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Spatial immobility and the dynamics of loneliness, social capital, and mental health during the COVID-19 pandemic

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ABSTRACT

Objectives: COVID-19 lockdowns and wider mixing restrictions severely disrupted people's lives with potentially acute implications for their mental health. This study examines how mixing restrictions affected people's loneliness and how far loneliness, in turn, can explain any impact of restrictions on psychological distress. In addition, the study explores whether local social capital (LSC) in residential communities buffered any impact of mixing restrictions on loneliness, and subsequently protected people's mental health, during the pandemic.
Study design: Individuals are drawn from three waves of the nationally representative COVID-19 UK Household Longitudinal Study (n = 24,481 person-observations). To measure the impact of social mixing restrictions, respondents are matched with daily community-level (Local Authority) spatial immobility data from Google COVID-19 Community Mobility Reports.
Methods: Fixed-effects longitudinal modelling is applied to address time invariant unobserved heterogeneity in estimates of the associations between spatial immobility, loneliness and psychological distress.
Results: Increasing spatial immobility is associated with increasing loneliness, which is linked with greater psychological distress. However, LSC moderates these associations. Spatial immobility has a weaker positive association with loneliness among individuals with higher LSC. It also has a weaker positive association with distress among higher-LSC individuals. LSC moderates the relationship between spatial immobility and psychological distress because individuals with higher LSC report less loneliness under conditions of increasing spatial immobility.
Conclusion: Spatial immobility increased loneliness, in turn, harming mental health. However, LSC protected individuals' mental health due to its buffering-effect against loneliness. Investing in communities to foster LSC is thus important for crisis-preparedness to minimise the harm of national crises on mental health.

1. Introduction

Studies demonstrate how mental health deteriorated significantly over the COVID-19 pandemic, especially during periods of lockdown and wider restrictions on social mixing.[1,2] This harm may have stemmed from multiple pathways, such as strained family relations, job loss, caregiving stresses, or difficulties in maintaining work/life balance.[3–5] However, one potentially critical pathway is increased feelings of loneliness. Loneliness constitutes negative feelings about the lack/loss of companionship stemming from a perceived mismatch between the quality/quantity of individuals' social relationships versus what they want.[6,7] Given mixing restrictions substantially reduced social connectivity, they likely had a significant impact on feelings of loneliness.[8–10] Greater loneliness, in turn, has been linked with the emergence of poorer mental health outcomes.[7,11–13] Accordingly, loneliness resulting from mixing restrictions could have had a significant knock-on effect on people's mental health.

If reduced levels of *overall* social connectivity from mixing restrictions worsened loneliness, undermining people's mental health, this raises a key question about what role social connectivity among the residents in people's *local* areas played during the pandemic, i.e., their local social capital (henceforth, LSC). LSC captures people's 'social networks [a structural component] and norms of reciprocity and trust [a cognitive component]' among neighbours, such as neighbourhood-ties, neighbour-trust, or volunteering.[14,15] Research shows both social network dimensions of LSC, as well as cognitive dimensions, such as neighbour-trust, can reduce loneliness, independent of overall social connectivity.[16,17]

Potentially, LSC could have protected individuals' mental health during the pandemic, cushioning the impact of mixing restrictions on

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their loneliness, by providing greater opportunities for social interactions and support. Mixing restrictions significantly restricted peoples' lives to their households and localities.[18] For many, neighbours therefore became the only available source of face-to-face interaction as well as social support, such as helping those struggling with care work and homeschooling, shopping for shielding vulnerable people, or checking on neighbours at risk of isolation.[19–21] Accordingly, access to LSC may have buffered (that is, moderated) how far mixing restrictions increased people's loneliness during the pandemic. If LSC protected individuals against the impact of mixing restrictions on their loneliness, then LSC may, in turn, have subsequently cushioned how far mixing restrictions harmed their mental health.[22,23] In other words, mixing restrictions may have had a weaker impact on mental health among individuals with more LSC because it cushioned the impact of such restrictions on loneliness.

Little research has directly tested how far loneliness can explain the impact of mixing restrictions on mental health, nor whether LSC cushioned the impact of restrictions on loneliness, subsequently protecting mental health.[19,24] This study seeks to fill this gap in the research by exploring several key research questions: how did mixing restrictions shape levels of loneliness? How far can loneliness explain any impact of mixing restrictions on psychological distress? Did LSC buffer the impact of mixing restrictions on loneliness? Did any cushioning by LSC on the impact of mixing restrictions on loneliness, in turn, reduce the impact of restrictions on psychological distress? In investigating these questions, the study aims to provide novel insights into: (a) the mechanisms (in particular, the role of loneliness) linking mixing restrictions to worsening mental health; (b) the protective role that LSC played during the pandemic; and (c) what mechanisms explain any buffering role of LSC for mental health during the pandemic. Through this analysis, the findings seek to provide important evidence on the efficacy of LSC for crisis-preparedness to minimise the harm of future large-scale crises on mental health.

2. Methods

2.1. Data

This study uses data from the nationally representative UK Household Longitudinal Study (UKHLS) COVID-19 panel survey, comprising a sub-sample of individuals from the UKHLS Mainstage data. The UKHLS Mainstage data is a random, stratified sample of adults (aged 16 and over) in UK households, based upon a proportionately stratified, equal probability (clustered) sample of residential addresses drawn to a uniform design throughout the UK. A two-stage processes was undertaken to select the sample of addresses.[25] Firstly, a random sample of postal sectors was selected to serve as the Primary Sampling Units (PSUs). Secondly, a random sample of addresses was selected within each PSU. The sample is designed to be representative of the UK adult population. The wave 1 (2009) to wave 9 (2017–18) response rate was approximately 70 percent. All respondents who participated in waves 8 (2016–18) and 9 (2017–19) of the Mainstage data were invited to participate in the COVID-19 study in April 2020 (48 percent response-rate) and were followed-up nine times during the pandemic (28 percent attrition between COVID-19 waves 1–9), via web-based surveying. More information on the data can be found in the survey documentation.[26]

Longitudinal weights are applied to correct for unequal selection probabilities/non-response. Robustness tests were undertaken, including running different modelling specifications (conditional logistic regressions with individual fixed effects) and using multivariate multiple imputation by chained equations (ten datasets), based on models using all key variables present in the models (including loneliness and psychological distress), to address potential bias from within-case missingness and complete case missingness (from panel attrition) (see below). The main analysis uses three waves of the COVID-19 study when data was gathered on LSC (neighbourhood networks/norms): wave 3 (June 2020), wave 6 (November 2020) and wave 8 (March 2021). Additional analysis of the volunteering dimension of LSC uses two waves: wave 4 (July 2020) and wave 8 (March 2021) when volunteering was asked. The data contains identifiers on the Local Authority Districts (LADs, average population: ~160,000 residents) in which respondents were living at the time of the surveys.

2.2. Measures

2.2.1. Loneliness, mental health and local social capital (LSC)

Loneliness is measured using a single item: 'In the last 4 weeks, how often did you feel lonely?' (3-category Likert scale of 'hardly ever or never', 'some of the time', and 'often'). Mental health is measured using the General Health Questionnaire-12 (GHQ-12), designed to identify psychological distress in the general population.[3,27] Individuals report the frequency they have experienced twelve psychological symptoms in the past few weeks, for example, depression or anxiety (e.g., 'been feeling unhappy and depressed'). The study uses the Likert scoring method, summing participants' scores across all 12-items (ranging from 0 to 36). Using the 'caseness' scoring approach returned substantively identical findings.

The data contains five questions capturing LSC (5-category Likert scales of 'strongly disagree' to 'strongly agree'): 'I think of myself as similar to the people that live in this neighbourhood', 'I regularly stop and talk with people in my neighbourhood', 'people in this neighbourhood can be trusted', 'people around here are willing to help their neighbours', and 'people in this neighbourhood generally don't get along with each other' (reverse coded). Testing shows the measures are highly related (factor analysis: minimum factor loadings>0.54, Eigen Value: 2.38; Alpha score: 0.81). A mean score of LSC is generated using the five measures, ranging from 1 (low) to 5 (high). The civic engagement dimension of social capital is measured by whether a respondent volunteered in the last 4 months (when first asked, in wave 4 (July 2020), this covers the period from the start of the pandemic (March 2020)).

2.2.2. Spatial immobility

To measure the impact of mixing restrictions we draw on spatial mobility data from Google Community Mobility Reports.[2,28] Google Mobility Reports use data from internet-connected devices using Google products. They provide a measure of the *change* in the duration of time people spent in residential settings in an area. The level of change is calculated from the daily amount of time people were spending in places of residence on each day of the pandemic compared to an equivalent pre-pandemic baseline day. Mobility data for each baseline day is constructed as the median time spent at home for each day of the week (Monday to Sunday) from a 5-week period from January 3rd to February 6th, 2020. Change in time estimates are therefore a positive/negative percentage, relative to the baselines, and are available for each spatial region (LAD) in the UK. For each day/region, we calculate rolling averages of spatial immobility based on the previous 7-days. The data are matched to respondents based on their interview-date/LAD of residence. Higher values signify people spending more time in residential spaces.

2.2.3. Covariates

Models include respondents' age, whether they live with a partner, employment status, whether there are children aged under 18 in the household, whether there are people aged over 70 in the household (excluding respondent), how frequently they work from home, and whether a respondent had COVID-19 related symptoms. Models using volunteering can also additionally adjust for subjective financial situation. All models also contain the 28-day COVID-19 death rate in LADs at the time of interview and survey-period dummy variables. The models will include individual-level fixed effects, meaning stable characteristics (e.g., gender, education, etc.) are omitted.

2.3. Modelling and analytic approach

Individual-level fixed effects models are applied to adjust for time invariant unobserved heterogeneity. As loneliness is a 3-category ordinal variable, we use Stata 17 to apply fixed effects ordered logistic regression modelling, reporting log odds.[29] When modelling GHQ-12, linear fixed effects regressions are used. This approach provides estimates of the average treatment effect on the treated.

The first analytic stage explores the spatial immobility/loneliness relationship. This involves modelling the association between spatial immobility and loneliness, and then exploring the mediating and/or moderating role of LSC in this relationship. An interaction-term between spatial immobility and LSC tests for any buffering (moderating) role of LSC. The second analytic stage explores the implications of the first stage findings for mental health (GHQ-12), modelling the association between spatial immobility and mental health; exploring whether LSC mediates and/or moderates this relationship; and examining how far loneliness can explain any relationships between spatial immobility, mental health, and LSC.

Analyses primarily focus on the neighbour networks/norms dimension of LSC. However, we also examine whether findings can be replicated using the civic/volunteering dimension of LSC (available in two waves). Given the networks/norms and volunteering dimensions of LSC appear in different waves of data they are modelled separately.

3. Results

The eligible sample consisted of 25,707 observations from 8569 adults who participated in all three key survey waves. Listwise deletion of missing data (<5 per cent) results in a balanced analytic sample of n = 24,481 person-observations. Of the analytic sample, 58 percent are female and average age is 51. Descriptive statistics of variables are in Supplementary-Analysis:S.1. N = 4575 individuals (n = 13,108 observations) are omitted from fixed effects ordered logistic regression models of loneliness because of no variation over time.

3.1. How spatial immobility and LSC are linked with loneliness

The first stage explores how mobility restrictions are linked with loneliness (Table 1). Model 1 demonstrates how increasing spatial immobility in respondents' communities (LADs) has a significant, positive association with individuals' likelihood of feeling lonely. Calculating the marginal effects of spatial immobility (based on Model 1, Table 1) shows a +1-percentage-point change in spatial immobility is associated with a +1-percentage-point increase in the probability individuals felt lonely 'some of the time'/'often' (compared to 'hardly ever/never').

Model 2 includes LSC in the model. There is little change in the spatial immobility coefficient, suggesting increasing loneliness with rising immobility is unlikely due to reductions in LSC. Model 3 then examines whether LSC buffers the association between spatial immobility and loneliness, via an LSC*spatial immobility interaction-term. This interaction is significant and negative, suggesting that the positive association between spatial immobility and loneliness is significantly weaker among respondents with higher LSC. Fig. 1 plots the marginal effects of spatial immobility on individuals' probability of feeling lonely (based on Model 3, Table 1). However, it estimates these marginal effects at different levels of LSC. At the lowest LSC, for every 1-percentage point increase in spatial immobility, respondents' probability of feeling lonely 'some of the time'/'often' increases by around 5-percentage points. As LSC increases, this positive association gets weaker and becomes non-significant.

Robustness tests suggest the moderating association between spatial immobility and LSC is not because LSC is acting as a proxy for other socio-demographic characteristics (Supplementary-analysis:S.2). We also tested one potential reverse causality explanation: that loneliness moderates the association between spatial immobility and LSC (rather than LSC moderating the immobility/loneliness association). However, this is not the case (Supplementary-analysis:S.3).

The previous analysis demonstrates the potential protective role of LSC as networks/norms among neighbours. Model 4 explores whether another form of LSC – volunteering – moderates the association between spatial immobility and loneliness, replicating Model 3 but substituting neighbourhood networks/norms for whether a respondent volunteered. The spatial immobility*volunteering interaction-term is significant and negative, suggesting spatial immobility had a weaker association with

Table 1
Spatial immobility, local social capital, and loneliness (fixed effects models).

	Model 1	Model 2	Model 3	Model 4
Outcome	Lonely	Lonely	Lonely	Lonely
Model type	FE ologit	FE ologit	FE ologit	FE ologit
Had COVID-19 symptoms	0.356	0.358	0.363+	−0.046
	(0.219)	(0.219)	(0.219)	(0.333)
baseline - Aged 15-34	ref.	ref.	ref.	ref.
Aged 35-49	0.461	0.489	0.469	0.865
	(0.695)	(0.696)	(0.686)	(1.046)
Aged 50-64	−0.024	0.012	−0.008	1.137
	(0.811)	(0.812)	(0.803)	(1.201)
Aged 65+	−0.317	−0.265	−0.305	1.202
	(0.895)	(0.896)	(0.886)	(1.319)
Not employed cf. Employed	0.351	0.364	0.351	−0.125
	(0.281)	(0.277)	(0.277)	(0.379)
Living with partner	−0.650*	−0.642*	−0.614*	−0.533
	(0.258)	(0.255)	(0.253)	(0.400)
Has children <18 in HH	−0.418	−0.413	−0.425	−0.294
	(0.331)	(0.330)	(0.328)	(0.515)
baseline - Never work from home	ref.	ref.	ref.	ref.
Sometimes	−0.070	−0.062	−0.065	−0.162
	(0.198)	(0.197)	(0.198)	(0.318)
Often	0.109	0.120	0.123	0.041
	(0.236)	(0.235)	(0.233)	(0.391)
Always	0.519+	0.532+	0.549+	0.486
	(0.312)	(0.311)	(0.310)	(0.348)
Has 1+ HH member aged 70+	−0.235	−0.233	−0.261	−0.506
	(0.443)	(0.444)	(0.456)	(0.471)
COVID-19 Death rate (Local Authority)	−0.012	−0.011	−0.010	0.381
	(0.063)	(0.063)	(0.063)	(0.420)
baseline - UKHLS COVID wave 3	ref.	ref.	ref.	
COVID study wave 6	0.478***	0.482***	0.484***	
	(0.091)	(0.091)	(0.091)	
COVID study wave 8	0.649***	0.656***	0.655***	
	(0.107)	(0.107)	(0.106)	
Spatial immobility (Local Authority)	0.087*	0.087*	0.427**	0.110
	(0.040)	(0.040)	(0.162)	(0.070)
Local social capital		−0.142	−0.07	
		(0.153)	(0.154)	
Spatial Immobility * Local social capital			−0.105*	
			(0.046)	
baseline - UKHLS Covid wave 4				ref.
COVID study wave 8				0.270
				(0.181)
Subjective financial situation				−0.159
				(0.142)
Volunteered				−0.910***
				(0.274)
Spatial Immobility * Volunteered				−0.161*
				(0.078)
N of waves	3	3	3	2
Observations	11373	11373	11373	5906

Notes: ***p < .001, **p < .01, *p < .05, + p < .10; UKHLS Covid study waves 3, 6 and 8; standard errors in parentheses; FE = fixed effects; ologit = ordered logistic regression; volunteering analysis (waves 4 and 8).
Models 1-4 apply fixed effects ordered logistic regression modelling (standard errors clustered at Local Authority District level); coefficients are log odds; loneliness = 4-point scale; significance value at 95%; time-invariant variables (e.g., gender) as dropped from the fixed-effects model.

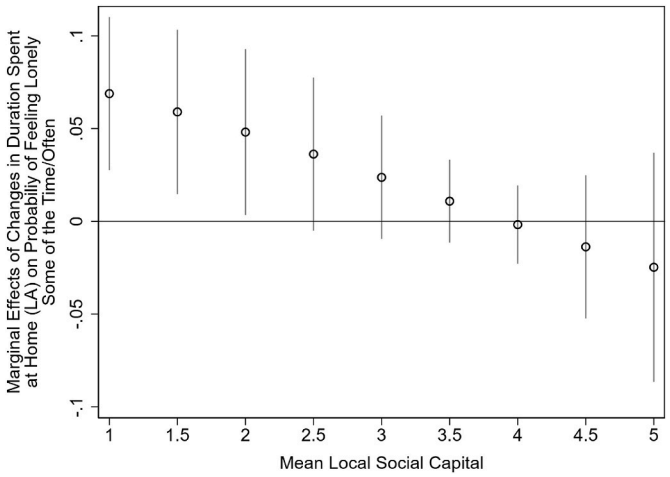

Fig. 1. Marginal effects of spatial immobility on loneliness across levels of local social capital *Notes:* showing 95 % confidence intervals; based on Model 3, Table 1.

loneliness among volunteers during the pandemic. Multiple imputation was applied to address potential bias from missingness, which returned substantively similar findings (Supplementary-analysis:S.4 and S.5).

3.2. How spatial immobility, loneliness, and LSC are linked with mental health

The second stage explores how the dynamics of spatial immobility, LSC and loneliness are linked with mental health (GHQ-12), where higher values equal greater psychological distress (Table 2). Model 1 demonstrates that spatial immobility has a significant, positive association with GHQ-12. Model 2 then includes LSC in the model to examine whether LSC mediates this association. However, there is little change in the immobility coefficient, suggesting changes in LSC cannot explain changes in distress.

Model 3 tests how far loneliness can account for the positive association between spatial immobility and GHQ-12 by adding loneliness into the model. Firstly, loneliness is strongly linked to higher GHQ-12. Secondly, the coefficient for spatial immobility is reduced by 17 per cent, suggesting part of the positive spatial immobility/GHQ-12 relationship is explained by more loneliness. Model 4 then tests whether LSC moderates the relationship between spatial immobility and GHQ-12 (as observed for loneliness). It removes the measure of loneliness from the model and includes an interaction-term between LSC and spatial immobility. The interaction-term is negative and significant, suggesting spatial immobility has a weaker positive relationship with GHQ-12 among respondents with higher LSC.

This moderating relationship is demonstrated graphically in Fig. 2, which plots predicted margins of GHQ-12 scores across percentiles of spatial immobility (1st to 99th). However, this association is subdivided between respondents with low LSC (10th percentile) and high LSC (90th percentile) (based on Model 4, Table 2). It demonstrates how spatial immobility has a positive association with GHQ-12 among low-LSC individuals but no significant association among high-LSC individuals.

One reason spatial immobility may be associated with larger increases in GHQ-12 among individuals with lower LSC is because they are more likely to experience loneliness under such conditions (as observed above). Model 5 (Table 2) replicates Model 4 but includes loneliness in the model. The spatial immobility*LSC interaction-term is reduced by 29 per cent and rendered non-significant. Increasing spatial immobility therefore appears linked with increasing GHQ-12 among individuals with lower LSC, in part, because their loneliness increased more.

Again, testing showed the associations remain robust for spuriousness and some reverse causality explanations (Supplementary-analysis:S.6 *and* Supplementary-analysis:S.7). We also test whether volunteering has a similar moderating relationship between spatial immobility and mental health. Model 6 replicates Model 4 but includes an interaction-term between volunteering (instead of networks/norms) and spatial immobility. The interaction-term is negative and significant (although only at the $p < .1$ level), suggesting immobility has a somewhat weaker positive association with GHQ-12 among volunteers. Model 7 then tests whether loneliness can explain this moderating association by adding loneliness into the model, which reduces the interaction-term by 25 per cent and renders it non-significant, suggesting lower loneliness explains why spatial immobility has a somewhat weaker association with GHQ-12 among volunteers. Applying multiple imputation to address potential bias from missingness returns substantively similar findings, although the interaction-term between spatial immobility and volunteering is non-significant for predicting GHQ-12, suggesting this association is more sensitive to modelling specification (Supplementary-analysis:S.8 and S.9).

4. Discussion

This study applied a novel measure of spatial immobility to explore how social mixing restrictions during the COVID-19 pandemic were linked with feelings of loneliness, how these processes shaped mental health, and the role LSC played in these relationships, especially as a buffering/protective factor. As expected, where spatial immobility in an area increased during the pandemic, individuals' loneliness also increased. This link between spatial immobility and loneliness, in turn, had implications for people's mental health. As prior work demonstrates, increasing spatial immobility was associated with greater psychological distress.[2] This study shows that part of the reason distress increased with greater mixing restrictions is due to increasing rates of loneliness among people, although a significant relationship remains suggesting other mechanisms are at work. However, importantly, the study demonstrates that the positive relationships between spatial immobility and both loneliness and psychological distress are conditional on individuals' LSC, particularly the social norms/networks in their neighbourhood.[22,23] While individuals with low LSC saw both their loneliness and psychological distress significantly increase as spatial immobility increased, those with higher LSC saw only marginal changes. In addition, testing suggests that a key reason why spatial immobility had a weaker association with psychological distress among high-LSC individuals is because they experienced less loneliness.

LSC therefore appears to have acted as a key buffering factor, reducing the impact of spatial immobility on loneliness, in turn, reducing the impact of immobility on mental health. As discussed, this may be because where LSC increased during the pandemic, it provided ties for interaction and sources of support when individuals were disconnected from wider networks. In addition, a sense of neighbourhood belonging and trust may have provided psychological support against reduced social connectivity.[22,30] Similar, albeit somewhat weaker buffering-relationships, were found for volunteering during the pandemic.

This study contributes to the wider literature on mental health during the pandemic. Firstly, it provides direct evidence that a key driver of poorer mental health during the pandemic was increasing rates of loneliness in response to social restrictions on mixing. Secondly, the findings provide important evidence of the buffering role LSC can play for wellbeing in the face of crises, such as the pandemic,[5,22,23] but also other crises, such as natural disasters.[31,32] Thirdly, the findings provide insights into the link between LSC and social/mental wellbeing. In particular, LSC becomes particularly important for people's wellbeing when experiencing greater adversity, in this case, greater mobility restrictions. When increases in spatial immobility were smaller, LSC played a weaker cushioning role, suggesting LSC might become a surrogate for social support when access to wider networks is curtailed.

There are several limitations. Firstly, the Google spatial mobility

Table 2
Spatial immobility, local social capital, loneliness, and psychological distress (fixed effects models).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Outcome	GHQ-12	GHQ-12	GHQ-12	GHQ-12	GHQ-12	GHQ-12	GHQ-12
Model type	FE linear	FE linear	FE linear	FE linear	FE linear	FE linear	FE linear
Had COVID-19 symptoms	0.393	0.434	0.339	0.457	0.356	0.949	0.910
	(0.413)	(0.409)	(0.357)	(0.407)	(0.355)	(0.651)	(0.574)
baseline - Aged 15-34	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Aged 35-49	0.639	0.672	0.814	0.639	0.789	1.010	0.594
	(0.993)	(1.031)	(0.959)	(1.038)	(0.965)	(1.318)	(1.072)
Aged 50-64	1.165	1.247	1.532	1.204	1.499	1.185	0.705
	(1.104)	(1.139)	(1.073)	(1.147)	(1.080)	(1.428)	(1.224)
Aged 65+	0.335	0.531	0.953	0.451	0.893	1.549	1.097
	(1.211)	(1.242)	(1.174)	(1.249)	(1.180)	(1.508)	(1.307)
Not employed cf. Employed	−0.139	−0.095	−0.372	−0.126	−0.392	0.023	0.266
	(0.476)	(0.463)	(0.455)	(0.461)	(0.453)	(0.506)	(0.475)
Living with partner	−0.197	−0.163	0.078	−0.153	0.086	0.749	0.831+
	(0.334)	(0.328)	(0.318)	(0.328)	(0.318)	(0.505)	(0.459)
Has children <18 in HH	−0.473	−0.513	−0.419	−0.532	−0.433	−1.508+	−1.274
	(0.609)	(0.617)	(0.547)	(0.618)	(0.548)	(0.858)	(0.866)
baseline - Never work from home	ref.	ref.	ref.	ref.	ref.	ref.	ref.
Sometimes	−0.424	−0.397	−0.441	−0.404	−0.446	0.595+	0.684+
	(0.293)	(0.292)	(0.301)	(0.291)	(0.300)	(0.355)	(0.355)
Often	−0.505	−0.472	−0.627+	−0.475	−0.628+	0.391	0.388
	(0.316)	(0.316)	(0.329)	(0.315)	(0.328)	(0.476)	(0.474)
Always	−0.679+	−0.671+	−0.898*	−0.667+	−0.894*	0.424	0.176
	(0.370)	(0.367)	(0.416)	(0.369)	(0.418)	(0.447)	(0.434)
Has 1+ HH member aged 70+	−0.118	−0.147	−0.052	−0.152	−0.056	−0.569	−0.292
	(0.367)	(0.369)	(0.332)	(0.371)	(0.334)	(0.696)	(0.577)
28-Day COVID-19 Death rate (Local Authority)	−0.128	−0.130	−0.136	−0.129	−0.134	−0.111	−0.227
	(0.103)	(0.104)	(0.097)	(0.104)	(0.097)	(0.287)	(0.277)
baseline - UKHLS COVID wave 3	ref.	ref.	ref.	ref.	ref.		
COVID study wave 6	0.563***	0.617***	0.456**	0.617***	0.457**		
	(0.152)	(0.153)	(0.147)	(0.152)	(0.147)		
COVID study wave 8	0.115	0.185	−0.021	0.182	−0.023		
	(0.153)	(0.153)	(0.146)	(0.153)	(0.146)		
Spatial immobility (Local Authority)	0.115*	0.118*	0.102+	0.590*	0.439+	0.178	0.130
	(0.056)	(0.056)	(0.055)	(0.260)	(0.253)	(0.109)	(0.089)
Local social capital		−0.951***	−0.910***	1.084	0.542		
		(0.247)	(0.232)	(0.991)	(0.970)		
baseline - Loneliness: Hardly ever or never							
Some of the time			2.616***		2.614***		2.438***
			(0.194)		(0.194)		(0.225)
Often			6.194***		6.168***		7.642***
			(0.582)		(0.581)		(0.583)
Spatial Immobility * Local social capital				−0.142*	−0.102		
				(0.072)	(0.070)		
baseline - UKHLS COVID wave 4						ref.	ref.
COVID study wave 8						0.225	0.136
						(0.253)	(0.200)
Subjective financial situation						−0.571*	−0.496*
						(0.223)	(0.216)
Volunteered						1.426	1.225
						(1.135)	(1.122)
Spatial Immobility * Volunteered						−0.165+	−0.124
						(0.097)	(0.093)
Constant	10.853***	13.808***	12.421***	7.105+	7.640*	10.350***	9.478***
	(1.190)	(1.444)	(1.357)	(3.758)	(3.670)	(1.700)	(1.411)
N of waves	3	3	3	3	3	2	2
Observations	22909	22909	22909	22909	22909	15084	15084

Notes: ***p < .001, **p < .01, *p < .05, + p < .10; UKHLS Covid study waves 3, 6 and 8; standard errors in parentheses; FE = fixed effects; volunteering analysis (waves 4 and 8).
Models 1-7 apply linear fixed effects regression modelling (standard errors clustered at Local Authority District level); coefficients are ordinary linear effects; GHQ = ranges from 0-36 points; significance value at 95%; time-invariant variables (e.g., gender) as dropped from the fixed-effects model.

data do not provide complete coverage of all individuals but only those with internet-connected devices or using Google products. Given the demographics of this group may differ from the general population (e.g., younger, higher incomes), spatial immobility estimates could be biased towards the pandemic-behaviour of these groups. In addition, the fixed, 5-week pre-pandemic baseline period the reports use to estimate changes in mobility means changes may be a product of both the pandemic but also seasonality-effects.

Secondly, while the individual-level fixed effects modelling approach helps address time invariant unobserved heterogeneity, it cannot address time variant unobserved heterogeneity, and omitted variables may still bias findings. In addition, results may still be biased by reverse causality. Several tests were also conducted suggesting that the moderating role of LSC between spatial immobility and mental health/loneliness is not solely a consequence of mental health/loneliness moderating the link between spatial immobility and LSC. However, the individual-level associations between loneliness, GHQ-12 and LSC could be driven by reverse causality or have bidirectional

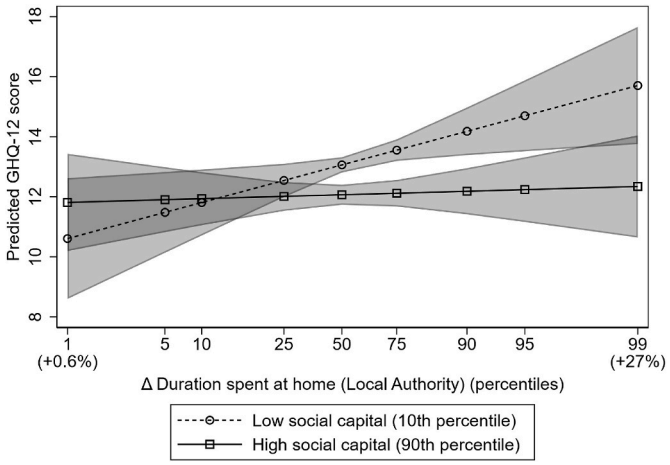

Fig. 2. Predicted GHQ-12 scores across levels of spatial immobility in an area by level of LSC *Notes*: showing 95 % confidence intervals; based on Model 4, Table 2; Percentages beneath the 1st and 99th percentiles represent percentage change in amount of time spent in residential locations.

relationships.[13] Lastly, while the UKHLS COVID-19 study data is representative of the UK adult population, allowing us to generalise to all adults in the UK, it does not contain groups who were particularly at risk during the pandemic, such as nursing home residents. Future research, able to examine the protective role of LSC for groups at particularly risk, is required to understand its efficacy for protecting such vulnerable groups.

In sum, this study demonstrates the harmful effects that mixing restrictions had on people's loneliness and subsequent mental health. However, it also shows the key role LSC played in cushioning this harm. Investing in communities to foster and maintain LSC is thus important in any crisis-preparedness to minimise the harm of national crises.[33]

Author statements

Ethical approval

The research received funding from the Economic and Social Research Council. Informed consent to (a) participate in the study and (b) for data to be published was attained by the data providers - the University of Essex, Institute for Social and Economic Research - when the data were collected (see User Guide for http://doi.org/10.5255/UKDA-SN-6614-19). The research was reviewed by the University College London ethics committee (ref.: 1837).

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data used in this study are from the University of Essex, Institute for Social and Economic Research. (2021). Understanding Society: COVID-19 Study, 2020–2021. [data collection]. 11th Edition. UK Data Service. SN: 8644, DOI: http://doi.org/10.5255/UKDA-SN-8644-11. Local Authority District spatial identifiers were provided by University of Essex, Institute for Social and Economic Research. (2023). Understanding Society: COVID-19 Study, 2020–2021: Special Licence Access, Census 2011 Lower Layer Super Output Areas. [data collection]. 7th Edition. UK Data Service. SN: 8663, DOI: http://doi.org/10.5255/UKDA-SN-8663-7. These data are restricted access and require a separate application. Spatial mobility data was downloaded from Google's COVID-19 Community Mobility Report: https://www.google.com/covid19/mobility/.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2025.105979.

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