 1 Green spaces and elements by neighbourhood

	Dierentuin (more green)		Sint-Jacobs (less green)	
	Number	% of streets	Number	% of streets
Visible green elements				
Street trees	334	71	114	44
Flower beds	12	32	9	17
Green facades	50	50	32	33
Front gardens	70	21	4	8
Flower tubs	87	71	53	52
Accessible green spaces				
Neighbourhood park <1 ha	1		1	
Neighbourhood park >1 ha	1		0	
City park >5 ha, <800 m	1		0	
City park >10 ha, <1,600 m	1		0	

Health and well-being measures

The questionnaire included two measures of self-reported health status (Belgian Health Interview Survey). General health was measured by the question: 'How would you rate your overall health status at present?' (1 = very good, 7 = very bad). Previous longitudinal studies have consistently demonstrated general self-rated health to be a strong independent predictor of overall mortality (Idler and Benyamini 1997; Mackenbach et al. 2002). Because of its skewed distribution, scores were dichotomised (% less than good). Several green space and health studies have also used the dichotomised version of such an overall measure of health status (De Vries et al. 2003; Maas et al. 2006, 2008, 2009a; Mitchell and Popham 2007). To assess bodily functioning, the somatic complaints subscale was used (12 common physical symptoms: headaches, dizziness, pains in heart or chest, nausea or upset stomach, etc.). The participants were asked: "In the last month to what extent have you been bothered by…" (1 = not at all, 5 = very much). An average score was calculated. This measure corresponds to the Dutch translation of the SCL-90-R somatisation scale (Arrindell and Ettema 2003) and reflects a respondent's physical symptom concerns or perceptions of bodily (dis)functioning (Derogatis 1983). Overall well-being was measured by asking whether participants agreed with the statement that they feel happy (1 = totally agree, 5 = totally disagree). The concept of happiness denotes the overall experienced well-being and this question has been proposed as the most inclusive summary indicator of quality of life (Veenhoven 1996; Abdel-Khalek 2006). Whereas previous studies on the determinants of well-being have often used such an overall happiness question, the impact of environmental factors on this indicator has scarcely been researched (for a review, see Dolan et al. 2008). On the other hand, several experimental studies have shown that contact with nature results in more positive emotions (Hartig 2007).

Physical activity measures

The measure of physical activity was adapted from the 'leisure-time physical activity' domain in the SQUASH (Short QUestionnaire to ASses Health enhancing physical activity), which is used in the Permanent Survey of Life Situation (POLS 1998) by Statistics Netherlands. Participants were asked whether they engage in physical exercise during leisure time (gardening, walking, cycling and participation in both indoor and outdoor sports activities). If so, they had to estimate the average number of hours a week they spent on each separate activity. This had to be done for both normal and sunny weather conditions. Two indicators were calculated, one for hours spent per week on all activities together in normal weather conditions and one for hours spent per week on walking and gardening in sunny conditions only. Whereas overall physical activity during leisure is more likely to be related to health, the latter indicator may be more clearly related to the greenness of the neighbourhood. Both indicators had skewed distributions; therefore, a logarithmic transformation was performed (similar applications in relation to green space provision are: Wendel-Vos et al. 2004; Maas et al. 2008).

Perceived stress and ability to concentrate

Perceived stress and ability to concentrate were each measured by two statements 'When I get up, I feel relaxed' and 'Usually, I feel quite nervous'; 'Once I am busy with something I am not easily distracted' and 'It is very easy to pull me out of my concentration' (all: 1 = totally agree, 5 = totally disagree). The choice of the items is based on previous research on the relation between green space and stress (Grahn and Stigsdotter 2003; Nielsen and Hansen 2007). These studies suggest using simple, direct questions regarding the clearest components of stress (see also Littman et al. 2006). Two indicators—perceived stress and ability to concentrate—were constructed from the responses to these statements. The Pearson correlation coefficient between each pair of variables (after recoding for same direction) was 0.50 and 0.65, respectively, indicating reasonable reliability. The other intercorrelation was below 0.30, which suggests that the two indicators measure different constructs.

Neighbourhood satisfaction and social cohesion

Satisfaction with the neighbourhood was measured with a general statement: 'I live in a nice neighbourhood'. Similar statements were formulated regarding seven specific neighbourhood qualities: the design and maintenance of public spaces and streets, the amount of greenery, neighbourhood cleanliness, neighbourhood safety, traffic safety and air pollution (all: 1 = totally agree, 5 = totally disagree). Because qualities may vary in importance between individuals, the single-item measure was considered the most appropriate to use as a measure of overall satisfaction with the neighbourhood (Parkes et al. 2002). In addition to environmental qualities, two statements regarding social cohesion were also included: 'People in this neighbourhood know each other well' and 'People in this neighbourhood get along well' (1 = totally agree, 5 = totally disagree). The Pearson correlation between the two scores was 0.61. The items of knowing each other and getting along together are commonly used to measure perceived social cohesion at the neighbourhood scale (e.g. Leyden 2003; ABF Research 2007; Echeverria et al. 2008).

Participants' background characteristics

The survey also included questions regarding other factors that could possibly influence the variables of interest: socio-demographics and housing conditions, health-related habits such as alcohol consumption and smoking (perceived health), longstanding illness (perceived health and physical activity), working conditions (physical activity) and having a pessimistic personality (trait happiness, Pavot and Diener 2008). The background characteristics of participants are summarised by neighbourhood in Table 2. The mean age of the respondents was 43.4 years, with 54% being women. Overall, the study group was well-educated group, with 72% having at least a higher education degree. The demographics, socio-economic status and housing conditions of the participants in both neighbourhoods were very similar. No significant differences were found (all variables showing p values

Table 2 Participant characteristics by neighbourhood: means (plus standard deviations) and percentages

Variable	Dierentuin ($n = 97$; more green)	Sint-Jacobs ($n = 93$; less green)
Female (%)	53.6	54.8
Age (mean)	43.2 (13.1)	43.6 (13.2)
Education (%)		
Low	0	0
Low sec	7.5	7.6
Sec	18.3	21.7
High	74.2	70.7
Employed (%)	68.0	69.9
Hours worked weekly (mean for participants with paid work)	42.5 (15.0)	42.7 (12.4)
Household size (mean)	2.4 (1.2)	2.2 (1.2)
Household income (%)		
<1,500 €	28.1	34.9
1,500–3,500 €	40.7	39.3
>3,500 €	31.2	25.8
Years lived in neighbourhood (%)		
<5	40.2	39.8
5–20	34	33.4
21–40	17.6	18.2
>40	8.2	8.6
Ownership second residence (%)	15	14
Car owner (%)	79	75
Dwelling type (%)		
Detached house	4.3	4.3
Semi-detached house	5.3	0
Terraced house	60.6	66.3
Flats	29.8	29.2
Private outdoor space (%)		
Terrace	21.1	23.9
Court	31.6	34.8
Garden*	31.6	17.4
None	15.8	23.9
Green view (%)**	55.7	23.7
Long standing illness (%)	26.0	34.1
Considerable alcohol consumption (>3 glasses per day, %)	9.4	4.3
Smoker (%)*	18.8	32.3
Pessimistic attitude (mean, lower is more)	4.0 (1.0)	4.0 (1.0)

NB differences between neighbourhoods were tested by means of *t* tests for means and by means of Chi-square tests for percentages

* Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$

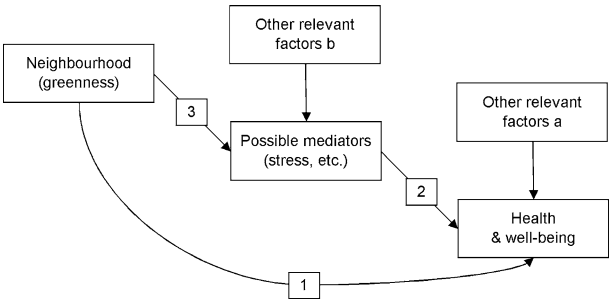

Fig. 1 Conceptual model of links between neighbourhood greenness and health and well-being

greater than 0.10), except for the view from the living room and having a garden. Dierentuin participants were more likely to have a green view ($\chi^2 = 20.28$, $p < 0.01$), which is not surprising given the higher number of green elements (see Table 1) and more often had a garden ($\chi^2 = 5.07$, $p < 0.05$), compared to those living in Sint-Jacobs.

Statistical analysis

Data analyses were performed with SPSS version 15. *T* tests and Chi-square tests were used to compare the neighbourhood samples on demographics, socio-economic status and housing conditions. Regression analyses, linear or logistic, were conducted to assess: (1) The relationship between neighbourhood greenness and indicators of health and well-being (general health, bodily functioning and happiness); (2) The relationship between health and well-being and possible mediators (physical activity, perceived stress, ability to concentrate, social cohesion and neighbourhood satisfaction); (3) The relationship between neighbourhood and possible mediators (see Fig. 1); and finally, in step 4, it was assessed to what extent the relationship between neighbourhood greenness and health and well-being is actually mediated by (one of) the possible mediators. See Baron and Kenny (1986) for more information on mediation analysis.

Main results

Neighbourhood and health and well-being

The first step in the analysis was to compare the two neighbourhoods for the three main dependent variables (general health, bodily functioning and happiness; Table 3). The dependent variables were corrected for personal characteristics and then compared for neighbourhood differences. The covariates we looked at were: gender, age, education, income, smoking, alcohol consumption and having a pessimistic personality. No significant differences between the two neighbourhoods were found for the two health indicators. However, a significant difference was

Table 3 Health and well-being and possible mediators by neighbourhood: means (plus standard deviations) and percentages

Variable	Dierentuin ($n = 97$; more green)	Sint-Jacobs ($n = 93$; less green)
Health and well-being		
General health (% less than good)	22.9	32.3
Bodily functioning (mean score)	1.65 (0.47)	1.68 (0.46)
Happiness (lower is happier)*	1.80 (0.79)	2.06 (0.78)
Possible mediators		
Overall physical leisure activity, hours per week under normal weather conditions (ln)	1.74 (0.78)	1.61 (0.91)
Walking and gardening during leisure, hours per week under sunny weather conditions (ln)	1.38 (0.73)	1.22 (0.95)
Perceived stress (sumscore)	5.29 (1.94)	5.57 (1.98)
Ability to concentrate (sumscore, lower is higher ability)	5.08 (2.00)	5.13 (1.87)
Social cohesion (sumscore, lower is more cohesive)	5.66 (1.96)	5.62 (1.81)
Neighbourhood satisfaction (lower is higher satisfaction)**	1.74 (0.91)	2.12 (1.08)
Neighbourhood aspect ratings (other than social cohesion)		
Amount of greenery (lower is more satisfied)***	1.98 (1.18)	3.32 (1.24)
Design (lower is more satisfied)***	2.37 (1.03)	3.10 (1.04)
Maintenance (lower is more satisfied)	2.45 (1.03)	2.72 (1.16)
Cleanliness	3.02 (1.16)	2.73 (1.24)
Safety of neighbourhood (lower is more satisfied)	2.42 (0.94)	2.59 (1.20)
Traffic safety	3.23 (1.18)	3.00 (1.21)
Air quality (lower is more satisfied)*	2.65 (1.23)	2.25 (1.20)

NB differences between neighbourhoods were tested by means of *t* tests for means and by means of Chi-square tests for percentages

* Significant at $p < 0.05$; ** Significant at $p < 0.01$; *** Significant at $p < 0.001$

found with regard to overall well-being: Dierentuin participants feel happier. In this analysis, two significantly contributing covariates were identified: household income (positive) and having a pessimistic personality (negative; Table 4).

Well-being and possible mediators

In a second step, the relationship between each of the possible mediators—physical activity, perceived stress, ability to concentrate, social cohesion and neighbourhood satisfaction—and the participants' well-being was analysed. Perceived stress was significantly related to happiness, as was neighbourhood satisfaction (both $p < 0.01$; Table 5). Ability to concentrate, social cohesion and physical activity were not. Happiness was higher among those with lower perceived stress, as well as among those who were more satisfied with their neighbourhood. The interrelationship between perceived stress and neighbourhood satisfaction was significant, but not very strong: $r = 0.16$; $p < 0.05$.

Table 4 Results of regression of happiness on neighbourhood (lower is happier)

Predictor	B	SE_B	Beta	*T* value
Household income	−0.058	0.021	−0.168	2.72**
Pessimistic nature	−0.402	0.048	−0.514	8.34***
Neighbourhood (higher is less green)	+0.217	0.098	+0.137	2.21*
Adjusted $R^2 = 0.31$				

* $p < 0.05$ (two-tailed test)

** $p < 0.01$ (two-tailed test)

*** $p < 0.001$ (two-tailed test)

Table 5 Results of regression of happiness on perceived stress and on neighbourhood satisfaction (lower is happier)

Predictor	B	SE_B	Beta	*T* value
Household income	−0.058	0.021	−0.167	2.72**
Pessimistic nature	−0.336	0.053	−0.431	6.31***
Perceived stress	+0.079	0.028	+0.194	2.83**
Adjusted $R^2 = 0.32$				
Household income	−0.060	0.021	−0.173	2.81**
Pessimistic nature	−0.386	0.048	−0.494	7.99***
Neighbourhood satisfaction (lower is higher satisfaction)	+0.136	0.049	+0.171	2.76**
Adjusted $R^2 = 0.32$				

* $p < 0.05$ (two-tailed test)

** $p < 0.01$ (two-tailed test)

*** $p < 0.001$ (two-tailed test)

Neighbourhood and possible mediators

Only two of the possible mediators are clearly linked to the only main dependent variable that significantly differs between the two neighbourhoods. A further requirement for mediation to take place is that the mediator itself differs between the two neighbourhoods. For perceived stress, no such difference was observed. However, the neighbourhoods did differ significantly on neighbourhood satisfaction ($p < 0.01$): residents of Dierentuin ($M = 1.74$) agree more with the statement that they live in a nice neighbourhood than those of Sint-Jacobs ($M = 2.12$). In short, neighbourhood satisfaction is the only potential mediator that is linked to both the neighbourhood and one of the main dependent variables, namely happiness.

Actual mediation by neighbourhood satisfaction

To test whether neighbourhood satisfaction did indeed mediate the link between neighbourhood and happiness, a regression analysis was performed with happiness as the dependent variable and household income, pessimistic personality and perceived stress as covariates in step 1, neighbourhood satisfaction in step 2, and

neighbourhood in step 3. Neighbourhood satisfaction did contribute, but for step 3, neighbourhood no longer did so, indicating complete mediation (Table 6). In line with this conclusion, the Sobel test as mentioned by Baron and Kenny (1986) results in a z score of 1.70, indicating that the indirect effect is significant at $p = 0.05$ (one-sided).

Additional results: neighbourhood greenness and satisfaction in more detail

The tests performed so far indicate that neighbourhood satisfaction mediates the link between residing in a more green or a less green neighbourhood and happiness. However, it would strengthen the argument whether it could be shown, or made plausible, that it is indeed the 'greenness' of the environment that makes residents more satisfied with their neighbourhood. As noted before, Dierentuin participants more often have a garden and a green view from the living room. A regression analysis showed that, of these two variables, the view from the living room—green or not green—is the only significant unique predictor of neighbourhood satisfaction. Furthermore, with view already included in the regression model, adding neighbourhood has no added predictive value, once again indicating complete mediation (Table 7). In line with this conclusion, the Sobel test now shows a significant indirect effect: z score $= 3.07$; $p < 0.01$. The complete path between neighbourhood and happiness emerging from the analyses is depicted in Fig. 2.

Another approach to assess the importance of the greenness of one's neighbourhood for achieving neighbourhood satisfaction is to see how strongly neighbourhood satisfaction is linked to the perception of a number of specific neighbourhood qualities: design and maintenance of public spaces and streets, amount of greenery, neighbourhood cleanliness, neighbourhood and traffic safety and air pollution. Social cohesion, although a possible mediator in its own right, was included since it may also be considered a quality of the neighbourhood. Satisfaction with the amount of greenery had the highest bivariate (positive) correlation with neighbourhood satisfaction ($r = 0.50$). When neighbourhood

Table 6 Results of regression of happiness on neighbourhood satisfaction and neighbourhood (lower is happier)

Predictor	B	SE_B	Beta	T value
Household income	−0.052	0.021	−0.148	2.44*
Pessimistic nature	−0.329	0.053	−0.422	6.27***
Perceived stress	+0.069	0.028	+0.169	2.49*
Neighbourhood satisfaction (lower is higher satisfaction)	+0.109	0.049	+0.138	2.22*
Neighbourhood (higher is less green)	+0.165	0.098	+0.103	1.69
Adjusted $R^2 = 0.35$				

* $p < 0.05$ (two-tailed test)

** $p < 0.01$ (two-tailed test)

*** $p < 0.001$ (two-tailed test)

Table 7 Results of regression of neighbourhood satisfaction on green view and neighbourhood (lower score is higher satisfaction)

Predictor	B	SE_B	Beta	*T* value
Green view from living room	−0.608	0.150	−0.296	4.06***
Neighbourhood (higher is less green)	+0.184	0.147	+0.092	1.26
Adjusted $R^2 = 0.10$				

* $p < 0.05$ (two-tailed test)

** $p < 0.01$ (two-tailed test)

*** $p < 0.001$ (two-tailed test)

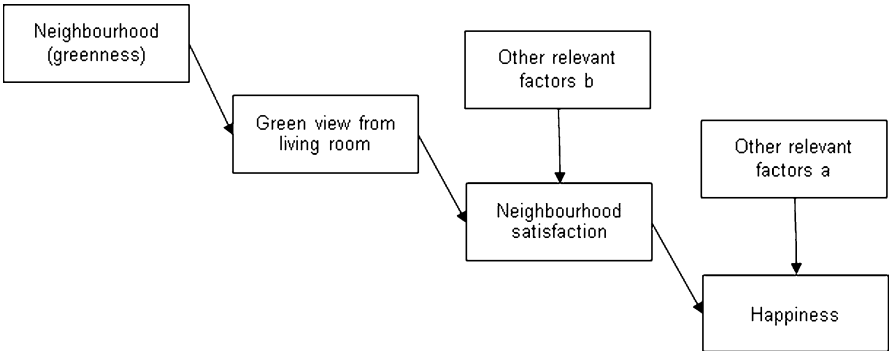

Fig. 2 Final model for happiness

satisfaction was regressed on all specific quality ratings, satisfaction with the amount of greenery remained the most important predictor. Additional contributing predictors were: neighbourhood safety, social cohesion and maintenance of public spaces and streets. This result supports the idea that neighbourhood 'greenness' is an important contributor to neighbourhood satisfaction (Table 8).

Table 8 Results of regression of neighbourhood satisfaction on perceptions regarding specific neighbourhood qualities

Predictor	B	SE_B	Beta	*T* value
Sufficient greenery	+0.250	0.047	+0.342	5.37***
Safe neighbourhood	+0.196	0.061	+0.208	3.19**
Social cohesion	+0.110	0.033	+0.206	3.36***
Well maintained public space	+0.167	0.061	+0.183	2.73**
Adjusted $R^2 = 0.38$				

NB all variables: a lower score indicates a more positive response

* $p < 0.05$ (two-tailed test)

** $p < 0.01$ (two-tailed test)

*** $p < 0.001$ (two-tailed test)

Discussion and conclusion

This study compared two inner-city neighbourhoods that differ objectively in green space provision, but which are highly similar in demographics, socio-economic factors, housing conditions and environmental characteristics other than green space. The study considered three indicators of self-reported health and well-being: general health, bodily functioning (list of somatic complaints) and happiness. The main purpose of the study was to contribute to a better understanding of the mechanisms—in particular, physical activity, perceived stress, ability to concentrate, social cohesion and neighbourhood satisfaction—by which green environments might contribute to these indicators.

The greener neighbourhood scored better for both self-reported general health and happiness. However, only the latter indicator showed a significant difference. Thus, taken together these findings suggest that neighbourhood greenness is more strongly related to general well-being or happiness than it is with health in the strict sense. As noted before, studies in the Netherlands and the UK (de Vries et al. 2003; Maas et al. 2006; Mitchell and Popham 2007) observed a positive relationship between green space and perceived general health. However, it was also concluded in a UK study (Mitchell and Popham 2007) that the nature of the relationship is dependent on both the level of urbanity and income deprivation. Given the strictly urban setting of the present study it is worth noting that in the two Dutch studies, the amount of green space had a health improving effect independent of urbanity, but this effect was less strong for areas with a high degree of urbanity. Another possible explanation for not finding a significant difference in perceived general health is the high representation of well-educated people in the study sample. According to the same studies, the relationship between green space and health tends to be stronger for people with a lower socio-economic status (who are hypothesised to spend more time in the vicinity of their homes). Lastly, the number of participants was rather low, especially when compared with other studies on the relationship between green space and perceived general health (e.g. Mitchell and Popham 2007; Maas et al. 2009a). This may have prevented worthwhile differences from being statistically significant. For example, the odds ratio observed for unhealthy versus healthy was 0.68 (after correcting for smoking) in favour of the greener neighbourhood. Compared to other cross-sectional studies using very large samples, this effect is about as large in magnitude. So, it is perhaps due to this lack of statistical power that the health difference between the two neighbourhoods was not significant and subsequent mediation tests for greenness and perceived general health could not be conducted.

Of all the investigated mediators, only perceived stress and satisfaction with one's neighbourhood were related to happiness, the former negatively and the latter positively. Neighbourhood satisfaction did differ significantly between the neighbourhoods, with those living in the greener neighbourhood being more satisfied. Regression analysis showed that the neighbourhood 'effect' disappeared when neighbourhood satisfaction was already included in the regression model, indicating complete mediation. Furthermore, among the specific (environmental and social) neighbourhood qualities asked about, perception of neighbourhood greenness was

found to be the most important predictor of residents' overall satisfaction with their neighbourhood. Particularly interesting in the present study is the finding that the view from the living room—green or not green—fully mediates the relationship between neighbourhood and satisfaction with one's neighbourhood. This is consistent with a study by Kaplan (2001) in which having natural elements in the view from the window—especially trees—was found to be associated with both residents' satisfaction with their neighbourhood and their sense of well-being. The finding is also in line with Kearney (2006), who found that visual proximity to nature has a greater impact on neighbourhood satisfaction than physical proximity.

Strengths, limitations and further research

The two neighbourhoods showed strong similarity regarding demographics, socio-economic status, housing conditions and environmental characteristics other than green space. This was also reflected in the sample characteristics. The only significant differences found were related to the greenness of the neighbourhood (view from the window and having a garden). However, despite the quasi-experimental design—all the relevant variables other than greenery that were expected to influence health/well-being or mediator variables were held constant—it may be that these particular neighbourhoods also had other, measured or unmeasured characteristics that influenced those variables. So, it is still possible that the effect of neighbourhood greenness on physical activity was underestimated. Although both neighbourhoods have a walkable mixed-use design, the less green neighbourhood (Sint-Jacobs) has higher street connectivity and better access to local shops. It is also worth noting that the neighbourhood selection approach, although proven effective for this study, could be difficult to use in other cases. It appeared that out of the 204 neighbourhoods in Ghent, only three neighbourhood pairs could be selected that both differed enough in green space provision and were comparable in demographics, socio-economic status and housing conditions (before taking into account small green elements and environmental characteristics other than green space). This is at least partly due to the fact that there is considerable correlation between the average income of a neighbourhood and the proximity of parks in large cities in Flanders (Van Herzele et al. 2004b).

Another strength of the study is that data on neighbourhood characteristics were objectively derived (national statistics, GIS calculations, field observations, etc.). Objective measures reduce the risks of respondent bias. In addition, since the data were derived from different sources to those in the survey instrument, the associations found between green space on the one hand and self-reported health and well-being and possible mediators on the other are not influenced by same-source bias (i.e. measuring both the independent and dependent variables from the same subjects). However, the relationships between health and well-being and possible mediators may be affected by same-source bias since both use self-report data. This is more likely to occur for subjective ratings (such as happiness, neighbourhood satisfaction and perception of specific aspects). It is less likely, however, that such bias affected the association between neighbourhood satisfaction and view from the window, since the latter is based on factual information.

But of course, the study also has its limitations. As already mentioned, a weakness of this study is the limited statistical power. Furthermore, measurement of some of the constructs could be criticised as having been rather limited. This may indeed apply to the ability to concentrate, where two items may have been too few to reliably measure the construct. For the other measurements, it may be argued that previous studies have shown that even single-item measurements are reliable and valid (see "Methods" section). Moreover, for these constructs, convergent validity has been established in the present study. However, for ability to concentrate, this was not the case. A lack of reliability may have attenuated the relationship we were looking for, rendering it insignificant. Finally, a well-known limitation is the cross-sectional nature of the study. This type of study does not allow firm conclusions regarding the causality of the observed relationships, despite efforts to rule out alternative interpretations. Since the present study relies on cross-sectional data, the effects of selection cannot be ruled out completely: those whose level of satisfaction is related to the greenness of the neighbourhood may choose to live in a place that is relatively green. However, even if greenness would have mattered more to Dierentuin residents compared with Sint-Jacobs residents, the latter were still less satisfied with their neighbourhood and perceived lack of greenery was the main predictor of this.

Only a few studies have examined the mechanisms underlying the relationship between green space provision and health in the residential environment. A unique feature of this study is that several possible mechanisms were examined within one setting. Taken together, the findings indicate that greater attention should be paid to the role of neighbourhood satisfaction in this relationship. In particular, future studies may benefit from a more detailed examination of neighbourhood satisfaction in relation to sense of well-being on the one hand, and local greenery on the other, in comparable samples recruited from neighbourhoods in different cities. A more differentiated neighbourhood selection would enable a better understanding of the role played by both the level of urbanity and socio-economic status of neighbourhoods. Furthermore, future studies may use intervention designs to determine to what extent the relationships found in this and other cross-sectional studies are actually causal relationships.

Finally, the significant potential benefit of having a green view from home suggests that green space provision should not only be evaluated in terms of surface area and physical distance from accessible green areas. Attention should also focus on visual proximity to green space, that is, whether and how it is experienced from the street and the home.

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