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Natural environments - healthy environments? An exploratory analysis of the relationship between greenspace and health

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ABSTRACT
Are people living in greener areas healthier than people living in less green areas? This hypothesis was empirically tested by combining Dutch data on the self-reported health of over 10 000 people with land-use data on the amount of greenspace in their living environment. In the multilevel analysis we controlled for socioeconomic and demographic characteristics, as well as urbanity. Living in a green environment was positively related to all three available health indicators, even stronger than urbanity at the municipal level. Analyses on subgroups showed that the relationship between greenspace and one of the health indicators was somewhat stronger for housewives and the elderly, two groups that are assumed to be more dependent on, and therefore exposed to, the local environment. Furthermore, for all three health indicators the relationship with greenspace was somewhat stronger for lower educated people. Implications for policymaking and spatial planning are discussed briefly.

INTRODUCTION

In recent decades the quality of the living environment has become an important issue for residents (see, for example, Heimlich, 1989). It also has become an important issue in spatial planning. This is visible in the nature and recreation policy of the Dutch Ministry of Agriculture, Nature Management and Fisheries (LNV, 2000) and in the housing policy of the Dutch Ministry for Housing, Spatial Planning and the Environment (VROM, 2000). An example of a recent publication that focuses on environmental quality is the Leefomgevingsbalans (Audit of the living environment) of the National Institute for Public Health and the Environment (RIVM, 1998). One of the reasons for this interest is the supposedly positive effect of a high-quality residential environment on public health and well-being. This paper focuses on the question whether there is in fact such a relationship for one important aspect of environmental quality: the `greenness' of people's living environment. Though people generally believe that living in a green environment is good for one's health (Buijs and Volker, 1997; Burger, 1994), empirical evidence has been lacking thus far.

The issue raised above not only touches upon important political issues, but it also relates to the international literature on the relationship between urbanity and health (for an overview, see Verheij, 1995). People living in urban areas are generally found to be less healthy than people living in more rural areas. Part of this phenomenon may be related to the greenness of people's living environment. However, as far as we know the relationship between the amount of greenspace in the living environment and public health as such has not been investigated before.

Mechanisms behind the relationship between greenspace and health

Generally speaking, spatial health differences can be the result of two types of mechanisms: selection and causation, also known as the drifter mechanism and the breeder mechanism, respectively (Verheij et al, 1998). Selection takes place if more healthy people move to greener living environments. It is likely that attractive, green areas attract wealthier and thus healthier people (for example, see Mackenbach, 1994; Stronks et al, 1993), at least in a densely populated country such as the Netherlands (Luttik and Zijlstra, 1997). This type of mechanism may cause greener areas to be inhabited by more healthy people, even if there is no health-promoting effect of living in a green environment as such. A causation mechanism exists if living in a green area does have such an effect.

In this paper, we will focus on the causation mechanism. We will try to rule out selection effects as much as possible, by statistically controlling for relevant demo- graphic and socioeconomic characteristics. The causation mechanism can take two possible forms (Ten Wolde, 1999):

(1) Through people's behaviour: green areas in one's living environment may lead people to spend a larger part of their spare time outdoors and/or be more physically active. Indeed, literature shows that natural environments are more often used for recreational walking and cycling than urban environments (see CBS, 1997) and that these activities have a positive health effect (Powell and Blair, 1994; Ten Wolde, 1999; US DHHS, 1996; Westerterp, 2001).

(2) Through exposure to a natural environment as such. Besides the obvious effect of the absence of pollution, it is known that even pictures of natural settings can have a positive effect on one's mood and ability to concentrate (Driver et al, 1991; Hartig et al, 1996; Ten Wolde, 1999). Therefore, even if a natural environment does not enhance outdoor physical activity, people in a greener living environment may become more healthy just by being more exposed to natural elements.

Data and methods

Two different datasets are used which were not originally intended for the subject under study. The health data come from a study conducted by the Netherlands Institute for Health Services Research (NIVEL) in 1987 - 88: the first Dutch National Survey of Morbidity and Interventions in General Practice. This study included a health interview survey among random samples of practice populations of 103 general practices in the Netherlands (N = 17 000, response 77%) (Van der Velden, 1999).The dataset included each respondent's postal code. Environmental data were derived from a number of sources and combined in one geographic information system (GIS) database. The major source was the National Land Cover Classification database (LGN3), which contains the dominant type of land use of each 25 X 25 m grid cell in the whole of the Netherlands (De Wit et al, 1999). Other sources dealt with, for example, infrastructure and noise levels due to traffic and industry. The GIS database we used contains characteristics of the physical environment at the level of a neighbourhood in 1996. At that time the Netherlands was divided up into about 10 000 neighbourhoods. The average neighbourhood had about 1500 inhabitants. The environment of a neighbourhood was defined as a circle with a radius of 3 km around the centre of the neighbourhood (see De Vries, 1999).We will call this the living environment. The GIS database and the health survey data were matched by using the respondent's postal code: for each six-digit postal code in the Netherlands it is known in which neighbourhood it is located.

Because the health and the environmental data were not acquired at the same time, some adjustments had to be made. Respondents whose neighbourhoods had changed in degree of urbanity during this time were excluded from the analyses. This applied to 2% of the health survey respondents. Furthermore, a second selection was made, based on the assumption that it would take some time for a new living environment to affect one's health. Respondents who had moved to their present house within the last twelve months were also excluded from the analyses. This involved 10% of the respondents. The two selections combined left 10197 respondents with valid values on almost all of the relevant variables. These respondents came from 1155 different neighbourhoods.

Self-reported health indicators

Three global health indicators were available and were used in this study:

1. Number of symptoms experienced in the last 14 days (maximum 43) (Foets and Van der Velden, 1990).
2. Perceived general health. Measured on a five-point scale, running from `very good' (1) to `very bad' (5) (for example, see Van der Meer, 1998). For our purposes the scores were dichotomised with `less than good' as the cut-off point. Classified in this way, 14.7% of the present sample fell in the category `less healthy'.
3. Score on the Dutch version of the General Health Questionnaire (GHQ) (Goldberg, 1972), indicating one's propensity to psychiatric morbidity. This variable was also dichotomised: scores of 5 and higher were classified as less healthy (Verhaak, 1995). This constituted 12.4% of the sample.

Demographic and socioeconomic characteristics

The following socioeconomic and demographic characteristics were taken to control for composition effects as well as possible:

a) gender: male (0) or female (1),
b) age (in years),
c) number of life-events (such as birth, divorce, loss of job, burglary) in the past year.

Measured according to the Groningse Gebeurtenissen Lijst (Groningen Life-event List) (Ormel and Koeter, 1985); four indicators of socio-economic status (SES):

1. type of health insurance: public (0) or private (1),
2. level of completed education of either the head of the household or his or her partner, whoever had the highest level of education: seven categories,
3. number of rooms in the house (maximum 10),
4. household income: fifteen categories.

With regard to household income it should be noted that there was a high degree of item-specific non-response. When this characteristic is included in the analysis, the number of respondents drops from 10179 to 7797. This is a reduction of 23%. For this reason, a model including household income was estimated in a separate analysis.

Characteristics of people's living environment

The following characteristics were derived from the environmental dataset:

a) percentage of greenspace (urban green, agricultural green, forests and nature areas);
b) percentage of `blue' space (fresh and salt water surface).

The information for both characteristics originated from the LGN3 database; several categories of land use were combined to arrive at the characteristics.

One environmental characteristic was derived from the health interview survey: presence of a garden: no (0) or yes (1). The presence of a garden may also be seen as an additional SES indicator. However, the perspective we take in this study is that a garden is primarily a private greenspace that may compensate for the absence of other, often public, green areas.

Another environmental characteristic, measured at the level of municipalities, was derived from a third source: the municipal database of Statistics Netherlands (CBS, version 1990): urbanity: in five categories, from very strongly urban (1) to non-urban (5). This indicator is based on the number of households per square km and is widely used in the Netherlands (Den Dulk et al, 1992). For this indicator, the municipal level was considered to be more appropriate than that of neighbourhoods, because household density was meant as an indicator not only of an urban physical environment, but also of an `urban' style of life. An `urban' lifestyle is generally regarded as an important factor in explaining rural - urban differences in health (Verheij, 1995).

METHODS

Linear multiple regression multilevel analysis was performed with number of symptoms as dependent variable, while for the other two health indicators the logistic version was applied. The scores on all variables at the (semi-)interval level had been centred (but not standardised). Multilevel regression analyses were performed with MLwiN (Goldstein et al, 1998) with two levels: individual and neighbourhood. A problem encountered when using multilevel logistic regression is that no deviance statistic is available. Therefore it is not clear whether the model as a whole improves significantly when an additional explanatory variable is included. However, the significance of the parameter value of the additional variable can be inspected and significance of this parameter indicates improvement of the model.[1]

RESULTS

Before analysing the relationship between health and people's living environment, we looked at bivariate correlations among the environmental characteristics. First, urbanity (low - high) was strongly negatively related to the combined percentage of green and blue space in the living environment. It was strongly positively related to the percentage of the living environment with a high noise level, as well as the population density. Second, the total amount of non-built-up area was strongly and positively correlated with the percentage of greenspace, and there was a weak and negative correlation with the amount of blue space. This indicates that the non- built-up area in our respondents' living environment consists mainly of greenspace. Third, we looked at the relationships among the three types of greenspace that together constitute the total amount of greenspace. This total amount was strongly and negatively related to the amount of urban greenspace and strongly and positively related to the amount of agricultural area. The correlation with the third type, the amount of forest and nature area, was much smaller. This indicates that agricultural areas dominate the total amount of greenspace. Furthermore, people with high levels of urban greenspace in their living environment usually have very low levels of agricultural space. Other correlations among the three types of greenspace were weak ($-0.10 < r < 0.10$).

Are more natural environments more healthy environments?

Three subsequent models were fitted for each of the three health indicators (table 1). The basic model included all socioeconomic and demographic characteristics, except household income (results not shown). In a second step urbanity was added. In the third step, the percentages of green and blue in the living environment were added, as well as the presence of a garden. To see whether introducing household income into the equation would change the results for the three environmental characteristics, it was added to the model in an additional fourth step.

[TABLE 1]

With respect to the number of symptoms and GHQ, a significant effect was found for urbanity: given their demographic and socioeconomic characteristics, people in highly urban areas tend to have more symptoms and a higher risk of mental illness. With respect to people's perceived general health, no effect of urbanity was found.

With respect to all three health indicators the model was significantly improved by adding the percentages of green and blue, and the presence of a garden, to the model. Given the other parameters in the model, people living in a greener environment appear to be significantly more healthy than others. The amount of water in people's living environment and the presence of a garden is positively associated with number of symptoms only. Adding the percentages of green and blue, and presence of a garden to the models renders the degree of urbanity insignificant. This clearly illustrates the high (negative) correlations between degree of urbanity and the amount of greenspace in the living environment, but it also indicates that the amount of greenspace is related to the health indicators more strongly than the degree of urbanity.[2]

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[1] MLwiN uses a quasi-likelihood method, based on Taylor series, as an approximation of the real likelihood. This method gives acceptable results for model parameter estimates. However, for the deviance test (to compare two models) this method is not accurate enough (see Hox, 2002, page 110).

[2] Additional analyses were performed in order to investigate possible effects of two other environmental characteristics: noise level and population density. This, however, did not change the conclusion above.

To see whether introducing household income into the equation would change the results for the environmental characteristics, step 3 was repeated but now only with the respondents who also had a valid entry for household income. Subsequently household income was introduced in step 4. The selection in step 3 led to slightly different parameter values and standard errors for the environmental characteristics. However, the pattern was quite similar to the one before the selection (see tables 1 and 2). Household income had a significant effect on all three health indicators, but the parameters for the three environmental characteristics changed even less than as a result of the selection. On these grounds we decided to conduct subsequent analyses without household income, to keep as many respondents in the analyses as possible.

[TABLE 2]

We were interested not only in the general effect of living in a more natural environment, but also in the separate effects of urban green areas, agricultural areas, and forests and nature areas (termed `real' nature for short). Therefore we replaced the percentage of greenspace with the percentages for its three components. Only the parameter for the percentage of agricultural space appeared to be significant, for all three health indicators.

Does the effect of a more natural environment occur in urban as well as rural areas?

The analyses above suggest that the amount of greenspace may have a strong and separate effect on people's health, apart from degree of urbanity. If this were true, a health effect should also occur when looking at the different degrees of urbanity separately. Therefore, the analyses described above were performed again for all five degrees of urbanity (table 3).

[TABLE 3]

Concerning the number of symptoms, the greenness of one's living environment had a significant effect only for people living in moderately and slightly urban municipalities. The effect of having a garden is observed only in moderately urban municipalities.

With respect to (perceived) general health condition, a significant effect of living in a more natural environment is found in moderately urban and non-urban municipalities. With respect to GHQ score, significant effects of living in a greener environment are not found within any of the five types of municipalities. The only significant environmental characteristic found is having a garden, but only for people living in the very strongly urban municipalities.

We may conclude that the significant effects of percentage of green and having a garden observed for the total sample, are often not observed when analysing different degrees of urbanity separately. Further analysis (not shown in the table) showed that this is not caused by a lack of variation in the amount of green within separate degrees of urbanity. For example, at the highest degree of urbanity 39% of respondents had a garden, whereas at the middle level of urbanity 88% had a garden.

Does the effect of a more natural environment vary according to one's socioeconomic status?

The effect of living in a more natural environment may vary according to socio- economic status. This may be a result of different lifestyles, which in turn may affect the amount of time spent in one's direct living environment. It is, for example, well known that lower SES groups are less healthy (Davey Smith et al, 1994; Mcintyre, 1997), thereby creating greater possibilities for health improvement by health promotion measures than is the case with higher SES groups. Besides possible differential effects, analyses for different SES groups may also give an indication as to whether the correction for possible selection effects, related to this status, has been sufficient. If the relationship between greenspace and health, as observed in the total group analysis, is mainly a result of higher status people living in greener areas, then this relationship is likely to be less strong in analyses on separate SES groups.

SES was operationalised as the highest level of education of either the head of the household or his or her partner, dichotomised with 6721 cases in the lower category and 3458 cases in the higher category.

For all three health indicators, a greener environment appears to have a significant beneficial effect solely in the lower educated group, suggesting that this group is indeed more sensitive to local physical environmental characteristics (table 4, see over). The difference in effect between lower and higher educated groups is not very large, however. Furthermore, the parameter sizes in the lower educated group are quite similar to those observed for the sample as a whole (compare tables 1 and 4).

[TABLE 4]

Is a natural local environment more beneficial to those who spend more time in and around their homes?

It was hypothesised that the amount of time spent in a green environment (exposure) could be an important mediating factor. This would mean that the relationship between the amount of greenspace and health is likely to be stronger for groups that spend more time in the vicinity of their homes: children (<16 years), housewives (self-defined), and elderly (>65 years).

With respect to children (*N* = 1966), none of the health indicators showed an effect of a green living environment. In fact none of the environmental characteristics showed such an effect, except urbanity. Children in very strongly urban municipalities have more symptoms than those in the non-urban municipalities [*IB* = 1.121; standard deviation (sd) = 0.485]. Generally, children do not seem sensitive to variations in their physical environment. With respect to housewives (*N* = 2001), the greenness of one's environment seems to be relevant only in the number of self-reported symptoms (*B* = -0.027; sd = 0.012). For the other two health indicators none of the environ- mental characteristics had a significant effect. The same pattern is observed for the elderly (*N* = 1119). Here too, the amount of greenspace was relevant for the number of symptoms only (*B* = -0.031; sd = 0.014). Both for the housewives and for the elderly, the effects are stronger than those for the sample population as a whole.

Is it better to have green close by than somewhat further away?

The previous analyses showed a consistent but moderate health effect of living in a relatively green environment. A factor that may have inhibited finding stronger effects is that we may have defined the environment too widely. Indeed, the presence of a garden also shows up as a significant predictor of health. This gives some support to the hypothesis that it is the greenness of the direct surroundings of one's home that affects people's health most. In order to investigate this issue further, we designed two new indicators for the amount of green in people's living environment: the percentage of green within a 1 km radius around one's home, and the percentage of green in the 1 km to 3 km zone. Note that these two zones have no physical overlap. Using these two indicators not only enabled us to investigate distance decay in the effect of natural environments. It also had a methodological advantage, as the amount of greenspace within 1 km is likely to be less strongly related to the urbanity of the municipality, thereby reducing problems of multi-collinearity.

In order to calculate the amount of green and blue in a 1 km and a 1 - 3 km radius, the survey data again had to be matched with the GIS database on land use. With these more refined indicators of greenness it was necessary to take the centre of people's six- digit postal code area as the midpoint of the 1 km circle, instead of the neighbourhood centre. Otherwise people might actually be living outside the 1 km circle defined for them. The average six-digit postal code area contains only about fifteen households. As expected, the amount of greenspace within the 1 km environment was less strongly related to urbanity than in the 3 km situation (*r* = 0.70 versus *r* = 0.82).

In order to investigate whether or not green close by has a stronger health effect than green further away, again multilevel multiple linear and logistic regression analyses were performed. Following the third step, in which percentages of green and blue in a 3 km radius were introduced (see table 1), in a new, fourth, step the percentages of green and blue in a 3 km radius were replaced with the percentages of green and blue in a 1 km radius and those in a 1 - 3 km radius. Table 5 shows the results for all three health indicators. The estimates for the urbanity parameters are not shown because none of them was significant in these latter analyses.

[TABLE 5]

The results for the number of symptoms show that the model as a whole does not improve by splitting up the living environment into two zones. Furthermore, only the parameter for the greenspace within 1 km is significant. The models for the other two health indicators, on the other hand, show that the amount of greenspace between 1 km and 3 km is more clearly related to health than the amount of greenspace within 1 km. An interesting additional finding emerges for perceived general health. Water nearby has a negative effect on this rating, whereas water between 1 km and 3 km has a positive effect. Furthermore it may be pointed out that, in the case of the number of symptoms, the parameter for the presence of a garden was not affected by introducing green nearby into the model. The garden continues to make its own contribution.

Thus, our hypothesis that greenspace nearby would have a stronger health effect than greenspace somewhat further away was not supported. If anything, the amount of greenspace between 1 km and 3 km seems to be more closely related to the health indicators than the amount of greenspace within 1 km.

DISCUSSION

The proximity of nature and opportunities for outdoor recreation are generally seen as important aspects of the quality of people's living environment. However, until now there was no clear empirical evidence that greenspace nearby was related to public health. Such a correlation has been shown for urbanity, however. This study shows that, at least in the Dutch situation, this latter relationship might partially be explained by the difference in the availability of greenspace at the different levels of urbanity.

Indeed our analyses have shown that greenness of the living environment has a stronger relationship with self-reported health than urbanity. In a greener environment people report fewer symptoms and have better perceived general health. Also people's mental health appears to be better. Furthermore, the additional presence of a garden seems to be beneficial to people's health, but only if measured in terms of the number of symptoms. The size of the effect is considerable. For example, assuming a causal relation between greenspace and health, 10% more greenspace in the living environment leads to a decrease in the number of symptoms that is comparable with a decrease in age by 5 years. Assuming that creating a new green area affects the amount of greenspace in the living environment of all people living in all neighbourhoods within a distance of about 3 km of this new area, the total health impact of this new green area may be considerable.

The total amount of greenspace within the living environment is a very global characteristic that is not geared to testing a specific causal mechanism. That is why an analysis was performed in which several types of greenspace were distinguished. In our view, the fact that, when split up, only agricultural green is related to perceived health, does not indicate a stronger effect of agricultural green on health than the other two types of greenspace. We find it more likely that the total amount of greenspace is what is relevant here, and within the total greenspace agricultural green is simply the largest component. Even when interpreted in this way, it is a remarkable outcome. Dutch people in general are known to prefer forests and nature areas to agricultural areas (De Vries, 1999; Reneman et al, 1999). Hartig et al (2003) mention that, in environmental evaluation studies, the assumption is often made that preferences for certain types of environments are predominantly based on innate sensitivities to which environmental qualities are important for effective functioning and survival. In other words, people like environments that have been good for them from an evolutionary perspective. However, our results do not support this popular hypothesis. When it comes to health, all types of green seem to be equally `effective'. It looks as if the difference between a `red' (brick) and green environment is more dominant than the differences within the green category (see Van den Berg and De Vries, 2000).

Separate analyses for each level of urbanity were performed in order to investigate whether the health effects of nature are consistent across different degrees of urbanity. Finding the same health effect across degrees of urbanity would have been a further indication that the amount of greenspace has a separate health effect, besides degree of urbanity. However, the analyses showed that the amount of greenspace had a health effect only in the middle range of urbanity. Therefore, we cannot ignore the possibility that the amount of greenspace is `simply' a new indicator for level of urbanity. This would imply that the relationship between greenspace and health might be explained by the same mechanisms as suggested for the relationship between urbanity and health, for example, a less healthy lifestyle in more urban areas (Verheij, 1995).

Separate analyses were also conducted for higher and lower educated groups, for similar reasons. We wanted to explore whether the relationship between greenspace and health could also be observed within each subgroup. However, the lower educated subgroup appeared to be more sensitive to the amount of green in their living environment: the difference in health effect between the two subgroups was small but consistent. Several mechanisms may be at work. Perhaps the tendency to a less healthy lifestyle of lower socioeconomic groups (Stronks, 1997) is counteracted by a green environment, and the possibilities it offers for outdoor recreation. Higher socioeconomic groups might be less dependent on their local living environment for realising a healthy lifestyle. It is also possible that the lower educated tend to spend a larger proportion of their time close to home. Long-distance commuting, for example, is more common among the higher educated (Van Wee, 2000). Finally, the possibilities for improvement might be less for people from higher SES, because of a ceiling effect.

Nevertheless, the observed parameters for greenspace in the lower educated group do suggest that a selection mechanism related to SES of the individual is not a very likely alternative explanation of the observed relationship between greenspace and health. Of course, education is only one determinant of SES, so there may still exist considerable differences in status within this subgroup. However, an analysis on the whole sample in which household income as well as education, type of health insurance, number of rooms in the house, and presence of a garden were included as predictors, led to quite similar results as far as greenspace is concerned.

Finally, separate analyses were performed on three groups that are likely to spend more time in their direct living environment and that are therefore exposed to it for longer periods of time: children, housewives, and the elderly. For housewives and especially the elderly, the relationship between the amount of greenspace and the number of symptoms is somewhat stronger than for the population in general. For children we find no such effect. This may be considered limited support for exposure as a mediating factor. More research, with better exposure measures, is needed to draw more definite conclusions.

In some analyses having a garden appeared to have a health effect. Therefore, we suspected that green nearby might have a stronger health effect than green somewhat further away. To study this in more detail, the amount of greenspace in a 3 km radius was divided into two zones: greenspace nearby (within 1 km) and greenspace somewhat further away (between 1 and 3 km). The amount of greenspace in a 1 - 3 km radius appeared to be more closely related to the health indicators than green in a 1 km radius. This, however, may not be taken to signify that green nearby is less important. One has to bear in mind that the area of the 1 km radius is eight times smaller than that of the 1 - 3 km radius. Therefore we are inclined to draw a similar conclusion with regard to the type of greenspace: it is the total amount of greenspace within the living environment that seems relevant. Within this environment, the distribution of greenspace over the two distance zones does not seem to be a matter of great importance. This latter interpretation of the results is consistent with the fact that for the number of symptoms the model as a whole did not improve by separating the living environment into two zones. However, it seems somewhat inconsistent with the presence of a small, private green area - a garden - having a separate effect on health. Maybe the mechanisms behind both effects, that of garden and greenspace, are different.

We would like to point out that, in general, selection effects are more likely to offer an explanation of the observed relationship between greenspace and health to the degree that the living environment is more narrowly defined. The larger the living environment, the more these environments will overlap for people living in different parts of a city. Thus larger living environments are less likely to reflect differences in, for example, the socioeconomic composition of the population that may exist at the level of the smaller, mutually exclusive neighbourhoods. This line of reasoning suggests that the fact that we did not observe a closer relationship between greenspace and health for the smaller living environment, argues against strong selection effects in general.

Limitations of this study and recommendations for further research

To our knowledge, the analyses presented here represent one of the first quantitative explorations of the relationship between the characteristics of land use, or more specifically the amount of greenspace, and perceived health. However, these analyses have their limitations. To begin with, the results may be specific to the Dutch situation, and possibly other densely populated countries or regions. In particular, the negative effects of living in an isolated rural area (with lots of greenspace) that may occur in larger, less densely populated countries, are likely to be less prominently present in the Netherlands, because in the Netherlands, even the most remote rural areas are not that isolated.

We had to overcome the fact that land-use data and health data were collected in different years. The fact that relationships were observed despite this source of (presumably) random error suggests that relationships between health and environ- mental characteristics may be even stronger when all data are collected at the same time.

Another issue is the possibility of the observed effects being caused by selection or composition mechanisms. Given the correlational nature of the study, this type of explanation is difficult to rule out completely. However, we do feel that as far as selection mechanisms related to socioeconomic status are concerned, the statistical corrections and subgroup analyses make this type of selection rather unlikely. For example, the observed relationship between greenspace and health was somewhat stronger within the lower educated subgroup. This is exactly the subgroup that is less likely to have much choice in their neighbourhood of residence. Other types of selection are more difficult to rule out. This is especially true for a selection mechanism in which one's health itself is the reason for selecting a neighbourhood - possibly with more health services nearby. The implicit negative relationship between health service provision and the local amount of greenspace seems worth further exploration. Longitudinal studies are another way to rule out selection effects. The outcomes of a recent example of such a study by Takano and others (2002) are consistent with a causal interpretation of the relationship observed in our study. In their cohort study they observed a positive effect of living in an area with `walkable green spaces' on the longevity of urban senior citizens.

A more methodological issue concerns the fact that the amount of greenspace in the living environment was more closely related to health than was urbanity, at municipal level. This finding could arise from the difference in the way both characteristics are operationalised. From the residents' viewpoint, the borders of their municipality are likely to have little or no relevance for their living environment. Because the living environment was defined in terms of the amount of greenspace around each resident's neighbourhood, this border problem has been avoided here. In other words, if we had been able to assess household density in a similar manner to the amount of greenspace, the results might have turned out differently.

In spite of these limitations, the results of our study seem promising enough to warrant further research. In our opinion special attention should be paid to mechanisms behind the observed relationship between the amount of greenspace and perceived health. Assuming for a moment that we succeeded in ruling out composition effects by including personal characteristics, we should be looking for causal mechanisms. At least three types of mechanisms can be discerned:

1. more greenspace leads to a less polluted environment;
2. more greenspace leads to more frequent or longer contact with, and therefore experience of, this greenspace;
3. more greenspace leads to more physical activity, such as walking and cycling.

The health effects of less pollution, experiencing nature, as well as physical activity, are well established in the literature. The effect of the local amount of greenspace on these factors is less well known. Likewise, little is known about the relative impact of the different mechanisms, or the type of greenspace that they require to function optimally. Studying possible mechanisms more closely ideally requires more data than are available in our present dataset; for example, data on air quality, time budgets, or outdoor recreational behaviour. However, further analyses are also possible with the current dataset. A further specification of the most likely mechanisms could lead to an analysis of specific symptoms, for example, allergies and pulmonary conditions.

These and other further studies may help to assess whether greenspace in the living environment is not only related to perceived health, but actually makes people healthier. If this proves to be the case, a green living environment may become a necessity rather than the luxury asset it is often thought to be.

Therefore such studies may have strong implications for spatial planning. For example, the ongoing process of the densification of cities, in order to save the countryside from urban sprawl, may turn out to have unexpected negative health consequences. Given the quite irreversible nature of such densification processes, we hope the present study will raise awareness of this issue. Furthermore, the study also points out that the health effects of nature areas are likely to depend on their distance from residential areas. Whereas from an ecological perspective, nature development may be best located far away from cities, to reduce human disturbance, such new nature areas are likely to contribute relatively little to public health. Nature for nature's sake, as well as an unspoilt countryside seem widely accepted goals in Dutch society. However, when space is scarce, as it is in the Netherlands, the pursuit of these goals implies that less space will be available for other functions, such as nature with a predominantly social function. If and when it can be shown that health issues are involved in this trade-off, the balance may shift considerably.

TABLES

Table 1. Regression analysis of the total sample for the three health indicators: parameter values and standard errors ($N = 10\,179$).

Predictor	Number of symptoms experienced		Perceived general health (less than 'good' = 1)		GHQ score[a] (≥ 5 = 1)	
	step 2	step 3	step 2	step 3	step 2	step 3
Very strongly urban[b]	*0.919*	−0.085	0.219	−0.277	*0.474*	−0.153
	(0.157)	(0.275)	(0.114)	(0.212)	*(0.114)*	(0.212)
Strongly urban	*0.480*	−0.011	0.090	−0.192	*0.280*	−0.076
	(0.147)	(0.199)	(0.113)	(0.158)	*(0.110)*	(0.154)
Moderately urban	*0.419*	0.086	0.063	−0.122	0.103	−0.096
	(0.132)	(0.154)	(0.100)	(0.121)	(0.103)	(0.123)
Slightly urban	*0.299*	0.169	−0.000	−0.065	(0.025)	−0.028
	(0.119)	(0.120)	(0.091)	(0.095)	(0.094)	(0.098)
Presence of garden		*−0.524*		−0.125		−0.179
		(0.139)		(0.098)		(0.104)
Percentage of 'green'		*−0.015*		*−0.009*		*−0.010*
		(0.004)		*(0.003)*		*(0.003)*
Percentage of 'blue'		*−0.016*		−0.008		−0.004
		(0.007)		(0.005)		(0.005)
χ^2 (degrees of freedom)	34.79 (4)	28.58 (3)				

Note. Variables already included in step 1 are: age, gender, education, number of rooms, type of health insurance, and number of life-events. Parameters in italics are significant at the 0.05 level; t-values may be calculated by dividing the parameter by its standard error. Given the large number of respondents, this t-statistic has a standard normal distribution: $p = 0.05$, $t = 1.96$; $p = 0.01$, $t = 2.57$; $p = 0.001$, $t = 3.29$.

[a] GHQ—General Health Questionnaire.

[b] Reference category: nonurban.

Table 2. Regression analysis of the 'household income' sample for the three health indicators: parameter values and standard errors ($N = 7797$).

Predictor	Number of symptoms experienced		Perceived general health (less than 'good' = 1)		GHQ score[a] ($\geqslant 5 = 1$)	
	step 3	step 4	step 3	step 4	step 3	step 4
Presence of garden	*−0.469*	*−0.425*	−0.135	−0.105	−0.071	−0.031
	(0.160)	*(0.160)*	(0.110)	(0.110)	(0.120)	(0.121)
Percentage of 'green'	*−0.014*	*−0.015*	*−0.010*	*−0.010*	*−0.012*	*−0.012*
	(0.005)	*(0.005)*	*(0.004)*	*(0.004)*	*(0.004)*	*(0.004)*
Percentage of 'blue'	*−0.021*	*−0.021*	−0.006	−0.006	−0.005	−0.005
	(0.008)	*(0.008)*	(0.006)	(0.006)	(0.006)	(0.006)
Household income		*−0.061*		*−0.060*		*−0.057*
		(0.014)		*(0.011)*		*(0.011)*
χ^2 (degrees of freedom)		20.35 (1)				

Note. Variables already included in steps 1 and 2 are: age, gender, education, number of rooms, type of health insurance, number of life-events, and urbanity (four indicator variables). Parameters in italics are significant at the 0.05 level.
[a] GHQ—General Health Questionnaire.

Table 4. Regression analyses on all three health indicators by level of education (low or high): parameter values and standard errors.

Predictor	Number of symptoms experienced		Own health rating (less than 'good' = 1)		GHQ score[a] ($\geqslant 5 = 1$)	
	low	high	low	high	low	high
Very high urbanity[b]	−0.249	0.334	−0.343	−0.050	−0.353	0.315
	(0.355)	(0.400)	(0.243)	(0.398)	(0.265)	(0.341)
High urbanity	0.101	−0.007	−0.137	−0.283	0.090	−0.239
	(0.261)	(0.271)	(0.183)	(0.286)	(0.193)	(0.240)
Moderate urbanity	0.078	0.173	−0.063	−0.187	−0.045	−0.143
	(0.199)	(0.218)	(0.137)	(0.229)	(0.151)	(0.202)
Low urbanity	0.147	0.214	−0.005	−0.262	−0.017	−0.010
	(0.150)	(0.179)	(0.105)	(0.194)	(0.118)	(0.165)
Presence of garden	*−0.561*	*−0.474*	−0.055	−0.379	−0.185	−0.188
	(0.177)	*(0.218)*	(0.113)	(0.198)	(0.128)	(0.179)
Percentage of green	*−0.018*	−0.006	*−0.009*	−0.005	*−0.011*	−0.006
	(0.006)	(0.006)	*(0.004)*	(0.007)	*(0.004)*	(0.006)
Percentage of blue	*−0.023*	−0.004	−0.009	−0.002	−0.007	0.005
	(0.009)	(0.009)	(0.006)	(0.009)	(0.007)	(0.008)

Note. Variables already included in earlier step are: age, gender, number of rooms, type of health insurance, and number of life-events. Parameters in italics are significant at the 0.05 level.
[a] GHQ—General health questionnaire.
[b] Reference class: nonurban.

Table 3. Regression analyses on all three health indicators by level of urbanity: parameter values and standard errors.

	Urbanity				
	Very strong (n = 1079)	strong (n = 1464)	moderate (n = 1826)	slightly urban (n = 2963)	nonurban (n = 2847)
Analysis for the number of symptoms experienced					
Presence of a garden	−0.291	−0.579	*−0.994*	0.405	−0.629
	(0.288)	(0.321)	*(0.315)*	(0.335)	(0.393)
Percentage of green	0.006	−0.007	*−0.027*	*−0.021*	0.023
	(0.011)	(0.011)	*(0.010)*	*(0.008)*	(0.014)
Percentage of blue	−0.011	−0.025	−0.010	−0.027	−0.018
	(0.032)	(0.015)	(0.017)	(0.022)	(0.014)
Analysis for perceived general health (less than 'good' = 1)					
Presence of garden	0.0107	−0.282	−0.294	−0.196	−0.215
	(0.181)	(0.234)	(0.200)	(0.237)	(0.270)
Percentage of green	−0.003	−0.002	*−0.027*	0.007	*−0.040*
	(0.007)	(0.009)	*(0.008)*	(0.007)	*(0.010)*
Percentage of blue	−0.009	−0.015	−0.022	−0.028	*−0.030*
	(0.019)	(0.011)	(0.013)	(0.023)	*(0.010)*
Analysis for General Health Questionnaire score ($\geqslant 5$ = 1)					
Presence of garden	*−0.381*	0.296	−0.212	−0.204	−0.323
	(0.183)	(0.260)	(0.225)	(0.279)	(0.348)
Percentage of green	−0.009	−0.014	−0.017	0.000	−0.007
	(0.006)	(0.008)	(0.009)	(0.007)	(0.013)
Percentage of blue	−0.034	−0.009	−0.002	−0.025	0.007
	(0.019)	(0.009)	(0.014)	(0.022)	(0.013)

Note. Variables already included in earlier step are: age, gender, education, number of rooms, type of health insurance, and number of life-events. Parameters in italics are significant at the 0.05 level.

Table 5. Regression analysis of the total sample for the three health indicators: parameter values and standard errors ($N = 10\,179$).

Predictor	Number of symptoms experienced		Perceived general health (less than 'good' = 1)		GHQ score[a] ($\geqslant 5 = 1$)	
	step 3	step 4	step 3	step 4	step 3	step 4
Presence of garden	*−0.524* *(0.139)*	*−0.521* *(0.139)*	−0.125 (0.098)	−0.129 (0.099)	−0.179 (0.104)	−0.179 (0.103)
Percentage of green within 3 km	*−0.015* *(0.004)*		*−0.009* *(0.003)*		*−0.010* *(0.003)*	
within 1 km		*−0.0053* *(0.0026)*		−0.0006 (0.0021)		−0.0018 (0.0021)
between 1 and 3 km		−0.0087 (0.0050)		*−0.0079* *(0.0038)*		*−0.0084* *(0.0038)*
Percentage of blue within 3 km	*−0.016* *(0.007)*		−0.008 (0.005)		−0.004 (0.005)	
within 1 km		−0.0036 (0.0088)		*0.0156* *(0.0066)*		−0.0079 (0.0068)
between 1 and 3 km		−0.0109 (0.0073)		*−0.0151* *(0.0059)*		0.0004 (0.0056)
χ^2 (degrees of freedom)		2.1 (1)				

Note. Variables already included in steps 1 and 2 are: age, gender, education, number of rooms, type of health insurance, number of life-events, and urbanity (four indicator variables). Parameters in italics are significant at the 0.05 level.
[a] GHQ—General Health Questionnaire.

REFERENCES

1. Buijs A E,Volker C M, 1997 Publiek draagvlak voor natuur en natuurbeleid [Public support for nature and nature policy], SC-rapport 546, DLO-Staring Centrum,Wageningen
2. Burger, I, 1994, ``De fysieke en sociale omgeving'' [The physical and social environment] Epidemiologisch Bulletin 29(1) 14 - 20
3. CBS, 1977 Dagrecreatie 1995/'96 [Day trips 1995/'96], Statistics Netherlands (CBS),Voorburg
4. Davey Smith G, Blane D, Bartley M, 1994, ``Explanations for socioeconomic differentials in mortality: evidence from Britain and elsewhere'' European Journal of Public Health 4 131 - 144
5. Den Dulk C J, Stadt H,Vliegen J M, 1992, ``Een nieuwe maatstaf voor stedelijkheid: de omgevings-adressendichtheid'' [A new measurement for urbanity: the environmental address density] Maandstatistiek van de bevolking 7 14 - 22
6. De Vries S, 1999 Vraag naar Natuurgebonden Recreatie in Kaart gebracht; inclusief een ruimtelijke confrontatie met het lokale aanbod [The demand for nature-based recreation mapped; including a spatial confrontation with the local supply], SC-rapport 674, DLO-Staring Centrum,Wageningen
7. De Wit A,Van der Heijden TGC,Thunnissen HAM, 1999 Vervaardiging en nauwkeurigheid van het LGN3-grondgebruiksbestand [The making of the LGN3 land use database, and its accuracy], SC-rapport 663, DLO-Staring Centrum,Wageningen
8. Driver B L, Brown P J, Peterson, G L (Eds), 1991 Benefits of Leisure (Venture Publishing, State College, PA)
9. Foets M,Van der Velden J,1990 Een nationale studie van ziekten en verrichtingen in de huisartsenpraktijk. Basisrapport: meetinstrumenten en procedures [A national study of morbidity and interventions in general practice. Basic report: measurement instruments and procedures] (NIVEL, Utrecht)
10. Goldberg D, 1972 The Detection of Psychiatric Illness by Questionnaire (Oxford University Press, Oxford)

11. Goldstein H, Rasbash J, Plewis I, Draper D, Browne W, Yang M, Woodhouse G, Healy M, 1998 A User's Guide to MLwiN Multi-level Models Project, Institute of Education, University of London, London
12. Hartig T, Book A, Garvill J, Olsson T, Garling T, 1996, ``Environmental influences on psychological restoration'' Scandinavian Journal of Psychology 37 378 - 393
13. Hartig T, Evans G W, Jamner L D, Davis D S, Gärling T, 2003, ``Tracking restoration in natural and urban field settings'' Journal of Environmental Psychology 23 109 - 123
14. Heimlich R E, 1989, ``Metropolitan agriculture: farming in the City's shadow'' Journal of the American Planning Association 55 457 - 466
15. Hox J, 2002 Multi-level Analysis: Techniques and Applications (Lawrence Erlbaum Associates, London)
16. LNV, 2000 Nature for People, People for Nature; Policy Document for Nature, Forest and Landscape in the 21st Century Ministry of Agriculture, Nature Management and Fisheries (LNV), The Hague
17. Luttik J, Zijlstra M, 1997 Woongenot heeft z'n prijs; het waardeverhogend effect van een groene en waterrijke omgeving op de huizenprijs [Residential pleasure has its price; the price-increasing effect of a green and water-abundant environment for houses], SC-rapport 562, DLO-Staring Centrum,Wageningen
18. Mcintyre S, 1997, ``The Black report and beyond: what are the issues?'' Social Science and Medicine 44 723 - 745
19. Mackenbach J P, 1994 Ongezonde verschillen: Over sociale stratificatie en gezondheid in Nederland. [Unhealthy differences: on social stratification and health in the Netherlands] (Van Gorcum, Assen)
20. Ormel J, Koeter M WJ, 1985 De Groningse Gebeurtenissen Lijst. Groningen, interne publicatie [Groningen life-event list, internal publication], State University of Groningen, Groningen; copy available from third author
21. Powell K E, Blair S N, 1994, ``The public health burdens of sedentary living habits: theoretical but realistic estimates ''Medicine and Science in Sports and Exercise 26 851 - 856
22. Reneman D,Visser M, Edelmann E, Mors B, 1999 Mensenwensen: de wensen van Nederlanders ten aanzien van natuur en groen in de leefomgeving [What people want: the aspirations of the Dutch regarding nature and greenspace in the living environment], reeks Operatie Boomhut nr. 6; i.o.v. LNV-directie Natuurbeheer, Intomart/DLO-Staring Centrum, Hilversum/ Wageningen
23. RIVM, 1998 Leefomgevingsbalans; voorzet voor vorm en inhoud [Audit of the living environment; first suggestions for formand content],National Institute of Public Health and the Environment (RIVM), Bilthoven
24. Stronks K, 1997 Socio-economic Inequalities in Health: Individual Choice or Social Circumstances? Dissertation, Department of Public Health, Erasmus University Rotterdam, Rotterdam
25. Stronks K,Van de Mheen H, Mackenbach J P, 1993, ``Achtergronden van sociaal-economische gezondheidsverschillen: een overzicht van de literatuur en een onderzoeksmodel'' [Backgrounds of socio-economical differences in health: an overview of the literature and a conceptual model for research] Tijdschrift voor Sociale Gezondheidszorg 71 1 - 10
26. Takano T, Nakamura K, Watanabe M, 2002, ``Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces'' Journal of Epidemiology and Community Health 56 913 - 918
27. Ten Wolde S J, 1999 Recreatie en gezondheid: effecten van beweging en natuurbeleving op de gezondheid [Recreation and health: effects of physical activity and experiencing nature on health], Stichting Recreatie, Kennis- en Innovatiecentrum, The Hague
28. US DHHS, 1996 Physical Activity and Health: A report of the Surgeon General National Center for Chronic Disease Prevention and Health Promotion, US Department of Health and Human Services, Atlanta, GA
29. Van den Berg A E, De Vries S, 2000, ``Het binnenstedelijke buitengevoel'' [The inner-city outdoor experience] De Levende Natuur/Journal of Nature Conservation and Management 101(6) 182 - 185
30. Van der Meer J, 1998 Equal Care, Equal Cure? Socioeconomic Differences in the Use of Health Services and the Course of Health Problems (Erasmus University Rotterdam, Rotterdam)
31. Van der Velden J, 1999 General Practice at Work: Its Contribution to Epidemiology and Health Policy (NIVEL, Utrecht)

32. Van Wee G P, 2000, ``Verkeer, milieu en ruimte: onderzoek en beleid in beweging'' [Traffic, environment and space: research and policy in motion] Oration, Faculty of Spatial Sciences, University of Utrecht, Utrecht
33. Verhaak P F M, 1995 Mental Disorder in the Community and in General Practice (Avebury, Aldershot, Hants)
34. Verheij R A, 1995, ``Explaining urban-rural variations in health: a review of interactions between individual and environment'' Social Science and Medicine 42 923 - 935
35. Verheij R A, 1999, Urban - rural variations in health care (Dissertation Utrecht University, NIVEL, Utrecht)
36. Verheij R A, Van de Mheen H, De Bakker D H, Groenewegen P P, Mackenbach J P, 1998, ``Urban - rural variations in health in the Netherlands: does selective migration play a part?'' Journal of Epidemiology and Community Health 52 487 - 493
37. VROM, 2000 Nota `Mensen, wensen, wonen' [Policy document `People, desires, living'], Ministry of Housing, Spatial Planning, and the Environment (VROM), The Hague
38. Westerterp K R, 2001, ``Pattern and intensity of physical activity; keeping moderately active is the best way to boost total daily energy expenditure'' Nature 410 539