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Comparing subjective and objective neighbourhood deprivation and their association with health over time among older adults in England

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ABSTRACT

The importance of neighbourhood on individual health is widely documented. Less is known about the relative role of objective and subjective reports of neighbourhood conditions, how their effect on health changes as people age, and whether they moderate each other's impact on health. This study uses the English Longitudinal Study of Ageing (ELSA) to determine whether older adults report worse self-rated health as they age, and whether this differs between objective and subjective measures of neighbourhood. ELSA data contain 53,988 person-years across six waves collected biannually between 2002 and 03 and 2012 and 13. Objective neighbourhood conditions are measured by the 2004 Index of Multiple Deprivation, and subjective neighbourhood conditions are captured by a summative neighbourhood dissatisfaction score. We find both objective and subjective neighbourhood composite scores independently predict poor health. There is no change over time in the probability of reporting poor health by baseline objective or subjective neighbourhood scores, suggesting neighbourhood effects do not compound as older adults age. There is no moderating effect of area dissatisfaction on the relationship between neighbourhood deprivation and health. The findings provide little support for causal neighbourhood effects operating in later life and indicate different causal pathways through which objective and subjective neighbourhood deprivation impact on health.

1. Introduction

A body of research suggests that a person's health is affected by their individual characteristics as well as the residential environment in which they live (Ross et al., 2004; Tunstall, 2005; Yen et al., 2009). Previous studies have investigated whether health inequalities are a result of the variations in the individual characteristics of those residing in a neighbourhood (i.e. compositional factors) or due to the physical and social neighbourhood characteristics (i.e. contextual factors) (Macintyre et al., 1993, 2002). Research has explored the link between neighbourhoods and health by taking into account the effect of either one or both objective (e.g. median income, unemployment rate, indices of multiple deprivation) and subjective (e.g. perceived neighbourhood quality, perceived cohesion, perceived safety, level of area dissatisfaction) characteristics on health outcomes (Weden et al., 2008). Considering both objective and subjective assessment of neighbourhood simultaneously are rare, and comparing their moderating effect on each other and how independently they affect health over time is rarer. We briefly review the evidence suggesting neighbourhoods affect self-rated health by exploring objective, subjective and simultaneously measured exposures.

The weight of evidence suggests an association between poorer objective neighbourhood environment and morbidity (Badland et al., 2013; Robert, 1999; Robinette et al., 2016). For example, Badland et al. (2013) included both individual and neighbourhood level factors in a study comprising adults aged 40–65, and showed that individuals living in underprivileged neighbourhoods were more likely to report lower self-rated health (SRH). Although that study adjusted for individual factors, such as individual socioeconomic status (SES), to prevent the overestimation of neighbourhood characteristics, it did not account for other potential confounding variables (e.g. years lived in the neighbourhood) or change over time in health conditional on baseline neighbourhood context (Badland et al., 2013). This is a common limitation in the literature, which may lead to misestimating neighbourhood effects.

A smaller body of work supports an association between subjective neighbourhood characteristics and individual health (Badland et al., 2013; Ellaway et al., 2001; Toma et al., 2015). Individuals with

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Table 1
Study sample characteristics over time.

	Wave					
	1	2	3	4	5	6
Outcome variable:						
Self-rated health						
Good or better	68.2	71.5	66.4	71.5	71.5	69.7
Fair or worse	31.8	28.5	33.6	28.5	28.5	30.3
Valid sample size	11,219	8682	7379	6403	5967	5379
Missing (% all respondents)	172 (1.5%)	1639 (15.9%)	2412 (24.6%)	2920 (31.3%)	2984 (33.3%)	3275 (37.8%)
Neighbourhood exposures:						
Index of multiple deprivation (IMD) quintile						
Least deprived	20	20.4	20.7	21	21.1	21.1
	20.1	20.5	20.6	20.9	21.1	21.1
	19.9	20	20	19.8	19.9	19.8
	20	19.9	20	19.7	19.6	19.6
Most deprived	20	19.2	18.7	18.6	18.4	18.4
Valid sample size	10,469	9548	9061	8624	8278	8008
Missing (% all respondents)	922 (8.1%)	773 (7.5%)	730 (7.5%)	699 (7.5%)	673 (7.5%)	646 (7.5%)
Neighbourhood dissatisfaction quintile						
Least dissatisfied	21.6	21.5	21.3	21	21	20.9
2	20	20.2	20.1	20.1	20.1	20.2
3	20	20	20.1	20.3	20.4	20.3
4	19.8	19.9	19.9	20	20	20.1
Most dissatisfied	18.5	18.4	18.6	18.7	18.5	18.5
Valid sample size	9527	8855	8438	8074	7772	7530
Missing (% all respondents)	1864 (16.4%)	1466 (14.2%)	1353 (13.8%)	1249 (13.4%)	1179 (13.2%)	1124 (13%)
Time invariant covariates:						
Age group						
50–59	36.6	31	24.2	14.5	5.7	0
60–69	29.8	33.2	35.8	40.8	44.5	44.6
70–79	22.5	24	26.4	29.3	31.1	33.4
80 and over	11.1	11.8	13.5	15.4	18.7	22
Valid sample size	11,391	10,321	9791	9323	8951	8654
Missing (% all respondents)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Gender						
Male	45.5	45	44.7	44.2	44	43.8
Female	54.5	55	55.3	55.8	56	56.2
Valid sample size	11,391	10,321	9791	9323	8951	8654
Missing (% all respondents)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Education						
None	42.8	40.6	39.8	39	38.4	38
Some	46.1	47.6	48.2	48.8	49.3	49.6
Degree	11.1	11.7	12	12.2	12.3	12.4
Valid sample size	11,361	10,295	9763	9298	8926	8629
Missing (% all respondents)	30 (0.3%)	26 (0.3%)	28 (0.3%)	25 (0.3%)	25 (0.3%)	25 (0.3%)
Wealth quintile						
Least wealthy	19.4	17.7	17.1	16.5	16	15.6
2	20	19.7	19.4	19.2	19.2	19.2
3	20	20.4	20.4	20.5	20.6	20.8
4	20	20.9	21	21.2	21.5	21.5
Most wealthy	20.6	21.4	22.1	22.6	22.7	22.9
Valid sample size	11,191	10,136	9609	9146	8774	8479
Missing (% all respondents)	200 (1.8%)	185 (1.8%)	182 (1.9%)	177 (1.9%)	177 (2%)	175 (2%)
Years lived at current address						
Less than 1 year	1.7	1.7	1.8	1.8	1.8	1.8
1–4 years	11.7	11.6	11.7	11.8	11.8	11.6
5–9 years	12.2	12.5	12.7	12.8	13	13
10–19 years	25.5	25.9	25.7	25.8	25.8	26
20 or more years	48.9	48.3	48.1	47.8	47.5	47.6
Valid sample size	11,313	10,261	9733	9269	8897	8600
Missing (% all respondents)	78 (0.7%)	60 (0.6%)	58 (0.6%)	54 (0.6%)	54 (0.6%)	54 (0.6%)
Time varying covariates:						
Employment status						
Retired	50.9	54.6	59.7	66.2	72.1	78.7
Employed	26.2	23.4	21.4	17.3	13.4	9.6
Self-employed	5.6	5.3	4.9	4.8	4.4	4.1
Other	17.2	16.7	14.1	11.6	10.1	7.6
Valid sample size	11,336	8754	7522	6620	6220	5647
Missing (% all respondents)	55 (0.5%)	1567 (15.2%)	2269 (23.2%)	2703 (29%)	2731 (30.5%)	3007 (34.7%)
Depression						
Not depressed	83.6	84.3	85.1	85.5	85.1	87.6
Depressed	16.4	15.7	14.9	14.5	14.9	12.4
Valid sample size	10,940	8559	7281	6318	5870	5307
Missing (% all respondents)	451 (4%)	1762 (17.1%)	2510 (25.6%)	3005 (32.2%)	3081 (34.4%)	3347 (38.7%)
Social support tertile						

(*continued on next page*)

Table 1 (*continued*)

	Wave					
	1	2	3	4	5	6
Least support	34.8	34.8	38	34.3	37.5	37.4
Middle	36.3	36.6	30	37.6	29.5	28.9
Most support	28.9	28.6	32	28.2	33	33.7
Valid sample size	7178	5578	4685	4023	3936	3492
Missing (% all respondents)	4213 (37%)	4743 (46%)	5106 (52.1%)	5300 (56.8%)	5015 (56%)	5162 (59.6%)
Couple status						
Not in couple	31.3	32.2	34.1	34.2	34.8	35.9
In couple	68.7	67.8	65.9	65.8	65.2	64.1
Valid sample size	11,391	8780	7535	6623	6242	5659
Missing (% all respondents)	0 (0%)	1541 (14.9%)	2256 (23%)	2700 (29%)	2709 (30.3%)	2995 (34.6%)

negative neighbourhood perceptions of environmental quality, recreational facilities and antisocial behavior tend to have lower SRH (Ellaway et al., 2001; Stronegger et al., 2010). Oshio and Urakawa (2012) found a significant association between overall neighbourhood dissatisfaction and worse SRH in a Japanese population sample. Although the sample might have been biased as participants were drawn from an internet survey, the study highlighted that higher levels of area dissatisfaction could cause stress and depressive symptoms, which in turn could lead to worse SRH among older adults (Oshio and Urakawa, 2012). This highlights the importance of adjusting for psychosocial factors when investigating the association between subjective neighbourhood characteristics and health to determine the strength of a direct effect

Research suggests simultaneously controlling for the effect of objective and subjective characteristics on health within a multivariable model is essential to capture the structural features of the environment and the resident's perception of the neighbourhood (Bowling and Stafford, 2007; Weden et al., 2008). Bowling and Stafford (2007) found no association between objective [measured with the ACORN (A Classification of Residential neighbourhoods) based on participant's postcodes] or subjective (measured with self-report data on perceived problems in the area, perceived neighbourhood safety, perceived neighbourliness of area and ratings of facilities in the area) neighbourhood measures in an English sample aged 65 and over, once individual SES and social support factors were controlled for. A study conducted by Wen et al. (2006) comprising of 230 individuals aged between 50 and 65 reported an association of poorer health outcomes with declining neighbourhood SES, yet this association was attenuated after controlling for neighbourhood perception (perceived physical, social and service environments) and individual SES. Furthermore, Weden et al. (2008) showed that the association between health and objective neighbourhood characteristics (neighbourhood disadvantage and affluence) in an American population sample was mediated by subjective characteristics (including perceived neighbourhood problems and air quality, living environment and safety). They also found there was a stronger association between subjective neighbourhood measures and health compared with objective neighbourhood measures and health (Weden et al., 2008). One limitation of the study was that its objective measures were drawn from census data, which might not capture the absolute effect of neighbourhood factors on health given that these data are limited to SES measures of neighbourhood or their proxies, rather than other aspects of neighbourhood deprivation (e.g. access to services, environmental quality and crime) (Weden et al., 2008).

The present study includes both objective and subjective neighbourhood measures and adds to the public health literature by assessing the moderating effect of area dissatisfaction on the relationship between neighbourhood deprivation and SRH among older adults as they age. We focus on older adults because people more restricted to their neighbourhood are more affected by its built environment on their physical activity (Ivory et al., 2015), so they will be exposed to their neighbourhood environment more regularly and may be more reliant on local services (Beard et al., 2009; Bowling and Stafford, 2007; Marshall et al., 2014; Stafford et al., 2011).

We tested the following research hypotheses:

Hypothesis 1. Higher objective neighbourhood deprivation is associated with worse SRH as older adults age.

Hypothesis 2. Higher subjective neighbourhood dissatisfaction is associated with worse SRH as older adults age.

Hypothesis 3. Higher neighbourhood dissatisfaction amplifies the relationship between neighbourhood deprivation and SRH.

2. Methods

2.1. Study population

This study used data gathered from six waves of the English Longitudinal Study of Ageing (ELSA), an observational, nationally representative and individual level panel study comprising English adults aged 50 and over living in private households (NatCen, 2018). The first wave of data collection was in 2002–2003 through a main face to face interview and a self-completion questionnaire returned after the main interview. It comprised 11,391 respondents born before 29 February 1952 which were drawn from the Health Survey for England (HSE) samples of 1998, 1999 and 2001. The data for this study included 10,469 sample members whose address information could be matched to census neighbourhood boundaries. The sample members were followed-up biennially using the same modes of interview. Table 1 demonstrates the level of attrition. It shows 5296 (51%) sample members from wave 1 (i.e. baseline) completed at least part of the interview at wave six.

2.2. Measures

2.2.1. Dependent variable

2.2.1.1. Self-rated health. The data were drawn from two versions of SRH questions asked in different waves. The first wave included two questions randomly allocated to the sample members during the in-person interview. The respondents chose from very good, good, better, fair, bad or very bad to answer, "How is your health in general?", and excellent, very good, good, fair or poor, to answer "Would you say your health is?". Each respondent answered both questions, with half answering the first question first and the other half answering the second question first. At wave three, only the former was used due to a clerical error. At waves two, four, five and six only the latter was used. For this study, SRH was dichotomised into fair or worse vs good or better to create a harmonised measured across waves. The "fair or worse" responses are referred to as poor health and coded as 1 whereas the "good or better" responses are referred to as good health and coded as 0. A sensitivity analysis on non-imputed data (see Supplementary

table 1) found that using a consistent SRH measure (i.e. excluding half the sample at wave 1 and all respondents at wave 3) did not alter the findings in relation to the research hypothesis. More generally, a body of work supports the validity of such measures of self-assessed health which has been shown to predict future health events such as hospital admission and mortality (Idler and Benyamini, 1997; Mitchell, 2005).

2.2.2. Independent variables

2.2.2.1. Neighbourhood deprivation. Data on time-invariant neighbourhood deprivation were taken from the 2004 Index of Multiple Deprivation (IMD), a relative measure of deprivation based on 38 indicators across seven domains of deprivation giving a transformed weight summary in England (DCLG, 2007). The domains are income, employment, health and disability, education, skills and training deprivation, barriers to housing and services, living environment deprivation and crime. The 2004 IMD scores were matched to ELSA sample members at wave one by the data holder (the National Centre for Social Research) at the Lower-level Super Output Areas (LSOA) geographical units. LSOAs, an output geography from the 2001 Census, contain 1500 residents, on average (ONS, 2018). The neighbourhood deprivation score was categorised into quintiles for the descriptive analysis and standardised for the regression analysis.

2.2.2.2. Neighbourhood dissatisfaction. Time-invariant neighbourhood dissatisfaction (NS) was measured by creating a summed score of nine items asked in the self-completion questionnaire at wave 1 that assessed the sense of belonging to the area, perception of vandalism, loneliness, trustworthiness, safety, friendliness, unkindness, cleanliness and helpfulness. The responses were coded on a range between 0 and 6 and were reverse coded where necessary such that the highest score of 54 represents the highest level of NS. A Cronbach's alpha of 0.78 suggests there is unidimensionality in the scale. Previous literature has suggested there are at least two domains to NS: cohesion and disorder (Yang et al., 2002). Cohesion and disorder sub-domains did not have a higher level of internal consistency in this study and therefore we used the overall NS score in our analysis. The NS score was categorised into quintiles for the descriptive analysis and standardised for the regression analysis.

2.2.2.3. Measurement occasion. Survey waves were used as the time variable centred at wave 1 (i.e. wave was coded as 0). The timing between waves two years with waves 2, 3, 4, 5 and 6 coded as 1, 2, 3, 4, and 5 respectively.

2.2.3. Covariates

Time invariant measures for age, age squared, sex, education, wealth and years lived at current were taken at baseline. Time varying measures for employment status, depression, social support and couple status were taken at each wave. Covariates were chosen on the basis of the existing literature and availability in ELSA. To examine the effect of individual socioeconomic characteristics on SRH, measures of employment status, education and non-pension wealth were used. Employment status was categorised as retired (including spontaneously self-defined: semi-retired), employed, self-employed, and other (unemployed, looking after family and permanently sick). Education was measured by grouping respondents into high (degree or above), some (other qualification), and none (no qualifications) education. Wealth was measured in evenly distributed quintiles. A measure for years lived at current neighbourhood was derived by subtracting the year when the participants moved in by the year in which their interview was conducted (2002 or 2003).

Psychosocial factors included were social support and depression. The social support score was created from nine items which respondents answered regarding the support they received from their children, family and friends. The questions included "How much do they really understand the way you feel about things?". The responses to each item are coded into 0 "not at all" 1 "a little" 2 "some" 3 "a lot" and then summed, such that the highest score of social support is 27. A Cronbach's alpha of 0.81 suggests there is internal consistency in the scale. An eight-item version of the Center for Epidemiological Studies Depression Scale (CES-D) was used to determine depression in those who report yes to four or more items, reverse-coding the positively worded questions (Steffick, 2000).

2.3. Statistical analysis

To examine the change in poor health as older adults age, logistic growth models were fitted using a multilevel approach. Repeated measures across waves 1–6 (level 1) are clustered within individuals (level 2) who are clustered within wave 1 neighbourhoods (level 3). The 53,988 person-years are clustered among 10,469 individuals with an average of 5.2 person-years per individual. The individuals are clustered within 5189 LSOAs with an average of 2.0 individuals per LSOA. We model 10.4 individuals per LSOA in the analysis because of the repeated measures per individual. Models were fitted in a series of steps with random intercepts. Models testing for random slopes on IMD and NS scores across individuals did not converge using quasi-likelihood estimation but suggest there is variation in the slope of IMD, but not NS across individuals. The covariance between the slope and intercept suggests that those with a lower baseline SRH are more strongly affected by IMD and NS.

The first presented model predicts change in probabilities in poor health on wave by baseline IMD score, controlling for baseline age, age squared, and gender. The model includes a cross-level interaction between IMD and wave. The second model is an equivalent model for NS, excluding IMD score and including the NS score. Models 1 and 2 provide an age-gender adjusted association between poor health over time conditional on baseline neighbourhood deprivation and neighbourhood dissatisfaction, as well as variance estimates at the individual and neighbourhood level testing Hypotheses 1 and 2, respectively. A third model includes neighbourhood deprivation and dissatisfaction simultaneously, including an interaction between the two measures to test Hypotheses 3. The fourth, fifth and sixth models add individual SES factors, individual psychological factors and years lived at baseline neighbourhood, respectively. Models 6 was fitted excluding individuals who moved since wave one to test whether those continuously exposed to the same neighbourhood experience the same change in poor health. Only one in twenty sample members changed residential address from wave 1 to wave 6. The results were almost identical and are not presented here.

Multiple imputation by chained equations was used to replace missing values for item non-response within a wave (e.g. missing social support values at wave one) as well as longitudinal non-response between waves (e.g. individuals who responded at one wave but not another) for all variables used in the analysis. Data were transformed to long format (i.e. a row of data for each wave of data for each individual) and 100 imputed datasets were created. A row of data within a wave was not imputed if the individual was known to not have responded due to death at that wave. Data on mortality were matched by the Office for National Statistics for all consenting respondents. The outcome of this process is that there are complete observations for every individual with a baseline neighbourhood (10,469) unless they died, in which case they contribute to the total person years (53,988) as long as they are alive. A sensitivity analysis using the complete case sample showed the substantive findings were unchanged (see Supplementary table 2). Non-response sampling weights were used to adjust for individual non-response at baseline in the descriptive and statistical analysis.

All analysis were conducted using Stata 15 using the *melogit* command to fit multilevel models and *mi* command to produce values for missing cases.

Table 2
Regression log odds coefficients [95% confidence intervals] for poor vrs good self-rated health.

		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Fixed part						
	Wave	**0.08 [0.06,0.1]**	**0.08 [0.06,0.1]**	**0.08 [0.06,0.1]**	**0.06 [0.04,0.08]**	**0.06 [0.04,0.08]**	**0.06 [0.04,0.08]**
Neighbourhood dissatisfaction	NS z-score		**0.31 [0.25,0.38]**	**0.26 [0.19,0.32]**	**0.23 [0.17,0.29]**	**0.15 [0.09,0.21]**	**0.15 [0.09,0.21]**
	NS#wave		− 0.02 [− 0.03,0]	− 0.02 [− 0.03,0]	**− 0.02 [− 0.04,0]**	− 0.02 [− 0.03,0]	− 0.02 [− 0.03,0]
Neighbourhood deprivation	IMD z-score	**0.5 [0.44,0.56]**		**0.45 [0.39,0.51]**	**0.14 [0.08,0.2]**	**0.14 [0.08,0.2]**	**0.14 [0.08,0.2]**
	IMD#wave	0 [− 0.02,0.01]		0 [− 0.02,0.02]	0 [− 0.02,0.02]	0 [− 0.02,0.02]	0 [− 0.02,0.02]
	IMD#NS			− 0.03 [− 0.07,0.01]			
Age	Age centred	**0.08 [0.07,0.08]**	**0.08 [0.08,0.09]**	**0.08 [0.07,0.08]**	**0.05 [0.04,0.06]**	**0.05 [0.04,0.06]**	**0.05 [0.04,0.06]**
	Age centred^2	**0 [0,0]**	**0 [0,0]**	**0 [0,0]**	**0 [0,0]**	**0 [0,0]**	**0 [0,0]**
Sex	Male	Ref	Ref	Ref	Ref	Ref	Ref
	Female	− 0.01 [− 0.09,0.08]	0.03 [− 0.05,0.12]	0.01 [− 0.07,0.1]	**− 0.17 [− 0.26,− 0.09]**	**− 0.24 [− 0.32,− 0.15]**	**− 0.23 [− 0.32,− 0.15]**
Education	None				Ref	Ref	Ref
	Some				**− 0.36 [− 0.46,− 0.27]**	**− 0.33 [− 0.43,− 0.24]**	**− 0.33 [− 0.43,− 0.24]**
	Degree				**− 0.72 [− 0.89,− 0.55]**	**− 0.67 [− 0.84,− 0.51]**	**− 0.68 [− 0.85,− 0.51]**
Wealth	Least wealthy				Ref	Ref	Ref
	2				**− 0.35 [− 0.49,− 0.2]**	**− 0.3 [− 0.44,− 0.16]**	**− 0.32 [− 0.46,− 0.17]**
	3				**− 0.77 [− 0.93,− 0.62]**	**− 0.7 [− 0.85,− 0.56]**	**− 0.71 [− 0.86,− 0.56]**
	4				**− 1.13 [− 1.29,− 0.97]**	**− 1.03 [− 1.18,− 0.87]**	**− 1.05 [− 1.2,− 0.89]**
	Most wealthy				**− 1.43 [− 1.6,− 1.26]**	**− 1.3 [− 1.46,− 1.13]**	**− 1.31 [− 1.48,− 1.14]**
Employment status	Retired				Ref	Ref	Ref
	Employed				**− 0.55 [− 0.68,− 0.42]**	**− 0.53 [− 0.66,− 0.4]**	**− 0.53 [− 0.66,− 0.4]**
	Self-employed				**− 0.62 [− 0.83,− 0.42]**	**− 0.62 [− 0.82,− 0.42]**	**− 0.63 [− 0.83,− 0.42]**
	Other				**0.26 [0.15,0.37]**	**0.21 [0.1,0.33]**	**0.21 [0.1,0.33]**
Depression	Not depressed					Ref	Ref
	Depressed					**1.51 [1.41,1.61]**	**1.51 [1.41,1.6]**
Social support	Least support					Ref	Ref
	Middle					**− 0.14 [− 0.23,− 0.05]**	**− 0.14 [− 0.23,− 0.05]**
	Most support					**− 0.25 [− 0.36,− 0.14]**	**− 0.25 [− 0.36,− 0.14]**
Couple status	Not in couple					Ref	Ref
	In couple					0.08 [− 0.02,0.19]	0.08 [− 0.02,0.18]
Years lived at baseline address	Less than 1 year						**0.35 [0,0.69]**
	1–4 years						− 0.08 [− 0.22,0.07]
	5–9 years						− 0.14 [− 0.28,0]
	10–19 years						**0.11 [0,0.22]**
	20 or more years						Ref
	Constant	− 1.49 [− 1.58,− 1.41]	− 1.49 [− 1.58,− 1.4]	− 1.5 [− 1.59,− 1.41]	− 0.23 [− 0.37,− 0.08]	− 0.44 [− 0.61,− 0.27]	− 0.43 [− 0.61,− 0.25]
	Random part						
	LSOA	0.46 [0.34,0.63]	0.67 [0.54,0.84]	0.45 [0.33,0.61]	0.3 [0.2,0.45]	0.26 [0.17,0.4]	0.25 [0.16,0.39]
	Individual	2.44 [2.22,2.67]	2.36 [2.15,2.59]	2.39 [2.18,2.62]	2.17 [1.97,2.38]	1.95 [1.76,2.15]	1.94 [1.76,2.14]
	N	53,988					

IMD – index of multiple deprivation; NS – Neighbourhood dissatisfaction; z-score coefficients refer change in log-odds of self-rated for standard deviation unit change.
Bold fixed coefficients, p-value < 0.05.

3. Results

Table 2 displays the stepwise models. All models suggest significant random variation in poor health at the individual and neighbourhood levels. There was a predicted increase in the probability of poor health over time from fifth at baseline to a third by wave 6. Individuals residing in more deprived neighbourhoods at baseline were more likely to have poor health (model 1). For example, the predicted probability of poor health at mean age at the 75th percentile on the IMD distribution was 28%, compared with 16% at the 25th percentile. There was no change in the probability of poor health over time by IMD at baseline. Subjective ratings of the neighbourhood were also associated with poor health at baseline (model 2); the predicted probability of poor health at mean age at the 75th percentile on the neighbourhood dissatisfaction distribution was 28% compared with 18% at the 25th percentile. There was no change in the probability of reporting poor health over time by baseline NS.

When taking into account objective and subjective neighbourhood measures in the same model (model 3) there was a slight attenuation in the IMD estimate (10%) and a larger attenuation in the neighbourhood dissatisfaction estimate (16%). The objective (IMD) standardized estimate was stronger by 1.73 times compared with the subjective association estimate. Both estimates remained statistically significant in model 3. There was no evidence of effect modification of neighbourhood dissatisfaction on the relationship between neighbourhood deprivation and poor health, or vice versa. The interaction is therefore removed from subsequent models in the interest of parsimony.

The relationship between IMD and baseline poor health changed considerably after controlling for individual socioeconomic characteristics (model 4). The strength of the association between IMD and baseline poor health was further reduced by 69% on adjustment for employment status, education, and non-pension wealth, while a more modest attenuation of 12% was observed for neighbourhood dissatisfaction. The strength of the association between neighbourhood dissatisfaction and baseline poor health declined by 35% after controlling for psychosocial factors (model 5). Adjustment for length of time at current address did not alter the estimates for IMD or neighbourhood dissatisfaction on baseline poor health (model 6).

4. Discussion

This study supports evidence showing older adults who reside in more objectively deprived neighbourhoods are more likely to report worse health compared to people residing in less deprived neighbourhoods (Badland et al., 2013; Poortinga et al., 2007; Riva et al., 2007; Sundquist et al., 2004). Consistent with previous studies (Bowling and Stafford, 2007; Robert, 1999; Weden et al., 2008; Wen et al., 2006) the present findings showed that the strength of this association reduces considerably after controlling for individual SES, including education, wealth, and employment status. This supports Poortinga et al. (2007) finding that the adjustment of individual SES led to a reduction in the effect of neighbourhood deprivation on SRH by half. The current study estimates a two-thirds attenuation. Bowling and Stafford (2007) found that the relationship between neighbourhood affluence and SRH was explained when adjusting for individual SES. The difference compared with the current study may lie in our use of a measure of deprivation, rather than affluence, of neighbourhood SES. We find no evidence supporting our first hypothesis that change in poor health differs according to baseline neighbourhood deprivation, and this was consistent when analyses were limited to individuals who did not move home during the follow-up period. Thus, in later life, neighbourhood deprivation appears to maintain but does not compound inequalities in self-reported health.

The results find that higher neighbourhood dissatisfaction predicts poor health in older adults (Bowling and Stafford, 2007; Ellaway et al., 2001; Ivory et al., 2011; Oshio and Urakawa, 2012; Wilson et al., 2004). The association was robust, despite attenuation, after adjustment for individual psychosocial factors. This is consistent with Oshio and Urakawa (2012) who found that after adjusting for personality traits and sense of coherence there remained a statistically significant association between neighbourhood satisfaction and SRH. Also, research suggests that individuals with a positive perception about their neighbourhood's physical environment tend to report good SRH and decreased risk of depressive symptoms (Wilson et al., 2004). As older adults are more likely to be confined to their neighbourhoods due to decline in mobility and retirement, perceptions of neighbourhood environment may have a greater effect on their subjective health compared to more spatially mobile age groups (Yen et al., 2009). Yet there was no support for our second hypothesis that change in poor health over time varied according to baseline neighbourhood dissatisfaction.

There is no support for a neighbourhood effect from these analyses given the neighbourhood association with health was only evident at baseline and not as older adults age. An explanation for this null finding is that any potential damage of living in a deprived neighbourhood on subjective health has already taken place at earlier stages of the life-course. An alternative explanation is selection into neighbourhoods well before age 50 by individual characteristics not adjusted for in the current analysis or imperfectly measured, for example individual SES earlier in life (Jokela, 2014; Kravitz-Wirtz, 2016). This may explain why poor health is associated with baseline neighbourhood deprivation but not baseline neighbourhood deprivation over time. Our findings demonstrate how the bulk of neighbourhood effect research, which is cross-sectional, may misestimate neighbourhood effects because of these biases.

We found no evidence to support the notion that neighbourhood dissatisfaction moderates the relationship between neighbourhood deprivation and SRH. We hypothesised that living in a neighbourhood deemed objectively and subjectively deprived would be a double disadvantage. Few studies have investigated the effect of subjective neighbourhood characteristics on the association between objective neighbourhood characteristics and SRH. Poortinga et al. (2007) conducted a multilevel analysis which showed a significant association between neighbourhood deprivation, the perception of neighbourhood, and SRH. The relationship between neighbourhood deprivation and SRH was attenuated by neighbourhood perception and this was seen as an indication that neighbourhood perception is a mediator (Poortinga et al., 2007). Another study showed that subjective characteristics mediated the relationship between objective characteristics and SRH by conducting a mediation analysis through structural equation modeling (Weden et al., 2008). The results in this study support the Poortinga et al. (2007) finding that indicates an independence in the objective and subjective neighbourhood effect on subjective health. This suggests improving one will not undo the negative effect of the other.

Our analysis suggests that the baseline associations between SRH and neighbourhood deprivation and SRH and neighbourhood satisfaction may operate through different causal pathways. This is because the associations that each neighbourhood characteristic exhibits with SRH are attenuated by different control variables. The association between IMD and SRH is attenuated most on controlling for socio-economic position, while the association between dissatisfaction and SRH is most attenuated after controlling for social support. Thus our results suggest that individuals with low income tend to end up in deprived neighbourhoods and have poorer health outcomes due to both individual and area deprivation. Individuals with weak social support tend to live in areas in which they feel dissatisfied towards. Thus, while dissatisfaction is independently associated with SRH, much of the poorer health outcomes observed in areas of dissatisfaction flows from the poorer social connections that such individuals enjoy and that are considered to be damaging to health (Kawachi et al., 2008).

The key strength of this paper is that it uses a large and nationally representative sample of the older, private household population in England with rich longitudinal detail on their health and other

circumstances. The key contributions of the paper flow from our access to a special version of ELSA that contains details of the neighbourhood, enabling us to quantify the evolution of health throughout later life according to both subjective and objective neighbourhood characteristics. The combination of three data characteristics, including the rich survey information on respondents, the fine geographical detail, and the longitudinal information is relatively rare in neighbourhood effects research with most papers lacking at least one of these components. Yet all three components are necessary for studies that seek to provide a stronger evidence base for causal links between neighbourhood characteristics and health.

There are a number of limitations of this analysis which should be recognised. First, while we have controlled for a set of social and economic variables we cannot rule out the possibility that omitted variables would remove the area effects observed if included in our analysis. Such issues of neighbourhood selection are well documented in the literature. It may be that uncaptured markers of social disadvantage might drive movement into (or lack of movement out of) deprived areas. Similarly, while in this paper we suggest that greater neighbourhood dissatisfaction may lead to poorer health outcomes, we cannot completely rule out the reverse causality: that poorer health leads to a greater dissatisfaction with one's area, perhaps as a result of not participating fully in neighbourhood life. We were able to replace missing values using multiple imputation under the assumption of missing at random. There is the possibility we have not been able to explain the response bias related to our outcome and explanatory variables which may misestimate the relationship between neighbourhood and SRH. We also did not measure change in objective and subjective neighbourhood perception over time. Further research could explore this if these data become available. Perception measures are only available at waves 1 and 3 in ELSA and we were only able to match IMD at baseline due to restriction of our data linkage agreement. A further limitation relates to the modifiable areal unit problem where differing boundary specification might lead to different conclusions around area effects (Openshaw, 1977). It is worth noting that the self-defined aspect of neighbourhood suggests that this measure is likely to have meaning for individuals while LSOAs are the finest geography that could be used in line with our expectation that it is individual's immediate surroundings that are most important for experience of neighbourhood living and its association with health.

5. Conclusion

This study showed an association between neighbourhood deprivation, neighbourhood dissatisfaction, and poor health in older adults. Individuals living in more deprived areas and those more dissatisfied with their neighbourhood were more likely to report poor health at baseline. Individual socioeconomic factors reduced the strength of the association between neighbourhood deprivation and poor health, whereas psychosocial factors reduced the strength of the association between neighbourhood dissatisfaction and poor health. There was no change over 12 years in poor health by baseline neighbourhood deprivation or dissatisfaction. The study therefore provides no evidence to support that the association between neighbourhood and health strengthens in later life. We also find that area dissatisfaction does not moderate the relationship between neighbourhood deprivation and poor health. Only a few studies in the past have accounted for both objective and subjective characteristics of neighbourhood to measure their effect on SRH and none to our knowledge have analysed trajectories in health longitudinally. Both types of characteristics were included in this study to take into account the broader effect of neighbourhoods on health outcomes. The findings suggest neighbourhood deprivation and neighbourhood satisfaction operate through different causal pathways that each might be tackled by policymakers interested in reducing health inequalities through area-based initiatives.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.healthplace.2018.10.006.

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