The association between physical environment and health: indicating the direction of effects using German panel data

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Background: A growing body of research has identified an association between health and physical residential environmental characteristics. However, the direction of effects remains unclear, and further research is needed to determine whether the residential environment influences health.

Objectives: To specify the direction of the association between environmental disadvantage and self-reported health.

Methods: Longitudinal data were obtained from the German Socioeconomic Panel and were examined at two points in time. Participants were grouped by relocation status assessed across a five-year period. Structural equation modeling was used to examine the effect of baseline environmental disadvantage on baseline health and on health five years later.

Results: In both groups, environmental disadvantage was cross-sectionally correlated with poor health. Only among people who did not relocate was baseline environmental disadvantage significantly related to health five years later in bivariate analyses. Results from the structural equation model found that environmental disadvantage was no longer significantly related to poor health five years later within the group of non-movers ($\beta = -.02$, $p = .052$). In addition, there was no effect in this direction within the group of movers ($\beta = .02$, $p = .277$).

Conclusions: Our results suggest the existence of a weak contextual effect as group differences in longitudinal associations indicated the direction of ecological effects.

Keywords: Perceived neighborhood, Self-rated health, Longitudinal study, Relocation, Environmental disadvantage

Introduction

In recent decades, a growing awareness of an ecological impact on health outcomes has led to an emergent body of research in this area.¹⁻⁴ In addition to individual factors, environmental conditions and characteristics have been hypothesized to influence health inequalities such as the distribution of chronic disease outcomes, health conditions, mental health, and health behavior.^{1,2} Self-reported health, a predictor of both morbidity⁵⁻⁷ and mortality,^{6,8} has been found to be related to environmental characteristics including neighborhood socioeconomic disadvantage,^{9,10} social environment,¹¹⁻¹⁵ the built environment,^{11-14,16,17} and the physical environment.^{11,15,17,18}

Taken from a large body of evidence, the following empirical studies provide examples of variables and methods typically used and that provide insights into common results in this area of research. Poortinga et al. found that perceptions of poor-quality neighborhood characteristics (poor access to amenities, poor neighborhood quality and disorder, and lack of social cohesion) were associated with poor self-reported health in a large sample of British adults ($N = 10,892$) even when controlling for individual characteristics.¹² Cummins et al. found that self-rated health was associated with poor physical residential quality, political climate and low political engagement, high unemployment and decreased access to private transportation, and lower transportation quality. However, they found no association of self-rated health with crime, health services, recreational facilities, and access to banks ($N = 13,899$).¹³ In a study

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by Dunstan et al., poor self-reported health was associated with objectively poor neighborhood quality, particularly physical incivilities and the poor maintenance of properties. Objective measures of green spaces were not related to self-rated health in this study.¹⁶ In a sample of older adults (65 years+), Bowling et al. identified perceived environmental problems that were predictive of poorer health (e.g. noise, crime, and air quality).¹⁸ In another sample of older adults, Wen et al. found an index of perceived neighborhood quality (housing, public parks, noise, crowdedness, and air quality) that was associated with self-reported health. The effects were partially explained by psychosocial factors in this multilevel study.¹⁷

Despite this large body of evidence, caution is required when comparing these empirical studies with each other because they varied widely in their measures, methods, and samples.^{3,19} In addition, most of these studies were limited by a severe methodological issue: they were cross-sectional in design, which does not allow the direction of effects to be determined.^{9–18} Longitudinal study designs are needed to determine directionality and temporality.¹ Therefore, the first objective of the current study was to replicate previous results by showing a cross-sectional relation between environmental disadvantages and self-reported health. The second objective was to longitudinally examine the direction of the association between environmental disadvantage and self-rated health while considering important individual characteristics and the continuity of the residential environment. We hypothesized a longitudinal effect only for people for whom the residential environment did not change over time. This study used a new methodological approach to contribute to the existing debate about the directionality of the association between environment and health.

Methods

Data-set

This longitudinal study used data from the German Socioeconomic Panel (SOEP), an annual survey that began in 1984. The study design and sampling procedures are described in detail elsewhere.²⁰ All participants of the German SOEP provide informed consent, and the data protection standards of the Federal Republic of Germany are observed and supervised by an independent advisory board.

In addition to the annual assessment of basic household and individual attributes, supplementary variables are examined at specific intervals in the SOEP. Self-perceived residential environment data were last assessed in the years 2004 and 2009,²¹ determining the time points that we used in our analyses. The entire matched sample for these years included 14,261 persons, but only the heads of households were asked for their perceptions of the environment, and their answers were coded for the entire household. For that reason, we used only data from the heads of households (N = 7,430). Due to missing data on basic information such

as relocations during the years of the study, the sample size was reduced to 7,198 persons after being adjusted for missing data.

Measures

To assess the continuity of the residential environment, we divided the sample into two groups based on relocation status in the five-year period. We recorded whether participants had moved at least once between 2004 and 2009 or whether they had not moved at all by combining the answers across the years from 2005 to 2009 to the annually recorded question: *Did you live in this flat the last time we interviewed you about a year ago?*

As the indicator of the physical environment (independent variable), we used self-perceived environmental disadvantage from the year 2004. Participants were asked about noise pollution, air pollution, and lack of accessible green spaces. For all three characteristics separately, participants were asked: *How strongly do you feel you are affected by the following environmental influences on your residential area?* Answers were rated on a five-point scale (*not, slightly, bearably, strongly, and very strongly*).

Self-rated health in 2004 and 2009 as the dependent variable was assessed with the first question from the SF-36: *How would you describe your current health?* Answers were rated on a five-point scale (*very good, good, satisfactory, poor, and bad*). Self-rated health is often dichotomized for analyses;^{12,13,15–17,22} however, we analyzed the scale in its metric form for increased precision.

We calculated the equivalized income to control for individual socioeconomic status.²³ Household income was converted into personal income by considering the size of the household and the ages of its members. A weight of one was assigned to the first household member, a weight of 0.5 to each additional adult and child equal to or older than 14 years, and a weight of 0.3 to each child younger than 14. Household income divided by the sum of the weighting provided the equivalized income.

Statistical analysis

For bivariate correlations, self-perceived environmental disadvantage in 2004 and 2009 were used as scales, each comprised of the ratings on noise pollution, air pollution, and lack of accessible green spaces. Descriptive statistics, mean differences, and bivariate correlations were all calculated using Statistical Package for the Social Sciences (SPSS) 20.0 for Windows.²⁴

Structural equation modeling was chosen for calculating direct and indirect effects in one model and for simultaneously dealing with latent variables (non-observable quantities) and manifest variables (directly observable quantities).²⁵ Our structural equation model represented the relation between the independent latent variable environmental disadvantage and the manifest dependent variable health in both 2004 and 2009. Self-perceived environmental disadvantage in 2004 was estimated by

Figure 1 Subgroup of people who did not move (N = 5,490).

Note: The structural equation model illustrates the relations between environmental disadvantage in 2004 and health in 2004 as well as in 2009, adjusted for age, sex, and income. Solid paths are statistically significant ($p < .05$). All parameters are shown as standardized estimates.

Figure 2 Subgroup of people who moved at least once (N = 1,708).

Note: The structural equation model illustrates the relations between environmental disadvantage in 2004 and health in 2004 as well as in 2009, adjusted for age, sex, and income. Solid paths are statistically significant ($p < .05$). All parameters are shown as standardized estimates.

the previously described three items. Prior factor analyses showed the appropriateness of building an index out of these three variables ($\alpha = .75$). Self-rated health in 2009 was predicted by the environmental disadvantage index in 2004 and self-rated health in 2004. Self-rated health in 2004 was predicted by the estimated environmental disadvantage index in 2004. The model was adjusted for age and sex.²⁶ In addition, we controlled for individual income as a confounding variable.^{27–29} The model was applied to two groups: people who did not move (Fig. 1) and people who moved at least once during the explored time span (Fig. 2). In addition, using relocation as a grouping variable, we tested for differences between the groups by comparing a model in which the path coefficients between the environmental index in 2004 and self-rated health in 2009 were allowed to vary between the groups to a model in which the path coefficients were constrained to be equal. Chi-square difference testing was used to make decisions about structural invariance. All parameters are reported as standardized estimates to enhance interpretability. Statistical significance was set at 0.05.

The global model fit of the structural equation models was measured by the chi-square (χ^2) statistic, the root mean square error of approximation (RMSEA), and the comparative fit index (CFI). A small χ^2 (with a non-significant

p-value), an RMSEA of less than .08, and a CFI of at least .90 characterize a model with good fit.³⁰ Mplus version 6.1 was used to estimate the hypothesized structural equation models.³¹

Results

Descriptive characteristics of the sample

A total of 7,198 heads of households were included in the analysis. The heads of household were 50.8% female with a mean age of 50.6 years in 2004 (Table 1). During the years between 2004 and 2009, a group of 1,708 persons moved at least once, whereas the remaining 5,490 persons did not move.

The people who moved differed systematically from those who did not move. On average, people who moved were significantly younger ($t(7,196) = 33.65, p < .001$), had lower incomes in both years (2004: $t(7,196) = 6.59, p < .001$, 2009: $t(7,196) = 2.06, p = .039$), reported better health in both years (2004: $t(7,186) = -8.62, p < .001$, 2009: $t(7,180) = -9.90, p < .001$), and perceived a higher level of environmental disadvantage in 2004 ($t(7,132) = -5.15, p < .001$) than people who did not move.

Despite the systematic intergroup differences in individual characteristics, in both groups, a higher level of disadvantage in 2004 was cross-sectionally associated with

Table 1 Descriptive characteristics of the sample (Mean, SD, and Range)

Characteristics	Total sample(N=7,198) ¹	People who did not move (N=5,490) ²	People who moved (N=1,708) ³
Sex			
Female	50.8%	49.5%	55%
Male	49.2%	50.5%	45%
Age 2004 [in years]	50.6 (15.3, 18–94)	53.7 (14.3, 19–94)	40.6 (14.0, 18–92)
Income 2004 [€/year]	20,879 (16,576; 1–737,669)	21,459 (17,780; 135–737,669)	19,012(11,713; 1–126,897)
Income 2009 [€/year]	22,848 (17,455; 0–443,643)	23,085 (17,777; 0–443,643)	22,089 (16,363; 1,377– 373,062)
Self-rated health 2004 [mean]	3.4 (0.9, 1–5)	3.3 (0.9, 1–5)	3.5 (0.9, 1–5)
Self-rated health 2009 [mean]	3.2 (0.9, 1–5)	3.2 (0.9, 1–5)	3.4 (0.9, 1–5)
Disadvantage 2004 [mean]	1.64 (0.67, 1–5)	1.62 (0.65, 1–5)	1.72 (0.72, 1–5)
Air pollution	1.7 (0.8, 1–5)	1.7 (0.8, 1–5)	1.8 (0.8, 1–5)
Noise pollution	1.9 (0.9, 1–5)	1.8 (0.9, 1–5)	1.9 (1.0, 1–5)
Lack of green spaces	1.4 (0.7, 1–5)	1.4 (0.7, 1–5)	1.5 (0.8, 1–5)
Disadvantage 2009 [mean]	1.64 (.66, 1–5)	1.65 (0.67, 1–5)	1.62 (.65, 1–5)
Air pollution	1.8 (0.8, 1–5)	1.8 (0.8, 1–5)	1.7 (0.8, 1–5)
Noise pollution	1.9 (0.9, 1–5)	1.9 (0.9, 1–5)	1.8 (0.9, 1–5)
Lack of green spaces	1.3 (0.7, 1–5)	1.3 (0.7, 1–5)	1.3 (0.7, 1–5)

¹Sample size varied between 7,128 and 7,198 due to missing values.²Sample size varied between 5,426 and 5,490 due to missing values.³Sample size varied between 1,700 and 1,708 due to missing values.

worse health in 2004 ($r = -.11, p < .001$), and a higher level of disadvantage in 2009 was cross-sectionally associated with worse health in 2009 ($r = -.09, p < .001$). In the longitudinal view, only for people who did not move during the study period was disadvantage in 2004 significantly related to health five years later ($r_{\text{did not move}} = -.08, p < .001$; $r_{\text{moved}} = -.02, p = .502$).

Structural equation models

For the group of people who did not move, the model provided a good fit, $\chi^2 = 95.187$ ($df = 18, p < .001$), RMSEA = .028, CFI = .990 (Fig. 1). The disadvantage index in 2004 was significantly negatively associated with health in 2004, meaning that people with higher disadvantage scores had worse health ($\beta = -.11, p < .001$). This relation was adjusted for age, sex, and income in 2004, showing that age ($\beta = -.29, p < .001$) and income ($\beta = .11, p < .001$) were associated with health: older people and people with lower incomes had worse health in 2004. Furthermore, the relation between the disadvantage index in 2004 and health in 2009 only barely failed to reach statistical significance ($\beta = -.02, p = .052$). This relation was adjusted for age ($\beta = -.17, p < .001$), sex ($\beta = -.01, p = .35$), income in 2009 ($\beta = .07, p < .001$), and health in 2004 ($\beta = .49, p < .001$). Older people, people with lower incomes in 2009, and people with worse health in 2004 had worse health in 2009. Moreover, there was an indirect effect of disadvantage in 2004 via health in 2004 on health in 2009 ($\gamma = -.06, p < .001$). The effect of disadvantage in 2004 on health in 2009 was mediated by health in 2004. The direct effect of disadvantage in 2004 on health in 2009 was quite small due to this indirect effect. The overall model explained 34.0% of the variance in health in 2009.

Figure 2 shows the same model for people who moved between 2004 and 2009. The model also had good fit

indices, $\chi^2 = 67.016$ ($df = 18, p < .001$), RMSEA = .040, CFI = .978. The disadvantage index in 2004 was negatively associated with health in 2004; people with higher disadvantage scores had worse health ($\beta = -.11, p < .001$). This relation was adjusted for age ($\beta = -.34, p < .001$) and income in 2004 ($\beta = .14, p < .001$): Older people and people with lower incomes had worse health. In addition, women had a higher probability of reporting worse health ($\beta = -.05, p = .032$). There was no significant association between disadvantage in 2004 and health five years later ($\beta = .02, p = .277$). However, again, age ($\beta = -.19, p < .001$), income in 2009 ($\beta = .06, p = .005$), and health in 2004 ($\beta = .42, p < .001$) were related to health in 2009. Moreover, there was an indirect effect of disadvantage in 2004 via health in 2004 on health five years later ($\gamma = -.05, p < .001$). The overall model explained 26.9% of the variance in health in 2009.

When testing for differences between the models with constrained versus unconstrained path coefficients between the disadvantage index in 2004 and self-rated health in 2009, the chi-square difference value was 3.69 ($df = 1, p = .055$).

Discussion

In a partial sample from the German SOEP, a large panel study of the German population, we analyzed the relation between perceived environmental disadvantage, operationalized by ratings of noise pollution, air pollution, and a lack of accessible green spaces, and self-rated health. To this end, we used data from two time points, namely, between the years 2004 and 2009. We divided the sample into people who did not move and people who moved at least once during this time period and hypothesized a longitudinal effect of environmental disadvantage on health only in the group of non-movers.

First, environmental disadvantage was found to be associated with health independent of individual characteristics such as age, sex, and income. Previous international study results were replicated in the cross-sectional analysis of the whole sample.^{15,17,18} Results differed slightly in effect sizes compared with the German studies by Voigtländer, Berger, and Razum³² and Müller¹¹ due to different modeling and adjustments.

Second, in the longitudinal examination, the most interesting association in the hypothesized model was the one between baseline disadvantage and health five years later as it indicates the direction of the relation between environment and health. This effect was nearly significant within the group of people who did not move, whereas there was no effect in the expected direction within the group of people who moved. In addition, there was a marked difference between the model in which the path coefficients between the environmental index in 2004 and self-rated health in 2009 were allowed to vary between the groups and the model in which the path coefficients were constrained to be equal. This indicates that the path coefficients differed between the groups, although the difference test was not quite statistically significant. This was accompanied by a greater ratio of explained variance as well as a greater indirect effect of disadvantage in 2004 via health in 2004 on health in 2009 in the subgroup of people who did not move. As the time factor indicates what came first, this relation may be interpreted as an effect of the environment on health. Also, the intergroup effect argues for a contextual meaning independent of important individual characteristics even though the effects were small and the long-term effect in the group of non-movers failed to reach significance. We suspect that the low variance in self-perceived environmental disadvantage in our study may provide an explanation for the small effects. However, even in cross-sectional considerations, previous studies have found small and attenuated ecological effects while simultaneously adjusting for individual characteristics,^{12,17} which are known to be very powerful and to explain a large amount of variance in multivariate models due to their strong influence on health. Furthermore, the characteristics of the environment that we considered do not operate deterministically. Environmental characteristics are supposed to interact with other characteristics (e.g. environmental resources and even individual aspects such as physical activity, general lifestyle, or preferences). The behaviors and attitudes of residents are also plausible mediators of the distal relation between environment and health.¹ We also do not know about dramatic life occasions that might have occurred in the mean time. These variables were not included in our model, but as proximal variables, they may be able to provide stronger associations. In addition, it is generally assumed that ecological effects are not restricted to residential areas.^{33–35} For example, Inagami et al. underlined the importance of other areas (e.g. the working environment) that may be possible

suppressors of effects of residential environments.³⁵ Last but not least, even for people who did not move, the bivariate relation between disadvantage and health in the same year was found to be much stronger than the bivariate association between previous disadvantage and health five years later. This difference may be due to environmental change because environment is not a fixed component as claimed elsewhere.^{1,19} Across a time period of five years, there may be environmental changes due to short-term events such as construction or even long-term changes in urban development. These ecological variations could not be explicitly included in our model but could have had an attenuating influence on the longitudinal associations.

In conclusion, our results suggest that there may be an independent contextual effect, but if there is one, it is small. Aversive environmental conditions seem to have a negative impact on health over time. With that, health policy and urban planning might be able to target people's health from their place of residence and help to reduce health inequalities.

Strengths and limitations

This study has several strengths. The data were obtained from a large and representative sample, and the use of structural equation modeling allowed us to include multiple determinants of health in one model. The longitudinal design allowed us to identify the direction of ecological effects, an aspect that was missing from most previous studies.^{11–13,16–18} However, our study is limited by a potential same-source bias, resulting from self-reported independent and outcome variables.^{16,17,36} In addition, the data-set offered no information about where participants moved. It is possible that participants moved yet remained in the same neighborhood. In these cases, our grouping would be imprecise and would lead to an underestimation of differences between the groups. Furthermore, participants were asked for their environmental perceptions without defining a spatial scale. Thus, it is not clear how large of an area their individual perceptions encompassed.

Implications

Future studies should replicate this approach in which we used information about people's relocation and should combine this information with objective environmental characteristics (e.g. from GIS or standardized observations) as well as with plausible mediators (e.g. health behavior and more proximal outcomes). In addition, health assessments should be better specified in future research to obtain additional information about environmental influences on physical compared with psychological health. Furthermore, changes in participants' environments should also be addressed by future studies as the environment is dynamic over time. Finally, longitudinal study designs are able to set a starting point in the debate of causality, but to clearly illuminate causality, and therewith the

health relevance of places, intervention, and experimental approaches are needed.

Ethical approval

As our study involved only the secondary analysis of anonymized data, ethical approval was not required.

Conflicts of interests

No potential conflict of interest was reported by the authors.

Funding

The first and the third author were supported by a doctoral scholarship from the European Social Fund [grant numbers: 100088552, 100087692] provided by the development agency of Saxony (Sächsische Aufbaubank, <http://www.sab.sachsen.de>).

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