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# The interplay between neighbourhood characteristics: The health impact of changes in social cohesion, disorder and unsafety feelings

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ABSTRACT

This study examined how the health of Dutch residents in 2012 was influenced by changes in neighbourhood social cohesion, disorder, and unsafety feelings between 2009 and 2011. Multilevel regression analyses on repeated cross-sectional survey data included 43,635 respondents living in 2100 areas. Deteriorating social cohesion and unsafety feelings were negatively associated with general health, while improvement in social cohesion was associated with better general health of the population. When the interplay of neighbourhood features was considered, deteriorating neighbourhood safety appeared decisive for health, i.e. improving social cohesion did not mitigate the health effect of deteriorating neighbourhood safety. Our results show it is important to take concurrent interactions between neighbourhood features into account when examining their health impact.



## 1. Introduction

Studies from various countries have reported that social neighbourhood features, such as social networks, social capital, cohesion, informal social control, disorder, and unsafety feelings affect people's health (Sampson, 2012; Kim, 2010; Diez Roux, 2001; Diez Roux and Mair, 2010; Macintyre et al., 2002). Living in cohesive neighbourhoods and in neighbourhoods with much social capital has been found beneficial for both physical and mental health (Hawe and Schiell, 2000; Kawachi et al., 2008; Diez Roux and Mair, 2010). Living in areas that are unsafe and with high levels of crime and disorder has been associated with worse health (Lorenc et al., 2012; Stafford et al., 2007; Ziersch, 2011).

Theories originating in criminology and sociology describe the interconnectedness of these so-called neighbourhood processes of organisation (e.g. social cohesion, social capital) and disorganisation (e.g. disorder, crime, unsafety feelings) (Sampson and Groves, 1989; Sampson, 2012; Hardyns and Pauwels, 2010). The social disorganisation theory, for example, elaborates on the interplay between social cohesion, disorder and unsafety feelings in neighbourhoods (Sampson and Groves, 1989; Sampson, 2012; Sampson et al., 1997; Markowitz et al., 2001). In contrast to this theory, so far most public health studies examining the elements described in the social disorganization theory have focused on features in isolation, thereby not taking into account other, interrelated social neighbourhood characteristics and how the interplay between all relevant social neighbourhood characteristics may impact health (Kim, 2010; Scarborough et al., 2010; Pampalon et al., 2007; Echeverria et al., 2008; Steptoe and Feldman, 2001; Baum et al., 2009; Bjornstrom et al., 2013; Ross and Miroswsky, 2001). This could result in incorrect conclusions about the relevance of specific neighbourhood characteristics for health. Furthermore, most previous studies addressing the health impact of social neighbourhood characteristics have a cross-sectional study design, thereby hindering conclusions concerning the causality of the relations reported (Diez Roux and Mair, 2010). Longitudinal studies can provide more information about the temporal relationship between characteristics, which can help in formulating causal conclusions concerning the health effects of neighbourhood characteristics.

Residents living in more urban neighbourhoods and in neighbourhoods with a low socioeconomic status (SES) might be more susceptible to the health consequences of negative changes in

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social cohesion, disorder or unsafety feelings, because of the presence of other undesirable area characteristics that can harm their health (i.e. poor housing, traffic unsafety, less green space, more air pollution and noise). Moreover, in low SES neighbourhoods the characteristics of the residents themselves may reinforce this susceptibility further (Kruize et al., 2014). Studies have reported that individuals with a lower socioeconomic status receive less social support and may use less effective coping strategies to address stressful events than individuals with a high SES (Taylor and Seeman, 1999). For instance, avoidant coping strategies, activities that keep people from directly addressing the stressful events (e.g. by drinking), seem to increase when SES decreases (Taylor and Seeman, 1999). Moreover, chronic stress appears greater among those in a lower social position (Baum et al., 1999). This may intensify the detrimental health impact of undesirable changes in social cohesion, disorder and unsafety.

This study assesses the simultaneous health impact of processes of organization (social cohesion), and processes of disorganization (physical disorder, social disorder, and unsafety feelings) in Dutch neighbourhoods. We examine the health impact of *changes over time* in social cohesion, physical disorder, social disorder, and unsafety feelings. This type of knowledge can help to gain more insight into the potential of neighbourhood-based public health interventions. The study has four specific aims:

- First, to examine how the changes in each social neighbourhood characteristic are related to health, univariate and multivariate, in order to assess the independent contribution of the social neighbourhood characteristics on health. Because previous research found indications that improving and deteriorating neighbourhood factors might be related to health differently (Jongeneel-Grimen et al., 2013), we investigate the health impact of improvements separately from deteriorations.
- Second, to identify neighbourhood patterns of change in social cohesion, physical disorder, social disorder, and unsafety feelings, in order to determine which patterns of change occur in the areas in reality.
- Third, to assess how the interplay of the four neighbourhood characteristics impacts the health of the residents, by examining the relation between the patterns of neighbourhood change and health.
- Finally, to examine if the health impact of changes in the social neighbourhood features differs by the SES or urbanicity level of the area. This way we want to assess whether there are differences between areas in the susceptibility to the health consequences of changes in the social neighbourhood features.

## 2. Method

### 2.1. Data

This study is based on secondary analyses of repeated cross-sectional data from existing nationwide datasets. We used separate datasets to obtain individual health information and the information about the area characteristics.

The health data and individual characteristics were obtained from repeated cross-sectional Dutch Housing Surveys (WoON) conducted in 2009 and 2012 by Statistics Netherlands (CBS). WoON is a nationwide, triennial survey of non-institutionalized adults, aged 18 years and older. Data were collected through telephone, Internet and face-to-face interviews. In total, 78,000 respondents completed the survey in 2009 (response rate 58%) and 69,330 in 2012 (response rate 63%).

Repeated cross-sectional data on safety, disorder and social cohesion were derived from the Dutch Integral Safety Monitor conducted in 2009 and 2011 (*Integrale Veiligheidsmonitor*) by Statistics Netherlands (CBS). The Safety Monitor IVM 2009 contained 198,122 respondents aged 15 years and older (response rate 40%). IVM 2011 contained 223,944 respondents of 15 years and older (response rate 43%). Respondents were excluded when they were younger than 18 years, had missing data on the area characteristics studied, or when the four-digit postal code was missing. A total remained of 112,880 respondents in 2009 and 122,663 respondents in 2011. The neighbourhood data from IVM was aggregated to the four-digit postal code area, using ecometrics and combined with WoON 2012 using the four-digit postal code.

Additional neighbourhood level data concerning the urbanicity level of the postal code areas and the socio-economic status of the areas in 2006 were derived from Statistics Netherlands (CBS) and The Netherlands Institute for Social Research (SCP) respectively.

### 2.2. Study population

We selected respondents from the WoON 2012 survey who had lived at their current address since 2009 in order to examine the health effect of exposure to safety issues measured in the Dutch Integral Safety Monitor of 2009 and 2011 ($n=48.734$ in $n=3310$ postal code areas). Next, respondents living in areas with data on safety, disorder and social cohesion in both 2009 and 2011 were selected ($n=47{,}061$ in $n=2766$ postal code areas). Finally, respondents living in areas from which the socio-economic status score was available (only for areas with over 100 inhabitants) and with data on general health in 2009 (areas where at least one respondent participated in WoON 2009) were selected. In total, 43,635 adults living in 2100 four-digit postal code areas (52% of the Dutch postal code areas) were included in the analyses (mean of 20.8 observations per area).

## 3. Measures

### 3.1. Self-rated health

Self-rated health was measured by the single question: 'In general, how do you rate your health?' Using a 5-point Likert-scale, answers ranged from 'very good' to 'very bad'. We dichotomized the answers into (very) good general health (0) versus less than good or poor general health (1). Self-rated general health has consistently proven to be an independent predictor of mortality (Idler and Benyamin, 1997) and morbidity (Simon et al., 2005).

### 3.2. Area characteristics

#### 3.2.1. Social cohesion

Respondents were asked whether they agreed with the following statements: "The people in this neighbourhood hardly know one another" (reversed), "the people in this neighbourhood are friendly to one another", "I live in a cosy neighbourhood with much solidarity", "I have a lot of contact with other neighbours", and "I feel at home with the people living in this neighbourhood". Answers ranged on a 5-point Likert scale from totally disagree to totally agree. A higher score indicated more social cohesion. Cronbach's alpha of the five items was 0.85 in both years, indicating good reliability.

#### 3.2.2. Physical disorder

Respondents were asked whether they judged the following five items to occur "never", "sometimes" or "often": vandalism of cars, graffiti on walls and buildings, demolition of phone booths and bus -/ tram shelters, dog faeces on the street, and street litter. A higher score indicated more physical disorder. Cronbach's alpha

of the five items was 0.71 in 2009 and 0.70 in 2011, indicating good reliability.

### 3.2.3. Social disorder

Respondents were asked they judged the following four items to occur "never", "sometimes" or "often": drunken people on the streets, visible drug use, nuisance from adolescents, and nuisance from residents. A higher score indicated more social disorder. Cronbach's alpha of the four items was 0.72 in 2009 and 0.71 in 2011, indicating good reliability.

### 3.2.4. Unsafety feelings

Respondents were asked whether they ever feel unsafe in their own neighbourhood ('yes' versus 'no').

We aggregated the individual scores for social cohesion, physical disorder, social disorder, and unsafety feelings to the neighbourhood level, because we wanted to examine whether the neighbourhood environment can impact the health of residents. This can provide information about whether interventions addressing the neighbourhood environment could be a promising public health strategy. Criminological studies have shown variations in safety-related measures to be most pronounced at the neighbourhood level, as compared to larger geographic scales, such as the municipality level (Hardyns and Pauwels, 2010; Oberwittler and Wikström, 2009). For the creation of social cohesion, small areas are needed that are relevant for social interactions between neighbours (Diez Roux and Mair, 2010). In our study, neighbourhoods were defined by the four-digit postal code. These Dutch postal codes comprise, on average, around 4000 residents. The area surfaces of the postal code areas range between 1 and 8 $km^2$, depending on population density. Due to differences in population density, this means that the neighbourhoods comprise relatively small areas in cities, but larger areas in more rural locations.

Following the work of Raudenbusch and Sampson (1999), we conducted ecometric analyses to calculate aggregated social cohesion and disorder scores and unsafety feelings prevalence for each four-digit postal code area. Ecometrics takes into account differences in the number of respondents per area, the individual characteristics of these respondents between areas, and the interdependence of the answers of one and the same respondent. We adjusted the aggregated measures for sex, age, educational level, ethnicity, and number of household members. To calculate the social cohesion measure and the disorder measures, three level (item, respondent, and area level) ordinal regression models were used. The measurements of unsafety feelings were aggregated using two-level (respondent and area level) logistic regression models. The measurements are related to a linear score through a link function. The link function depends on the distributional assumptions of the outcome variable and is an essential part of Generalized (Linear) Mixed Models (McCullagh and Nelder, 1989). For the ordinal regression models this is the cumulative logit function and for the logistic regression models this is the logit function. The area level scores were characterized by the best linear unbiased predictors (BLUPs), which can be seen as a latent variable (Hartzel et al., 2001; McCulloch and Searle, 2004). We added the overall area mean to each residual to be able to subtract the area scores of 2009 from 2011 to produce a change score for each area. A positive score indicated improvement and a negative score deterioration over time. For more information about the ecometrics approach, see Appendix A.

Table 1 shows the change scores for the four area characteristics. On average, areas improved between 2009 and 2011 in the case of social disorder, while they deteriorated in case of social cohesion, physical disorder and unsafety feelings. The means and standard deviations indicate that generally the changes were small. When we divided the areas in improvement versus deterioration, in about half of the areas, social cohesion, physical disorder, and unsafety feelings improved between 2009 and 2011, and in about a third of the areas the social disorder improved (Table 1, right column). Correlations between the change scores were moderate and in the expected direction: an increase in social cohesion coincided with a decrease in disorder and unsafety feelings (and vice versa), and an increase in physical disorder, social disorder, or unsafety feelings was associated with an increase in the other indicators. The moderate correlations support the assumption that the indicators represent overlapping but distinct area phenomena and can be analysed simultaneously in the regression models.

Next, we used the four change indicators to determine patterns of area change, using k-means clustering (Hastie et al., 2009).

**Table 1**
Characteristics of the four-digit postal code areas ($n=2100$).

| Area indicator | Change between 2009–2011 | | | | | | | Change in groups[a] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Improvement | | Deterioration | |
| | Mean | SD | Mean change score by area percentiles[b] | | | | | % | Mean | % | Mean |
| | | | 10 | 25 | 50 | 75 | 90 | | | | |
| **Social cohesion** | −0.033 | 0.49 | −0.63 | −0.31 | −0.04 | 0.26 | 0.55 | 47 | 0.36 | 53 | −0.38 |
| **Physical disorder** | −0.031 | 0.42 | −0.54 | −0.27 | −0.01 | 0.23 | 0.44 | 51 | −0.34 | 49 | 0.29 |
| **Social disorder** | 0.154 | 0.44 | −0.39 | −0.12 | 0.17 | 0.44 | 0.68 | 35 | −0.30 | 65 | 0.40 |
| **Unsafety feelings** | −0.021 | 0.38 | −0.48 | −0.25 | −0.01 | 0.22 | 0.43 | 51 | −0.30 | 49 | 0.28 |

**Pearson's Correlation matrix**

| Changes in: | Social cohesion | Physical disorder | Social disorder | Unsafety feelings |
|---|---|---|---|---|
| **Social cohesion** | 1 | | | |
| **Physical disorder** | −0.27** | 1 | | |
| **Social disorder** | −0.28** | 0.54** | 1 | |
| **Unsafety feelings** | −0.25** | 0.27** | 0.33** | 1 |

[a] For each indicator, the areas were divided into two groups: those areas that improved over time and those areas that deteriorated.
[b] a positive score indicates an improvement in social cohesion and a deterioration in physical disorder, social disorder and unsafety feelings.
** $p < 0.01$.

K-means clustering aims to partition observations into *k* clusters in which each observation belongs to the cluster with the nearest mean. This method aims to minimize the sum of squared distances from all points to their cluster centres. The optimal number of clusters is determined by the percentage explained variance. When adding another cluster does not result into a considerable improvement of the model (improvement of the explained variance), the optimum of the number of clusters is reached. To determine the number of clusters, we used the sum of squared error (SSE) scree plot, that showed a bend at two and four clusters (figure available on request).

### 3.3. Confounders

The following individual characteristics will be included in the analyses as control variables: sex (male/female), age (continuous), highest achieved educational level (no education/only primary school, lower secondary, upper secondary, tertiary), household composition (partner/married no child(ren), partner/married with child(ren), single no child(ren), single with child(ren), other), ethnicity (ethnic Dutch, non-Dutch western origin, non-western origin), and disposable household income (continuous). At the area-level, we controlled for urbanicity to adjust for urban-rural differences in the sizes of the postal-code areas. The measurement of urbanicity, provided by Statistics Netherlands, was based on the number of addresses per km$^2$ of the municipality and translated into a five-point scale, where higher values indicate higher urbanicity (5=urban (more than 2499 addresses/km$^2$); 4=semi-urban (1500–2499 addresses/km$^2$); 3=intermediate urban-rural (1000–1499 addresses/km$^2$); 2=semi-rural (500–999 addresses/km$^2$); and 1=rural (up to 499 addresses per km$^2$).

### 3.4. Area-level SES and urbanicity

The SES levels were based on the Dutch Status Scores from 2006, which are calculated every four years for each four-digit postal code in The Netherlands. The score is based on: the percentage low educated residents in the area, the percentage of people that are unemployed, the mean income of the residents, and the percentage of the residents with a low income. We divided the score into quintiles (very low, low, intermediate, high and very high area SES). The five categories of urbanicity described above, were used to test for moderation by urbanization level.

## 4. Analytical approach

Generalized mixed models were applied to assess how changes in the four area characteristics were associated with the general health of residents. We started with estimating an empty model to establish the clustering of self-rated health at the neighbourhood level. The intraclass correlation (ICC) was calculated using the formula by Snijders and Boskers (1999), p. 244. Next, we performed analyses separately for the areas that improved over time and the areas that deteriorated (stratified analyses) in order to examine whether the health impact differed by type of area change. The relation between changes (either improvement or deterioration) in the four area characteristics and general health were examined for each neighbourhood characteristic univariately, as well as controlled for the continuous change score of the other neighbourhood characteristics. This way, we examined the health impact of the area characteristics independently from one another. Thirdly, we examined how the interplay of changes in the four area characteristics impacted the health of residents, by analysing the health impact of the four change patterns, established through K-means clustering analyses. These clusters represent the real-life patterns of change that occurred in the areas. Finally, moderation was tested by including interaction terms between the area change indicators (improvement scores, deterioration scores, and the clusters) and area SES and urbanicity. For the moderation analyses with improvement and deterioration scores, the multivariate models were used. Significant interaction terms ($p < 0.05$) were used as an indicator of existing moderating effects. All analyses were adjusted for age, sex, household composition, ethnicity, household income, educational level, urbanicity, and the area characteristics scores and health at the area level in 2009. Analyses were carried out using R, version 3.0.2 and SPSS version 20.

## 5. Results

In the total study population, 23 percent of the respondents perceived their general health as poor. Four percent of the variation in general health was attributable to between area differences (intraclass coefficient (ICC) of 4.03).

### 5.1. The health impact of changes in social cohesion, disorder and unsafety feelings

Greater deterioration of social cohesion between 2009 and 2011 was associated with more people reporting poor general health (Table 2). Greater improvement of social cohesion was associated with less people reporting poor general health. A deterioration of social cohesion had a stronger effect on health than an improvement in social cohesion.

When the area characteristics were examined separately, deteriorating social disorder was related with more people reporting poor health. However, neither an improvement in disorder (physical or social) nor a deterioration of disorder was associated with health, independent of the other area characteristics (Table 2, right column).

Finally, improving area safety was not related to general health, but the deterioration of area safety (more people feeling unsafe in the area), was related to more people reporting poor general health.

For all area characteristics, the univariate and the multivariate analyses yielded similar results.

### 5.2. Patterns of change in social cohesion, physical and social disorder and unsafety feelings

We identified four clusters of areas that showed distinct real-life patterns of area change, explaining almost 50% of the variance in area change (Table 3). Between 2009 and 2011, 18 percent of the areas experienced an overall improvement in social cohesion, physical disorder, social disorder, and unsafety feelings. Around the same amount of areas (20%) experienced an overall deterioration in this time period. The largest group of areas (37%) experienced moderate deteriorations of disorder and unsafety feelings between 2009 and 2011, with simultaneous improvement of the social cohesion. Finally, a quarter of the areas showed the reverse pattern: moderate improvement in disorder and unsafety feelings, in combination with a deterioration of social cohesion.

### 5.3. Patterns of area change and the relation with general health

In the areas where the social environment deteriorated overall between 2009 and 2011, more people reported poor general health than in the areas that improved overall in that time (Table 4). Furthermore, the areas experiencing moderate deterioration combined with improving social cohesion also showed a higher prevalence of

**Table 2**
Relations between changes in social cohesion, physical disorder, social disorder and unsafety feelings with individual level poor general health, stratified by type of change (deterioration versus improvement) (coefficients).

| | N | Poor general health *Univariate*[a] | | Poor general health *Multivariate*[a,b] | |
|---|---|---|---|---|---|
| | Respondents (areas) | B | p-Value | *B* | p-Value |
| **Social cohesion** | | | | | |
| Improvement[c] | 21,159 (983) | −0.1400 | 0.05* | −0.1479 | 0.04* |
| Deterioration[d] | 22,475 (1117) | 0.2243 | < 0.01* | 0.2206 | < 0.01* |
| **Physical disorder** | | | | | |
| Improvement[e] | 20,465 (1069) | −0.0950 | 0.22 | −0.0877 | 0.30 |
| Deterioration[f] | 23,169 (1031) | 0.1162 | 0.18 | 0.1402 | 0.13 |
| **Social disorder** | | | | | |
| Improvement[e] | 12,919 (738) | −0.0164 | 0.87 | 0.0087 | 0.93 |
| Deterioration[f] | 30,715 (1362) | 0.1197 | 0.04* | 0.0916 | 0.16 |
| **Unsafety feelings** | | | | | |
| Improvement[e] | 21,761 (1081) | −0.1066 | 0.17 | −0.0907 | 0.26 |
| Deterioration[f] | 21,873 (1019) | 0.4323 | < 0.001* | 0.4472 | < 0.001* |

[a] Adjusted for age, sex, education, ethnicity, household composition, income, urbanicity and neighbourhood situation in 2009, and general health at the neighbourhood level in 2009.
[b] Adjusted for the other change scores (continuous).
[c] One unit of change represents more improvement (increase in social cohesion between 2009 and 2011).
[d] One unit of change represents more deterioration (decrease in social cohesion between 2009 and 2011).
[e] One unit of change represents more improvement (decrease in disorder /unsafety feelings between 2009 and 2011).
[f] One unit of change represents more deterioration (increase in disorder/ unsafety feelings between 2009 and 2011).

**Table 3**
Characteristics of the patterns of change in four area clusters.

| Patterns of area change[a] | N | Social cohesion | | Physical disorder | | Social disorder | | Unsafety feelings | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| **Overall area improvement** Areas with improvement in social cohesion, physical & social disorder and unsafety feelings | 369 | 0.534 | 0.36 | −0.493 | 0.38 | −0.304 | 0.37 | −0.279 | 0.35 |
| **Overall area deterioration** Areas with deterioration in social cohesion, physical & social disorder and unsafety feelings | 424 | −0.541 | 0.37 | 0.312 | 0.33 | 0.588 | 0.35 | 0.291 | 0.32 |
| **Moderate area deterioration with social cohesion improving** Areas with deterioration in social disorder and moderate deterioration in physical disorder and unsafety feelings, combined with moderate improving cohesion | 767 | 0.168 | 0.26 | 0.125 | 0.26 | 0.299 | 0.27 | 0.035 | 0.29 |
| **Moderate area improvement with social cohesion deteriorating** Areas with (moderate) improvement in physical & social disorder and unsafety feelings, combined with deteriorating social cohesion | 540 | −0.307 | 0.30 | −0.207 | 0.30 | −0.087 | 0.30 | −0.169 | 0.34 |

[a] The mean change scores of the area characteristics differed significantly between the four clusters (*t*-test).

**Table 4**
Relation between patterns of area change and poor general health (coefficients)[a].

| Patterns of area change | Poor general health | |
|---|---|---|
| | B | p-Value |
| **Overall area improvement (reference)** | 0 | – |
| **Overall area deterioration** | 0.1225 | 0.01* |
| **Moderate area deterioration with social cohesion improving** | 0.1010 | 0.01* |
| **Moderate area improvement with social cohesion deteriorating** | 0.0204 | 0.63 |

[a] Adjusted for age, sex, education, ethnicity, household composition, income, urbanicity, neighbourhood situation in 2009, and general health at the neighbourhood level in 2009.

poor general health compared to the areas that improved overall. The general health in areas that experienced some area improvement in combination with deteriorating cohesion, on the other hand, did not differ from the areas that improved overall.

### *5.4. The health impact of changes in area characteristics between areas with a different socioeconomic status and urbanicity level*

The health impact of changes in the area characteristics did not differ according to the socioeconomic status of the area. Urbanicity only moderated the impact of an improvement in physical disorder between 2009 and 2011 on general health ($p=0.03$). In little urbanized areas, more people reported poor general health when the physical disorder improved (0.3824, $p=0.03$), while in areas with different levels of urbanicity there was no association between an improvement in physical disorder and poor general health.

## 6. Discussion

We observed that deteriorating social cohesion and unsafety feelings in the area was negatively associated with the health of residents, independent of the other area aspects, while improvement in social cohesion was associated with better general health of the population. Changes in physical and social disorder were not

independently associated with the general health of the population. We identified four distinct patterns of area change in our dataset. When these real-life patterns of change in the areas were examined, the relation between changes in social cohesion and general health was counterbalanced by the health impact of concurrent changes in unsafety feelings in the opposite direction. We found no indications that the relationship between changes in the area characteristics and general health differed with the SES or urbanicity level of the areas.

### 6.1. Strengths and limitations of the study

Before elaborating further on the research findings, the strengths and limitations of this study are discussed. One strength of our study is the use of different data sources for the exposure and health measures, thereby limiting same source bias (Macintyre and Ellaway, 2003). In addition, we used repeated data to investigate changes over time in social cohesion, disorder and unsafety feelings. This approach provides us with stronger clues for a causal relation between the social neighbourhood features and health than possible with cross-sectional studies. Furthermore, in this study we used ecometrics to compute our area-level indicators. Ecometrics is a more reliable way to aggregate survey data to the area level than the traditional, simpler calculation of an average for each neighbourhood based on individual information. However, because we calculated *change* scores, ecometrics may have introduced bias too. Ecometrics corrects the area-level score towards the mean score of all areas when data from only a few respondents is aggregated. If the number of respondents is very small in one year, though not in the other year, then one would introduce a spurious change, derived from the difference in the accuracy of the two measurements, not from an actual change. To estimate the impact of this potential 'ecometrics bias', we performed sensitivity analyses. We removed areas with less than five respondents in one year and over twenty respondents in the other year (11% of the areas in the dataset). The regression coefficients changed slightly, but without a clear pattern, and the statistical significance of the findings was similar to the main findings. We conclude that our results are robust against ecometrics bias.

A limitation of the study is the short observation time to detect health effects, i.e. one year after the changes. Since we only found associations between deteriorating cohesion and unsafety feelings and health, it is possible that the lag-time was too short to find an impact of area improvements on health. It is therefore recommended to also study the health effects of improvements in social cohesion, disorder and unsafety feelings over a larger time span in future research. Furthermore, our general health measure has the limitation that it less likely captures mental health aspects (Davies and Ware, 1981; Bailis et al., 2003). Most evidence so far has been found for a relation between the social neighbourhood environment and depression/depressive symptoms, and to a lesser extent physical health (Diez Roux and Mair, 2010). Using a mental health measure might have resulted in stronger relationships with our social neighbourhood indicators.

Finally, it is possible that the changes in social cohesion, disorder and unsafety feelings coincided with other unmeasured neighbourhood characteristics, such as physical neighbourhood features, that instead were responsible for the health effects found. While we included the most important individual level confounders, we cannot be certain that neighbourhood level confounding did not occur. This should be a point of interest for future research on neighbourhood effects on health.

### 6.2. Interpretation and implications of the findings

We showed that improvements in the area characteristics were unrelated to the general health of the population after one year, with the exception of improvements in social cohesion. This either implies that improvements in social and physical disorder and unsafety feelings do not impact general health, or that it takes longer than one year for health benefits to develop. We know of one other study that examined improvements in neighbourhood level characteristics in relation to health. Mair et al. (2015) examined the relation between changes in neighbourhood social cohesion, safety, violence, stress and aesthetic environment and changes in depressive symptoms. Similar to our findings, improvements in neighbourhood safety were not related to changes in depressive symptoms, only improvement in social cohesion. Future studies examining improvements in social environmental characteristics and health are needed in order to gather more empirical evidence.

In contrast with the lack of a health impact of improvements in area safety, the detrimental health impact of deteriorating area safety became visible already after one year. Policymakers and health professionals should respond swiftly to signs of increasing unsafety feelings among residents, in order to prevent negative health consequences. Even more so, because our results suggest that this negative health impact is not as quickly reversed by reducing the area level unsafety feelings.

This study shows that it matters if the relation between social neighbourhood characteristics and health is studied for each area characteristic univariately, multivariately, or by taking into account the interplay of social neighbourhood characteristics. The conclusion on the health impact of changes in the four neighbourhood characteristics when examined univariately or multivariately did not differ much. Changes in social cohesion and deterioration of area safety remained associated with health when the other area characteristics were taken into account. However, when studying the real-life change patterns, the associations between health and changes in social cohesion were counterbalanced by concurrent changes in disorder and unsafety feelings that occurred in the opposite direction. The results from the present study suggest that interventions addressing the social cohesion in an area with the aim to improve the health of residents should address other possible social neighbourhood problems as well, to ensure an effective public health strategy.

Two of the four patterns of area change seemed to represent different stages in the process of social disorganization. Areas with deteriorating social cohesion, but moderate improvements in disorder and unsafety feelings might be at the verge of neighbourhood disorganization, which is believed to set in after the cohesion between the residents has been broken down (Sampson and Groves, 1989; Sampson, 2012). In these areas we found no difference in the impact on health compared to the areas where all social neighbourhood characteristics had improved, arguably because only social cohesion had deteriorated at that time and not yet the other social neighbourhood features related to health. The areas that experienced moderate deterioration in disorder and unsafety feelings, but moderate improvements in social cohesion, might, at the other hand, be at the start of upward neighbourhood development. The people in these latter areas did not report better health than the people living in areas that deteriorated on all four neighbourhood characteristics. Possibly, areas must undergo the whole process of social neighbourhood improvement before the health of residents will benefit from this upward development, which could explain why we found no positive health impact of the improvement of social cohesion in these areas.

We found no evidence suggesting that residents living in more urbanized or in low SES areas may be more susceptible to the health consequences of deteriorating social neighbourhood features. In the environmental equity literature, communities' vulnerability to environmental exposures is an important research topic. Vulnerability is defined as the combination of exposure to

environmental conditions (e.g. ambient environmental quality, housing conditions), characteristics of potential vulnerability of the community (such as socioeconomic composition), and resources that determine the ability to respond to or recover from environmental stressors (e.g. health care, transportation, community social capital) (DeFur et al., 2007). Given this description, the neighbourhood SES and urbanicity levels in our study measured parts of neighbourhood vulnerability (i.e. the potential vulnerability of the neighbourhood population and indirectly the exposure to environmental stressors), but not all elements, which could be the reason why we did not detect a moderation effect. Future research should include direct measures of all three components of vulnerability to better examine whether certain neighbourhoods are more susceptible for changes in the social neighbourhood environment.

Four percent of the total variation in general health was attributable to the neighbourhood level. This magnitude might seem small, but compared to interventions targeting the individual, interventions targeting the neighbourhood environment can benefit the health of many people, therewith contributing considerably to the health of the population.

## 7. Conclusion

Even though changes in social cohesion were related to health, in those areas where concurrently opposite changes in neighbourhood safety occurred, the safety issues were decisive for the health of the residents. Policymakers and health professionals implementing area-based health interventions addressing the neighbourhood social environment should integrate the broad range of social neighbourhood characteristics in their public health interventions to create an effective public health strategy.

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## Appendix. : Ecometrics method to aggregate individual data to the neighbourhood level

Ecometics was used to calculate our neighbourhood measures from the survey data. With ecometrics, more reliable estimates of the context effect of the neighbourhood can be calculated by accounting for composition effects. The ecometrics approach has several advantages; first, it accounts for individual differences in response to survey items, based on individual characteristics. For example, older people might feel more vulnerable in the public realm, because they are less able to defend themselves against an attack than their younger counterparts. As a result, they might perceive their neighbourhood as less safe. If the number of elderly in the study sample is not representative for the study population, their perceptions bias the neighbourhood measure of safety. Second, ecometrics takes differences in the number of observations per neighbourhood into account by shrinking deviating neighbourhoods with smaller numbers of respondents to the general average (Hox, 2010). This approach makes the estimates more robust (less sensitive to outliers). Third, ecometrics takes into account the interdependence of the answers of one and the same respondent.

We adjusted the aggregated measures for five individual characteristics that may influence the perception of the social neighbourhood features, i.e. sex, age, educational level, ethnicity, and number of household members. To calculate the social cohesion measure and the disorder measures, three level (item, respondent, and area level) ordinal regression models were used. The measurements of unsafety feelings were aggregated using two-level (respondent and area level) logistic regression models, because we included only one item at the item level. The residuals of the neighbourhood measurement, i.e. the part that cannot be attributed to participants' response patterns and measurement error, constitutes the neighbourhood features.

For each measure, the reliability score has been calculated using the formula by Hox (2010), with an adjustment made by Snijders and Bosker (2012, p. 305), because multilevel logistic and ordinal regression models do not have individual level and item level variations:

For the two–level logistic models:

$$\lambda_j = \sigma^2_{neighbourhood}/[\sigma^2_{neighbourhood} + [3.29/n_j)]]$$

For the three–level ordinal models:

$$\lambda_j = \sigma^2_{neighbourhood}/[\sigma^2_{neighbourhood} + [\sigma^2_{individual}/n_j] + [3.29/[p{\cdot}n_j]]]$$

$\lambda_j$ is the reliability of the neighbourhood measure. $\sigma^2_{neighbourhood}$ is the variance between neighbourhoods; 3.29 represents the variance between individuals within the neighbourhoods in the two-level logistic models and the variance between the items in the three-level ordinal models; $n_j$ is the mean number of respondents per neighbourhood. Finally, $p$ is the number of items used.

The reliability $\lambda_j$ is close to 1 when group sizes are large and/or the variability of the intercepts across the groups is large. The reliability $\lambda_j$ is close to 0 when group sizes are small or when there is little variation across groups (Hox, 2010). The interpretation of the reliability score is similar to Cronbach's alpha, where scores above 0.60 represent good reliability. The average reliability of our neighbourhood measures is 0.89 (scores ranged between 0.85 and 0.92), indicating good reliability.

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