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## Green space as a buffer between stressful life events and health<sup>☆</sup>

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### ABSTRACT

This study investigates whether the presence of green space can attenuate negative health impacts of stressful life events. Individual-level data on health and socio-demographic characteristics were drawn from a representative two-stage sample of 4529 Dutch respondents to the second Dutch National Survey of General Practice (DNSGP-2), conducted in 2000–2002. Health measures included: (1) the number of health complaints in the last 14 days; (2) perceived mental health (measured by the GHQ-12); and (3) a single item measure of perceived general health ranging from ‘excellent’ to ‘poor’. Percentages of green space in a 1-km and 3-km radius around the home were derived from the 2001 National Land cover Classification database (LGN4). Data were analysed using multilevel regression analysis, with GP practices as the group-level units. All analyses were controlled for age, gender, income, education level, and level of urbanity. The results show that the relationships of stressful life events with number of health complaints and perceived general health were significantly moderated by amount of green space in a 3-km radius. Respondents with a high amount of green space in a 3-km radius were less affected by experiencing a stressful life event than respondents with a low amount of green space in this radius. The same pattern was observed for perceived mental health, although it was marginally significant. The moderating effects of green space were found only for green space within 3 km, and not for green space within 1 km of residents’ homes, presumably because the 3-km indicator is more affected by the presence of larger areas of green space, that are supposed to sustain deeper forms of restoration. These results support the notion that green space can provide a buffer against the negative health impact of stressful life events.

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### Introduction

Many people seek out nature in times of stress. For example, following the attacks on the World Trade Centre in 2001, managers of national parks observed a pronounced increase in the number of visits. In an interview published on the Environment News Service, one manager remarked, “People were going out that day, going for walks, reflecting on what was going on” (Lazaroff, 2002). Such nature-based coping strategies appear to be effective, as evidenced by a growing number of studies showing that contact with nature can have beneficial health effects (De Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Maas, Verheij, Groenewegen, De Vries, & Spreeuwenberg, 2006; Mitchell & Popham, 2007). Controlled, experimental research has found especially strong evidence for

a positive relation between exposure to nature and restoration from stress and attention fatigue (Hartig, Evans, Jamner, Davis, & Garling, 2003; Ulrich et al., 1991).

Unfortunately, due to increasing urbanization, combined with spatial planning policies of densification, modern people’s homes have become more and more removed from green environments. According to dynamic stress-vulnerability (DSV) models (Heady & Wearing, 1989; Ormel & Neeleman, 2000), restricted access to green space may increase people’s vulnerability to the impact of stressful life events on mental and physical health. In general, individuals living in areas that lack green space may be more vulnerable to the negative impacts of stressful life events because they have less opportunities for nature-based coping strategies than individuals living in areas with abundant green space (Kaplan & Kaplan, 1989). Thus, the availability of green space in the living environment may be an important environmental factor that moderates the relationship between stressful life events and health.

The aim of the present study was to investigate to what extent the presence of green space can buffer adverse health impacts of

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stressful life events. In the following paragraphs, we first discuss the importance of neighbourhood characteristics for well-being, and the increasing recognition of green space as a valuable neighbourhood resource. Next, we review theoretical and empirical research on restorative effects of green space. We also consider evidence for buffering effects of green space. Finally, we present and discuss the results of a large-scale study that examined moderating effects of green space nearby and farther away from the home on relationships between stressful life events and self-reported physical, mental, and general health.

#### *Neighbourhoods, green space, and stress*

There is a long tradition of research exploring the relationship between neighbourhood characteristics and individual well-being (Macintyre & Ellaway, 2000). Traditionally, this research has focused mostly on sociological and psychosocial factors such as social cohesion, social capital and sense of community (Gee & Payne-Sturges, 2004). However, there is growing recognition for the importance of physical neighbourhood circumstances as both sources of stress and as resources that can help residents to cope with stress (Diez-Roux, 1998). One physical characteristic that has recently received much attention from researchers and policy makers as a potentially powerful physical neighbourhood resource is green space.

Findings from recent EU research programs on urban green spaces confirm their role in improving people's life quality (De Ridder, 2003). Like other public areas, parks and other green spaces can support physical activity and facilitate social cohesion (Kaczynski & Henderson, 2007; Maas, Verheij, Spreeuwenberg, & Groenewegen, 2008). However, green spaces appear to have a special quality that is lacking in other public areas: contact with green space can provide restoration from stress and mental fatigue. This so-called 'restorative quality' of nature is corroborated by results of national surveys in several countries, which have consistently shown that people consider contact with nature one of the most powerful ways to obtain relief from stress (Grahn & Stigsdotter, 2003).

Restorative effects of green space have generally been explained from an evolutionary perspective. Most of these explanations have in common the argument that, as a remnant of two or three million years of evolution in natural environments, modern humans have developed a partly genetic readiness to respond positively to habitable settings that were favourable to well-being and survival for pre-modern people (Kellert & Wilson, 1993). Notably, this readiness to respond positively to habitable settings is assumed to be triggered only by natural environments, humans do not possess such a disposition for most built environments and materials (Ulrich, 1993).

An important implication of people's readiness to respond positively to nature is that their attention is easily and almost effortlessly held by natural scenes. This attention-drawing quality of natural settings is referred to as 'soft fascination' (Kaplan & Kaplan, 1989). Soft fascination is assumed to play an important role in the restorative quality of nature. When nature captures people's attention, executive systems that regulate directed attention get to rest, pessimistic thoughts are blocked, and negative emotions are replaced by positive ones (Parsons, 1991). Prolonged exposure to high-quality natural settings may even stimulate reflections on life's larger questions such as one's priorities, goals, and one's place in the larger scheme of things (Mayer, Frantz, Bruehlman-Senecal, & Dolliver, 2009). This may help a person to find new sense and direction in life.

A small but growing body of well-controlled empirical research speaks directly to the restorative effects of green space (Health

Council of the Netherlands, 2004; Van den Berg, Hartig, & Staats, 2007). In general, this research has shown more positive affective, cognitive, and physiological responses to natural settings as compared to built settings. These positive responses have been observed in diverse settings including remote wilderness areas (Hartig, Mang, & Evans, 1991) as well as nearby green space such as gardens (Ottosson & Grahn, 2005). Notably, people need not go outdoors to profit from nature's restorative functions. Merely viewing green space through a window can already have restorative effects (Faber Taylor, Kuo, & Sullivan, 2002).

The findings of field studies are backed up by laboratory experiments in which stressed participants are randomly assigned to conditions of viewing visual simulations of natural and urban environments (e.g. Berto, 2005; Ulrich et al., 1991; Van den Berg, Koole, & van der Wulp, 2003). These experiments have consistently shown that viewing slides or videos of natural environments leads to a faster and more complete stress recovery than viewing built environments. In sum, there is convergent evidence from different lines of research that contact with real or simulated natural environments can provide restoration from stress and mental fatigue.

#### *Buffering effects of green space*

Green space may not only affect stress and mental fatigue directly, but may also have indirect effects by serving as a buffer against the health impacts of stressful life events. A *buffer* is a moderating variable that decreases the association between a negative independent variable and a negative outcome variable, explaining how or under what circumstances the independent variable affects the outcome variable (cf. Baron & Kenny, 1986). As graphically illustrated in Fig. 1, buffering effects are indicated by the interaction of the independent variable and hypothesized moderator variable in explaining the outcome variable. There may also be significant main effects for the predictor and the moderator, but these are not directly relevant conceptually to testing the buffering hypothesis (Baron & Kenny, 1986, p. 1174).

A few studies have explicitly examined buffering effects of green space on various outcome variables. For example, research in rural communities in New York showed that nature in the residential environment may serve as a buffer for the impact of stressful life events on rural children's psychological well-being (Wells & Evans, 2003). The impact of stressful life events on psychological distress and self-worth was weaker among children with a large amount of nature in or around their house than among children with a small amount of nearby nature. A study among employees of a Southern European company found that a view of natural elements (i.e., trees, vegetation, plants, and foliage) buffered the negative impact of job stress on intention to quit and general well-being (Leather, Pyrgas, Beale, & Lawrence, 1998). An experimental study showed that exposure to nature-dominated roadside views, as compared to artefact-dominated views, decreased the magnitude of the galvanic skin response to a consequent stressor (Parsons, Tassinari, Ulrich, Hebl, & Grossman-Alexander, 1998). A recent Swedish study

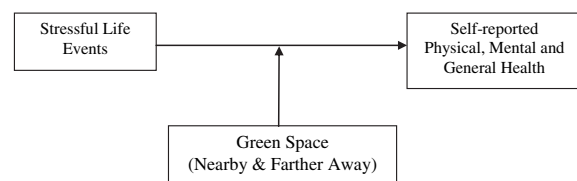


Fig. 1. Conceptual model for the analysis of green space as moderator of the relationship between stressful life events and health.

found that the influence of a “personal crisis” (i.e., a difficult event or severe loss with a strong emotional impact) on self-reported mental health and attention was weaker among individuals who spent much time contemplating nature and wildlife (Ottosson & Grahn, 2008).

Other studies have investigated protective effects of contact with nature among individuals who are undergoing stressful life events. For example, an intervention study among women diagnosed with breast cancer showed that women who engaged in nature-based activities on a daily basis showed greater improvement in performance on attention tasks than a nonintervention group (Cimprich & Ronis, 2003). A Swedish study among residents of high-noise neighbourhoods found that residents with “better” availability of green areas exhibited less stress-related psychosocial symptoms than residents with “poorer” availability of green areas (Gidlöf-Gunnarsson & Öhrström, 2007). Because the latter studies did not include unstressed control groups, they do not provide direct evidence for buffering effects of green space. Nevertheless, they are consistent with the idea that contact with nature can help individuals to better cope with stressful life events.

Research on the buffering effects of green space has mostly relied on psycho-physiological and cognitive stress measures as outcome variables. Although some studies have used measures of general well-being or mental health (e.g. Leather et al., 1998; Ottosson & Grahn, 2008; Wells & Evans, 2003), the ability of green space to protect people against the impact of stressors on physical health indicators has not yet received much attention. Theoretically, however, green space could be highly relevant to buffering physical health outcomes. Research has shown that stressful life events may lead to a sudden onset or worsening of different physical illnesses, depending on many moderating factors, including environmental resources (Tosevski & Milovancevic, 2006). Thus, buffering effects of green space may not only become manifest in decreased symptoms of stress, but also in better physical health.

#### *Green space close by or farther away?*

To date, research on the buffering effects of green space has mostly focused on readily available green space in the close vicinity of the home or workplace, e.g. plants in the living room or grass in the yard (Wells & Evans, 2003), a view of nature from the window (Leather et al., 1998; Parsons et al., 1998), or green areas “close to your dwelling” (Gidlöf-Gunnarsson & Öhrström, 2007). The results confirm that green space “on one’s doorstep” can serve as a buffer against stress. Indeed, as Rachel Kaplan has put it, “accumulating from many short episodes, the view from the window can provide long-term contact with the natural environment. Perhaps such an enduring connection is particularly useful for sustaining restoration” (Kaplan, 2001, p. 540).

In times of stress, however, possibilities for contact with more large-scale areas of nature farther away from one’s home may be equally, or perhaps even more important for staying healthy. When people are confronted with major life events, such as death or divorce, they need time to reflect on their life, their actions, and priorities, to cope with the events. Such reflection involves a deep level of restoration (Kaplan & Kaplan, 1989, p. 197). To be sure, such deep restoration is possible in nearby green space (think of a person contemplating fish in a garden pond). However, it is presumably more easily obtained in more extensive natural areas farther away from one’s home, where one can more readily obtain a sense of being away and connection with nature. A survey about the choice of restorative settings among elementary school teachers in Chicago provides some support for the validity of these notions (Gulwadi, 2006). Teachers who frequently suffered from job stress

preferred to actually go out into nature and stay away for a longer period of time (such as taking a walk in the woods), whereas teachers with low levels of job stress found sufficient merit in brief sensory enjoyment of nearby nature (such as listening to birds’ chirping). Thus, the availability of more large-scale natural settings at a somewhat farther distance from home may become more important in times of severe stress or crisis. As yet, however, health buffering effects of green space have not yet been related to the distance of the green space from home.

#### *The present study*

In the present study, we used quantitative data of a representative sample of Dutch residents to investigate to what extent the presence of green space in the living environment can buffer the adverse impacts of stressful life events on perceived health. In contrast to previous studies, we not only measured mental health, but also physical and perceived general health. To gain more insight into the importance of the distance to green space, we distinguished between green space within a 1-km radius around the home, and green space within a 3-km radius. Our main hypothesis was that the adverse impacts of experiencing stressful life events on physical, mental, and general health is less severe in living environments with more green space, because green space can reduce vulnerability and thus promote resilience against stress. We also hypothesized that buffering effects would be stronger for green space in a 3-km radius than for green space in a 1-km radius, because having larger areas of green space farther away from one’s home provides more opportunities for deep restoration.

## **Methods**

### *Data*

The data for this study were derived from two separate datasets. The health data and data on stressful life events were collected within the framework of the second Dutch National Survey of General Practice (DNSGP-2), conducted in the Netherlands in 2000–2002 (Westert et al., 2005). The DNSGP-2 included a nationwide representative sample of 104 general practitioners practices with nearly 400,000 patients on their list. As part of the DNSGP-2 a random sample of 12 699 respondents participated in a health interview survey (response rate 64.5%). Questionnaires were administered by trained interviewers in face-to-face interviews. To avoid seasonal patterns in morbidity, all interviews were carried out within 1 year (2001) and were distributed equally across all four seasons. To reduce the length of the interviews, each respondent randomly received a subset of all questions. For the purpose of the current research, complete data were available for 4529 respondents of 18 years and older who had been registered as a resident in their current municipality for at least 12 months. The number of respondents per practice varied between 16 and 127, with an average of 44 respondents per practice. The socio-demographic characteristics of the sample were comparable to those of the total Dutch population, although men, younger age groups and migrants were slightly underrepresented.

Environmental data were derived from the National Land Cover Classification database (LGN4) in 2001, which contains the dominant type of land use of each 25 × 25 m grid cell in the Netherlands (Thunnissen & De Wit, 2000). The two datasets were matched on the basis of the x and y coordinates of the respondent’s six character postal code (on average about 15–20 households have the same six character postal code).



## Measures

### Health indicators

1. *Number of health complaints* experienced in the last 14 days (Foets & Van der Velden, 1990). This measure covers a wide array of common, minor health problems, such as headache, coughing, sweating, and sleeplessness. Because all complaints in the list are about equally important, a simple additive strategy was used to calculate the total number of health complaints. After removing items that were relevant for children only, such as bedwetting, the list consisted of a total of 37 items (thus, the range of this measure was 0–37).
2. *Perceived mental health*. Measured with the Dutch 12-item version of the General Health Questionnaire (GHQ-12; Goldberg, 1972; Koeter & Ormel, 1991).
3. *Perceived general health*. Measured by the question “In general, would you say your health is Excellent, Very good, Good, Fair, Poor”. For consistency with the other measures, scores on this scale were reverse-coded so that 1 = ‘excellent’ and 5 = ‘poor’.

### Stressful life events

Stressful life events were assessed using the List of Threatening Experiences (LTE-Q), a self-report questionnaire that examines the incidence of 25 stressful life events during someone’s life course (Brugha, Bebbington, Tennant, & Hurry, 1985). The 25 items fall in 12 categories, including serious illnesses or injuries to the subject or a close relative, death of a family member or close friend, separation or break-off of a steady relationship, interpersonal problems, unemployment or getting fired, financial crises, legal problems, and losses. The questionnaire shows acceptable levels of reliability and validity (Brugha & Cragg, 1990). Besides asking about the incidence of stressful life events during the life course it was also asked for each life event when this event occurred (one month ago, two months ago, three months ago, or longer ago). With this information we constructed a new measure that assessed whether or not people experienced one or more stressful life events in the past three months. To avoid confounding between predictor and dependent health measures, the event category “serious illness or injury to the subject” was excluded from this measure.

### Green space

The percentage of green space within a 1-km radius (3.14 km<sup>2</sup>) and within a 3-km radius (28.27 km<sup>2</sup>) around a respondent’s home was calculated from the LGN 4 database (Thunnissen & De Wit, 2000). All urban green, agricultural green, forests and nature conservation areas were regarded as green space. Because the LGN 4 database only contains information on the dominant land use in 25 by 25 m grid cells, small-scale green spaces, such as street trees and green roadsides, were not represented in the dataset. In the LGN4 database houses as well as the land within a zone of 10 m from the house are classified as urban built environment. Thus, greenery in the immediate vicinity of the houses, such as gardens or trees, were also not included in the measures of green space.

In the exploratory phase of our data analysis we assessed the predictive power of many different types of green space indicators, varying from the original continuous variable to divisions in quartiles and dichotomous groupings with various cut-off points. Patterns of results were robust across indicators. For ease of interpretation, dichotomous green space indicators (created via median split) were used in the analyses presented below (Farrington & Loeber, 2000). In the 1-km radius, respondents with 39.77% or less green space were classified as having a low amount of green

space group; in the 3-km zone, respondents with 62.82% or less green space were classified as having a low amount of green space.

### Socio-economic and demographic characteristics

Because health differs according to people’s background characteristics we statistically controlled for gender, age (in years), level of education and household income (unknown, low, middle, high), and urbanity (non urban, slightly urban, moderately urban, strongly urban, very strongly urban; Den Dulk, Van de Stadt, & Vliegen, 1992). Level of education and income were categorised because we wanted to include the categories ‘unknown’ to increase the sample size. Table 1 shows the definitions and descriptive characteristics of all variables used in the analyses. Correlation tests did not show problems of multicollinearity.

### Statistical analyses

Given the two-stage character of the sample (individuals within GP practices), multilevel analysis is appropriate (Snijders & Bosker, 1999). The GP practice can also be seen as a rough proximate of the geographical area in which the respondent resides. A Null Model specified in MLwiN 2.0 showed that there was small but significant amount of variation at practice level for number of health complaints (4%) and perceived general health (2%) and marginally significant between-practice variation for perceived mental health (1%).

Because the distributions of number of health complaints and perceived mental health were positively skewed, we applied a log-transformation  $y = \log_e(x+1)$  to these two outcomes on which all test statistics are based (Bland & Altman, 1996). However, since the results for the untransformed data were very similar to those of the

**Table 1**  
Characteristics of the study population (N = 4529).

Gender (% Male)	44.3%
Age (years)	49.3 (SD 16.6; range 19–97)
<i>Level of education</i>	
Unknown	12%
Elementary school or less	15.4%
Secondary school	53.1%
Higher vocational or academic education	19.5%
<i>Income</i>	
Unknown	4.8%
Low (<1350 euro)	30.1%
Modal (1350–2450 euro)	40.5%
High (>2450 euro)	24.6%
<i>Urbanity</i>	
Very strongly urban (>2500 addresses/km <sup>2</sup> )	15.6%
Strongly urban (1500–2500 addresses/km <sup>2</sup> )	23.9%
Moderately urban (1000–1500 addresses/km <sup>2</sup> )	20%
Slightly urban (500–1000 addresses/km <sup>2</sup> )	30.2%
Non urban (<500 addresses/km <sup>2</sup> )	10.3%
<i>Percentage of green space</i>	
Average percentage of green space in 1-km radius	42.45% (SD 24.2; range .4–99.3)
Average percentage of green space in 3-km radius	60.7% (SD 21.7; range 6.16–97.3)
<i>Health</i>	
Average number of complaints (0–37)	4.32 (SD 3.85)
Mean perceived mental health (0–12)	1.18 (SD 2.29)
Mean perceived general health (1–5)	2.78 (SD .95)
<i>Stressful life events</i>	
% of respondents who experienced a stressful life event in the past 3 months	19.1%

transformed data, estimated means based on the original scale of measurement are reported. Effects of stressful life events and green space on health outcomes were estimated in the multilevel regression model with age, gender, education level, income, and level of urbanity as covariates. Separate analyses were conducted for green space within a 1-km and a 3-km radius. Interactions between green space and life events were used as an indicator of buffering effects. Significance of effects was tested by means of the Wald-test, which uses  $z = (\text{unstandardized estimate})/(\text{standard error})$  as test statistic.

**Results**

We first examined the correlations between the three health measures. The correlation between log-transformed number of health complaints and perceived general health was .41,  $p < 0.001$ , the correlation between log-transformed number of health complaints and log transformed perceived mental health was .42,  $p < 0.001$ , and the correlation between log transformed perceived mental health and perceived general health was .26,  $p < 0.001$ . Given that the three measures showed only modest correlations, they appear to represent distinct aspects of perceived health.

*Main effects of stressful life events*

Stressful life events were significantly related to number of health complaints and perceived mental health (Table 2). Respondents who had recently experienced a stressful life event reported more health complaints ( $M = 5.0, SE = .13$ ) than respondents who had not experienced such an event ( $M = 4.16, SE = .06$ ). Likewise, respondents who had recently experienced a stressful life event reported poorer mental health ( $M = 1.80, SE = .08$ ) than respondents who had not experienced such an event ( $M = 1.03, SE = .04$ ). Stressful life events did not have a significant influence on perceived general health.

**Table 2**  
Summary of results of multilevel regression analyses predicting health from stressful life event in past three months and amount of green space in a 1 and 3 km radius ( $N = 4529$ ).

	$\beta$	$z$	$p$
<i>Number of health complaints</i>			
Main effect stressful life event	.08	5.30	<.001
Main effect green space 1 km	-.03	-1.46	.14
Interaction stressful life event × green space 1 km	.01	.39	ns
Main effect green space 3 km	.00	.03	ns
Interaction stressful life event × green space 3 km	-.05	-2.36	.02
<i>Perceived mental health</i>			
Main effect stressful life event	.15	10.12	<.001
Main effect green space 1 km	-.02	-1.30	.19
Interaction stressful life event × green space 1 km	.01	.38	ns
Main effect green space 3 km	.00	.03	ns
Interaction stressful life event × green space 3 km	-.04	-1.65	.10
<i>Perceived general health</i>			
Main effect stressful life event	.02	-1.26	ns
Main effect green space 1 km	-.02	1.03	ns
Interaction stressful life event × green space 1 km	-.02	.75	ns
Main effect green space 3 km	-.01	.55	ns
Interaction stressful life event × green space 3 km	-.05	-2.35	.02

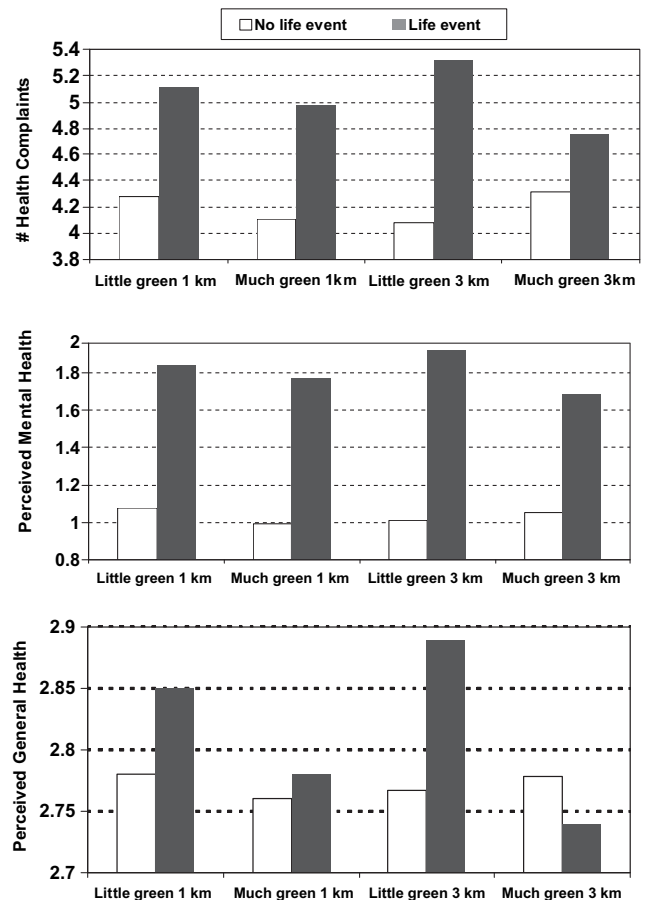
Note: Beta weights were calculated from the MLwiN output by multiplying the unstandardized coefficients with  $SD(x)/SD(y)$ .  $p$ -values are based on two-tailed tests. All analyses are controlled for age, gender, level of education, income, and level of urbanity

*Effects of green space in a 3-km radius*

Table 2 shows that the main effect of green space in the 3-km zone was not significant for any of the three health measures. However, consistent with the expectations, there was a significant interaction between percentage of green space in the 3-km radius and stressful life events for number of health complaints and for perceived general health. In addition, there was a marginally significant interaction for perceived mental health. As illustrated in Fig. 2, the negative health impacts of experiencing a stressful life event were generally weaker for respondents with a high amount of green space in a 3-km radius than for respondents with a low amount of green space in this radius. Within the group of respondents who had recently experienced a stressful life event ( $N = 866$ ), those with a high amount of green space in a 3-km radius reported significantly fewer health complaints,  $p = 0.03$ , and marginally better general health,  $p = 0.09$ , than respondents with a low amount of green space. However, the difference in perceived mental health of respondents with a high and low amount of green space who had recently experienced a stressful life event was not significant,  $F > 1$ .

*Effects of green space in a 1-km radius*

Percentage of green space in the 1-km zone was not significantly related to any of the three health measures, neither as a main effect, nor in interaction with stressful life events (cf. Table 2 and Fig. 2).



**Fig. 2.** Estimated marginal means of health complaints in last two weeks (range 0–37), perceived mental health (range 0–12), and perceived general health (1 = excellent; 5 = poor) as a function of stressful life events in past three months and amount of green space in a 1-km and 3-km radius, corrected for age, gender, income, education level, and level of urbanity.

## Conclusions and discussion

We investigated whether the presence of green space in people's living environment can buffer the adverse impacts of stressful life events on three self-reported health outcomes: number of health complaints, perceived mental health, and perceived general health. The results indicate convergent evidence across these health outcomes for buffering effects of green space within the wider living environment on the adverse impact of stressful life events. Green space in a 3-km radius around the home significantly decreased the relationships of stressful life events with number of health complaints and perceived general health. In addition, we found a marginally significant interaction effect between green space in a 3-km radius and stressful life events on perceived mental health. Notably, these buffering effects were found only for the 3-km radius, not for the 1-km radius, which supports our hypothesis that green space farther away from the home is particularly important in helping people to cope with the negative health impacts of stressful life events.

Buffering effects of green space were less pronounced for mental health than for physical and general health indicators. This may be explained by the fact that self-ratings of mental health tend to be more strongly related to stressful life events than assessments of one's (physical) health status, which is also confirmed by our data. Indeed, some of the items in the mental health questionnaire, such as "Have you recently lost much sleep over worry?" tap almost directly into the incidence of stressful life events. Consequently, the assessment of mental health might leave less room for buffering effects of green space, because green space in the living environment is unlikely to alter the incidence of stressful life events.

The finding that buffering effects of green space were found only for the wider 3 km zone and not for the 1 km zone is consistent with our theoretical analysis. Because urban green space areas, such as parks, greenways, or gardens, seldom cover more than 5 km<sup>2</sup>, high percentages of green space within a 3-km radius usually reflect the presence of more large-scale nature areas, such as forests, dune areas or agricultural fields. Theoretically, a greater availability of such areas in one's living environment can provide opportunities for reflection and restoration at a deeper level that cannot, or to a lesser extent, be achieved in a 1 km zone. Nevertheless, because our data do not provide any information on the actual use of green space by the respondents, alternative explanations cannot be ruled out. For example, the buffering effect of green space in the wider living environment may have been caused by better air quality, or by a stimulating effect of green space on physical exercise. However, previous research has shown that there are generally few differences in air quality and pollution between areas with and without greenery (cf. Verheij, Maas, & Groenewegen, 2008). Moreover, empirical evidence for stimulating effects of green space on physical exercise in adults has thus far been inconclusive (Kaczynski & Henderson, 2007; Maas et al., 2008). In view of these findings, we do not consider these alternative mechanisms very plausible.

Although the general pattern of findings is consistent with our expectation, the finding that green space in the 1 km zone did not have any buffering effects was unexpected, and seems at odds with the prominent role of nearby nature in the restorative environments literature (Kaplan, 2001). However, it should be kept in mind that in the current study, green space in a 10 m radius around the home was not included in our green space indicator. Opportunities for "micro-restorative" experiences with nature in or around the house, e.g. a glimpse of nature from the window, or listening to birds, were thus not represented. In this respect, the current study provides a conservative and rather limited test of the buffering effects of green space close to the home.

Another unexpected finding is that there were no main effects of green space on health. This finding is inconsistent with previous studies by our own group (De Vries et al., 2003; Maas et al., 2006) which have revealed general relationships between green space and health using measures similar to the ones used in the current study. This is probably a consequence of a smaller sample size which reduces the power to detect small differences. In particular, our data showed small differences in health between respondents with a small and large amount of green space in a 1 km radius which might have turned significant in a larger sample. In general, the results of the present study suggest that people can be more or less affected by the amount of green space in their living environment depending on their personal needs and circumstances. Consequently, it remains of considerable importance to pursue the search for variables that may modify general relationships between green space and health.

In absolute terms, the health impacts of green space found in the current study are not very large and may not be of great clinical importance. For example, a high amount of green space was associated with a reduction in the general health score of respondents who recently experienced a stressful life event by only .15 points on a 5-point scale. One reason for these small effects may lie in the fact that we had no information on the extent to which the respondents were affected by stressful life events. Previous research suggests that relationships between green space and health are stronger when people are greatly affected by a crisis (Ottoosson & Grahn, 2008). Previous research has also shown that relationships between green space and health tend to be stronger for groups who are homebound and to a greater extent exposed to the characteristics of their living environment, such as children, elderly, and people with a low income (Faber Taylor et al., 2002; Maas et al., 2006). Unfortunately, we had no data on stressful life events of children, and the numbers of elderly and low-income respondents in the sample was too small to conduct separate analyses for these groups. In general, the use of secondary datasets that cover only a part of all relevant information makes it difficult to ascertain the full extent of buffering effects of green space.

### *Limitations and future perspectives*

The present study is one of the first to investigate the buffering effects of objectively measured green space on the health impacts of stressful life events in a healthy, representative adult population. However, the study is not without limitations. For example, our land cover database did not include small-scale natural elements and areas, like for instance trees along streets, green roadsides, and greenery within 10 m from the home. This could mean that actual exposure to green space was in some neighbourhoods different from what we measured. Another limitation of our measure of green space is that road and rail networks were not considered, which means that it may have included green spaces that are hard to reach for a population of an area because of natural or physical boundaries. Future research may overcome these limitations by using indices of vegetation from satellite images (e.g., NDIV, Lillesand, Kiefer, & Chipman, 2004) or by conducting in-situ inventories of local green space with observational checklists (e.g., URGE, 2004; Broomhall, Giles-Corti, & Lange, 2004).

Another limitation concerns the three months time laps between the stressful life event and the health assessment. The impacts of stressful life events can be more enduring than three months, and often a reference period of six months or more is used in research on impacts of stressful life events (Brugha & Cragg, 1990). Thus, our control group may have included respondents who had experienced a stressful life event longer than three months ago but were still not 'healed'. This may have diminished

the discriminatory power of our analyses. Asking respondents to give a more exact indication of when a stressful life event occurred, and how strongly they were affected by it will provide more detailed insights into the course and development of health impacts and potential buffering effects of green space on these impacts.

As already noted, our data did not provide information on the actual use of green space by the respondents. Therefore, our interpretation that respondents in areas with a high percentage of green space farther away from their home more often visit nature to reflect on their lives must necessarily remain speculative. Future research may shed more light on the mechanisms underlying buffering effects of green space by comparing the coping behaviours of residents of green and barren neighbourhoods after they have experienced a stressful life event. For example, respondents could be asked to keep a time-activity diary for a certain period, or they could be asked to wear global positioning system (GPS) data recorders to track their behavioural patterns in a more objective manner (Phillips, Hall, Esmen, Lynch, & Johnson, 2001).

Finally, we should point out that the cross-sectional design used in the current study does not make it possible to draw strong inferences about the direction of causality. It is well-established that internal migration flows are influenced by socio-demographic characteristics such as age, income and education (Cushing & Poot, 2004). Because these characteristics are also related to health, part of the buffering effects of green space may be the result of selective migration (Verheij, van de Mheen, De Bakker, Groenewegen, & Mackenbach, 1998). We tried to rule out such indirect selection effects as much as possible by controlling statistically for socio-demographic characteristics. However, it cannot be ruled out that we did not fully control for all potentially confounding influences. Longitudinal research is needed to firmly establish the direction of causality for the buffering effects of green space found in the present study. For example, residents of neighbourhoods that are facing substantial changes in the amount and structure of green space could be followed over a longer period of time. In general, follow-up research needs to move beyond secondary data analysis and collect primary data that can shed light on the specific temporal and spatial conditions that shape the complex behavioural patterns involved in buffering effects of nature.

### Concluding remarks

In their influential book “The experience of nature: a psychological perspective” Rachel & Stephen Kaplan (1989) distinguish four progressive levels of restoration that require increasing time and intensity of the experience: clearing the head, recharging directed attention capacity, reducing internal noise, and finally “reflections on one’s life, on one’s priorities and possibilities, on one’s actions and one’s goals” (Kaplan & Kaplan, p. 197). Thus far, empirical research has focused mostly on the first level of restoration and the short-term benefits of micro-restorative experiences with nearby nature. However, the importance of green space farther away from the doorstep should not be overlooked, because it may provide important opportunities for deeper reflection and restoration. Results of the current study support the notion that in times of crisis, the availability of green space farther away from the home is particularly important to stay physically healthy. However, because the exact mechanisms underlying the relationships found are unknown, more research on the actual coping strategies and use of green space by individuals undergoing a crisis is needed to substantiate our interpretations.

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