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# Neighbourhood effects, local crime and mental health: Longitudinal analyses over the life course

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## Author's Declaration

I declare that this thesis has been composed solely by myself and that it has not been submitted, either in whole or in part, in any previous application for a degree. Except where stated otherwise by reference or acknowledgment, the work presented is entirely my own.

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## Abstract

Mental health conditions are major contributors to global disability and suffering, with a substantial social and economic burden. Besides well-established individual-level biopsychosocial determinants, emerging literature emphasises that social and physical features of the residential environment are associated with mental health. However, there is a limited understanding of how, where and for whom neighbourhood matters for mental health, partly because of the methodological shortcomings of existing literature. This thesis takes a longitudinal approach to examine the links between place-based factors, in particular neighbourhood crime, and anxiety, depression and psychosis.

A systematic review and meta-analysis on the association between local crime and mental disorders sets the context for the thesis. Based on 50 studies meeting the inclusion criteria, random-effects meta-analyses indicated higher risk of depression and psychological distress in high crime areas; for anxiety and psychosis there was only limited evidence. Associations varied by study design (longitudinal versus cross-sectional), type of crime measurement (perceived versus objective) and between different age groups. Importantly, the review identified research gaps, which were the focus of the following chapters. The thesis was structured around four longitudinal investigations, two utilizing perceived and two objective neighbourhood measurements.

First, available evidence in the field is limited to a few countries and there is no information on country-level heterogeneity. Data on perceived neighbourhood conditions and depression from 16 countries were utilised across three ageing cohorts (English Longitudinal Study of Ageing; Health and Retirement Study; Survey of Health, Ageing and Retirement in Europe [SHARE]) capturing adults aged 50 and over (n=32,531). Findings indicated elevated risk of depression amongst participants living in an area with perceived neighbourhood disorder (including crime) or with lack of social cohesion. Further analyses uncovered cross-level interactions by income

inequality, population density and air pollution for social cohesion and by forest coverage for neighbourhood disorder.

Second, neighbourhood effects might be determined by vulnerability build up over the life course; however, no information is available on the long-term impact of childhood stressors, a sensitive period in human development. Prospective and retrospective data on adults aged 50 and over (n=10,328), were analysed from the SHARE survey. In addition to a higher risk of depression when living in areas with perceived neighbourhood nuisances (including crime), and lower in areas with good access to neighbourhood services, childhood socioeconomic conditions modified neighbourhood effects. Older adults who grew up in better childhood circumstances benefited more from neighbourhood resources, but they were at higher risk of depression when exposed to neighbourhood problems.

Third, there is a lack of understanding of different neighbourhood crime and mental health associations across psychiatric conditions. A large data-linkage study (Scottish Longitudinal Study [SLS]), on small area-level crime rates and prescribed psychotropic medications was carried out (n=129,945). Findings indicated higher risk of antidepressants and antipsychotics, but not anxiolytics medications in high crime areas. Moreover, there was higher risk of antidepressants prescriptions among adults aged 24-53 in 2009, antipsychotics among men aged 44-53 in 2009, and among those in the middle of the social ladder, when living in high crime areas.

Fourth, although changing levels of neighbourhood exposure may help in understanding the causal relationship between context and health, very few studies have utilised repeated measurements of small area-level crime. Analysis based on the previous study (SLS) with additional linkage for three consecutive area crime measurements were carried out, to explore the association of changing crime rates with self-reported mental illness and prescribed medications among residential stayers and movers (n=112,251). Recent increase in crime exposure was associated with mental health problems among stayers aged 16-30 (self-reported mental illness, antidepressants), and among movers aged 31-45 (self-reported mental illness, antipsychotic medication). After excluding individuals with pre-existing mental

health conditions, findings suggested causation for the former, and health selective migration for the latter group.

Neighbourhood crime and other contextual factors in the residential area are significant determinants of mental health, but associations differ by childhood and adult socioeconomic conditions, across sex and age groups, and between anxiety, depressive and psychotic disorders. Place-based interventions aimed at reducing crime, supporting social cohesion and allocating targeted mental health preventions and services in the vicinity of high crime areas, may have long-term benefits for residents' mental health, especially for those more vulnerable. Future research should investigate the relationship between area stressors and mental health by exploring direct and indirect pathways, studying crime effects at different geographical levels, and applying the life course framework.

## Lay summary

Mental health problems are common, causing emotional suffering for affected individuals and a substantial economic burden for society. We know that living in adverse residential areas is likely to be a factor affecting mental disorders. This work looked at how neighbourhood stressors, especially local crime rates, were linked to common (anxiety, depression) and more severe (psychosis) mental disorders. At the beginning of the thesis, a systematic review and meta-analysis was conducted, which suggested that although depression and distress are more common in high crime areas, there are gaps in our knowledge. I addressed these by utilizing several longitudinal datasets, which follow the same individuals over time and provide stronger support for a potential causal relationship.

- First, based on data from 16 high-income economies, analyses confirmed that the relationship between perceived neighbourhood problems (including crime), lack of social cohesion and later life depression slightly varied across countries. Differences could be, for example, explained by population density: in countries where people lived closer to each other, the lack of social cohesion was more detrimental for mental health.
- Second, although childhood is crucial in human development, we do not know whether stressors in this age determine how people react to their residential environment in later life. Data on older European adults highlighted that coming from a more advantaged childhood background was more beneficial for mental health if one lived in an area with good access to services; but it was linked to depression when reporting more problems in the neighbourhood (e.g. crime).
- Third, neighbourhood crime may be linked to different mental health conditions differently. Data on Scottish adults linked with information on prescribed medications suggested higher risk of having antipsychotics prescribed among middle-aged men, and antidepressants among younger

adults if they lived in high crime areas. Anxiolytics were not linked to neighbourhood crime.

- Fourth, not only living in adverse neighbourhoods might cause mental health problems but also people with existing mental disorders can move to disadvantaged areas. Using the same Scottish dataset, findings showed that rising crime in the neighbourhood increased the risk of antidepressant prescriptions among young stayers. However, middle-aged adults with antipsychotic medications were more likely to move to higher crime neighbourhoods.

This work can contribute to the public health priorities of the Scottish Government aiming to support resilient, safe and healthy communities. First, reducing crime and other stressors in residential neighbourhoods using complex area-based approaches (e.g. area rehabilitation) may have benefits for population mental health. Also, providing better access to neighbourhood amenities and supporting community cohesion can contribute to healthy ageing. Second, prevention of mental health problems in high crime areas, especially in the first half of the life course or among those more vulnerable, could reduce the burden of mental disorders. Finally, allocating mental health services in the vicinity of high crime areas may improve health and social outcomes of those suffering from mental disorders, and reduce the associated burden on communities.

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## Abbreviations

ACE, adverse childhood experience;

CES-D, Center for Epidemiological Studies Depression Scale;

CHP, childhood health problem;

CI, confidence interval;

CMD, common mental disorder;

CSC, childhood socioeconomic condition;

DSM, Diagnostic and Statistical Manual of Mental Disorders;

ELSA, English Longitudinal Study of Ageing;

GP, general practitioner;

HRS, Health and Retirement Study;

ICD, International Classification of Diseases;

IPD, individual participant data;

NHS, National Health Service;

OR, odds ratio;

SHARE, Survey of Health, Ageing and Retirement in Europe;

SIMD, Scottish Index of Multiple Deprivation;

SLS, Scottish Longitudinal Study;

UK, United Kingdom;

WHO, World Health Organization.

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# CHAPTER 1

# 1. Introduction

## 1.1 Chapter overview

The large and increasing burden of mental health problems constitutes a serious public health, societal and economic concern worldwide.[1,2] In high-income countries more than 25% of the people are affected at least once during their lives by a mental health condition,[3,4] leading to a total economic burden of over 4% of the national Gross Domestic Product.[5] To acknowledge this global burden, the United Nations has included mental health in the Sustainable Development Goals emphasising the need for mental health becoming part of the universal health coverage worldwide.[6] Still, there is disproportionate public funding in mental health care provision and research, with national policy slowly taking measures to address treatment gap and prevention needs.

Mental disorders are a heterogeneous group of conditions with complex multifactorial aetiology. While substantial amount of research addresses individual-level determinants, less is known about how contextual factors may contribute to mental well-being. Contextual determinants at local- or at macro-level are modifiable and present opportunities for prevention and intervention without directly involving individuals.[7] Local or neighbourhood stressors such as area-level crime rates and neighbourhood disorder have been linked to health outcomes over the last decades. Still, existing literature exhibits methodological constrains and theoretical gaps on how, where and for whom contextual factors impact mental health. Addressing these limitations while exploring the relationship between mental health and crime in the residential area is the main focus of this dissertation.

## 1.2 Defining mental health

In 1946, the founding Member States of the World Health Organization (WHO) declared that the highest attainable standard of health is a fundamental right of every human being and an inevitable basis for worldwide peace and security. Health integrates physical, mental and social components.[8] As the original concept of mental health, proposed by WHO,[9] has been criticized for being strongly influenced by Anglophone cultural values (e.g. positive functioning as the key component of mental health),[10] this thesis operates with a broader and more inclusive definition:

> *"Mental health is a dynamic state of internal equilibrium which enables individuals to use their abilities in harmony with universal values of society. Basic cognitive and social skills; ability to recognize, express and modulate one's own emotions, as well as empathize with others; flexibility and ability to cope with adverse life events and function in social roles; and harmonious relationship between body and mind represent important components of mental health which contribute, to varying degrees, to the state of internal equilibrium.(p. 231-32)[10]"*

Although the majority of the population is usually free of mental disorders, they do not inevitably feel mentally healthy. Current research differentiates between a psychopathological or negative (e.g. mental disorders) and a more wellbeing-oriented or positive aspect of mental health. Rather than a single continuum, they are correlated axes, with relatively few individuals (20%) being mentally healthy even in the complete absence of diagnosable psychiatric disorders.[11] This dissertation follows the psychopathological concept of mental health in line with the overwhelming majority of research in health geography and epidemiology.

## 1.3 The global burden of mental disorders

Mental health is not only a human right but also a public good, crucial to sustainable development.[2,6] To acknowledge the substantial diseases burden and linked economic costs, mental health has been included in the Sustainable Developmental Goals of the United Nations in 2015, endorsed by all member states.[6]

### 1.3.1 Diseases burden

According to the Global Burden of Diseases study, in 2016 worldwide 18.6% of years lived with disability were due to mental health and substance use disorders, making them the leading causes of disability among all health conditions.[1] Because of the different age structure and epidemiologic profile of the population (i.e. low prevalence of communicable and high of non-communicable diseases), this figure is even more pronounced in high-income economies: in the United Kingdom (UK), 28% of lost years caused by disability are attributable to mental health and substance use disorders.[12]

While mental health associated disability is widely recognised (i.e. years lost due to disability), the impact on mortality (i.e. years of life lost due to premature mortality) is often overlooked as individuals with mental disorders usually do not die directly of their condition.[13] However, mental disorders can contribute to morbidity and mortality:

- Mental disorders are associated with behavioural risk factors of mortality such as drug and alcohol use, smoking, physical inactivity or unhealthy diet.[13]
- Mental disorders affect cognitive functioning, e.g. patients with major depression are more likely to present clinically relevant cognitive deficits, affected visual learning, memory and executive functions.[14]
- Mental disorders are prevalent in clinical groups (e.g. patients with diabetes, stroke or cardiovascular events) and increase the risk of developing more severe physical health outcomes leading to higher mortality due to natural causes.[13,15,16]
- Mental disorders increase the risk of unnatural causes of mortality. Individuals with depression have 20 times, with schizophrenia 13 times and with anxiety disorders 3 times higher risk of dying of suicide, in comparison to the general population.[17]

The total effect of mental disorders on mortality is attributable to approximately 8 million annual deaths and leads to an average life loss of 10 years among affected

individuals.[13] More importantly, the mortality gap between people with and without mental disorders has increased since the 1970s, indicating that the former group could not fully benefit from worldwide rising life expectancy.[13]

However, mental disorders are manageable and (in several cases) preventable conditions. While pharmacotherapy and psychotherapy are the two main pillars of treatment,[15,18] there is evidence on successful prevention programmes reducing the incidence of psychiatric illnesses.[15,19] For example, a meta-analysis on randomised controlled trials indicated that preventive interventions can reduce the onset of major depression by 21%.[20] Despite available evidence on treatment and prevention, the gap between the number of individuals in need and those in treatment is large;[21] and prevention programmes are often not translated into 'real-world effects'.[2]

### 1.3.2 Economic burden

Mental disorders are a major economic challenge, generating not only direct costs materialised in the health care system through inpatient and outpatient care, but also indirect costs due to reduced ability to work or early retirement.[5,22] On the European level, in 2010 the total costs of all brain disorders were estimated at 800 billion EUR, more than the amount of all cardiovascular diseases, cancer, and diabetes together.[22] The total cost of all mental disorders ranges annually between 70 and 100 billion GBP in the UK,[5] and approximates 10.7 billion GBP for Scotland;[23] affecting a significant proportion of the national Gross Domestic Product (~4.5%).[5] However, these estimations might be rather conservative not taking into account mental health associated mortality (1.3.1).

Despite the substantial diseases and economic burden, in the UK only 13% of the total National Health Service spending goes into mental health care.[24] There is also a lack of public investments in research:[25] while the UK spends on average 115 million GBP annually on mental health research, 9.75 GBP per affected individuals, the total public spending on cancer research is approximately five times higher. Taking into account

the smaller number of people suffering from cancer, 160-times more funding per patients (1571 GBP) goes into cancer in comparison to mental health research.[25]

## 1.4 Depression, anxiety and psychotic disorders

Although mental disorders are a heterogeneous group of conditions with different symptoms, severity, psychopathology and treatment needs, research on the contextual determinants of mental health overwhelmingly focuses either only on depression[26] or on psychological distress,[27] or do not differentiate appropriately between conditions.[28] As this thesis will propose condition-specific conclusions, it is important at this point to provide a short introduction on anxiety, depression and psychotic disorders, the main outcomes of this work.

### 1.4.1 Common mental disorders: depression and anxiety

A substantial part of the mental health burden is associated with depressive and anxiety disorders, which are often called together as common mental disorders (CMDs). They are generally marked by emotional or psychological distress, problems in daily functioning and significant impairments in quality of life.[24] Moreover, CMDs share similar psychopathology[29,30] and are highly comorbid: about 60% of individuals with depression report lifetime history of anxiety disorders.[31]

#### *1.4.1.1 Depressive disorders*

Unipolar depression (ICD-10 [International Classification of Diseases, 10th Edition]: F32-33; excluding depression with psychotic features [F32.3; F33.3]) is characterised by negative changes in mood, interests and pleasure, and accompanied by a range of cognitive, vegetative and behavioural symptoms, causing significant distress for affected individuals.[15,29] Cognitive changes include reduced attention, mental slowing,[29] and negative views about oneself, the world and the future.[32] Behavioural and physical symptoms comprise irritability, social withdrawal, fatigue, diminished activity, tearfulness, lack of libido, changes in sleep patterns and in appetite, and self-harm or suicide attempts.[29] The prevalence rate of major depression varies between

countries; the average 12-month prevalence is 5-6% worldwide, while approximately 11-15% of the population suffers at least once during their lifetime under this condition.[33] Epidemiological studies point to an average onset in the mid 20-ies[33] and show consistently higher rates of depression in women than in men (female-male ratio of 2:1).[15,34] The prevalence of depression varies largely across the life course with a modest decrease after the peak in young adulthood,[15] and increase again among the oldest old (80+).[35]

#### *1.4.1.2 Anxiety disorders*

Anxiety disorders (ICD-10: F40-43) are one of the most common mental health conditions and include generalised anxiety disorder, social anxiety disorder, post-traumatic stress disorder, panic disorder, obsessive–compulsive disorder and specific phobias.[36] The common symptom of anxiety is a mental state anticipating (potential) threats accompanied by behavioural and physiological responses. In a pathological form, sensations become inappropriate and anxiety can severely interfere with normal life.[37] The global 12-month prevalence of all anxiety disorders is approximately 12%, with higher estimates among women than men.[38] The average onset of anxiety disorders is in the early 20-ies,[39] slightly earlier in comparison to depressive disorders.

### 1.4.2 Psychotic disorders

Psychotic disorders are severe mental illnesses with profound effects on the life of affected individuals and their community. They refer to a group of disorders (ICD-10: F20-29) including e.g. schizophrenia, schizoaffective disorder and delusional disorder, and are characterised with changes in the person's perception, thoughts, behaviour and mood, causing significant disability.[40] The lifetime prevalence of psychotic disorders is 0.75%;[41] however, psychotic symptoms or psychotic-like experiences might exceed this rate.[42]

#### *1.4.2.1 Schizophrenia*

The main disorder within psychotic illnesses is schizophrenia (ICD-10: F20), responsible for disproportionately high diseases and economic burden, and associated with very high unemployment and 10-20 years reduced life expectancy among those affected.[43] Schizophrenia has two core features: (1) positive symptoms including delusions (falsely held beliefs), hallucinations (perceptions in the absence of any stimuli) and disconnectedness from reality; and (2) negative symptoms referring to reduction of spontaneous speech, social withdrawal, impaired motivation and emotional apathy.[40,43] In addition, cognitive impairment and episodes of elated or depressive mood may occur, creating a unique clinical presentation of symptoms and varying experiences by each patient.[40,43] In a large meta-analyses, the pooled lifetime prevalence of schizophrenia was 0.4% with relevant between country differences.[44] In contrary to findings on the majority of CMDs, more men than women (female-male ratio of 1.0:1.4) are suffering from schizophrenia.[45] The highest incidence of first episode psychosis is in the 20-ies with a substantial decline of new cases in later ages.[46]

## 1.5 Determinants of mental disorders

In 1939, Faris and Dunham published a pioneering psychiatric epidemiological work on the varying rates of psychosis across neighbourhoods in Chicago.[47] Since then, growing evidence has indicated spatial variation in the incidence and prevalence of mental disorders.[48-50] Different approaches have been developed to explain these inequalities. The *compositional approach* postulates that not only health but also its individual-level risk and protective factors are spatially patterned (e.g. socioeconomic status, unemployment),[51] so that associations linked to places may be merely unexplained residual confounding.[49] In contrary to this proposition, the *contextual view* assumes that various features of places are relevant determinants of their own, and may influence health independently from individual characteristics.[51] However, artificially separating between places and people neglects their important interplay

over time; therefore, it is more plausible that composition and context together produce spatial health inequalities (*relational approach*).[51,52] Recognising the complex multifactorial aetiology of mental disorders,[2] this thesis builds on the relational approach by considering the interrelationship between differential contextual exposures at varying geographic scales and differential individual susceptibility to exposures.[52,53]

In the following section, first a short introduction to relevant individual-level biological, psychological and social determinants of mental health will be given, with highlighting main differences in the aetiology of depression, anxiety and psychosis. Many of these factors are important confounders in the relationship between context and mental health, and will be included and further examined in the empirical chapters. Second, contextual determinants of mental health will be presented in more detail, separating between neighbourhood-level or local factors, with a special focus on crime, and macro-level determinants.

### 1.5.1 Individual determinants

Criticising the prevailing biomedical concept at his time, Engel presented in 1977 an alternative framework on how to understand diseases aetiology and to respond adequately patient's health care needs.[54] Besides biological and genetic factors, the biopsychosocial model stresses the importance of psychological, behavioural and social determinants of health *(Figure 1.1)* and is one of the predominant paradigms in public health and epidemiology.

#### *1.5.1.1 Biogenetic factors*

Research on biogenetical determinants demonstrate clustering within families and has revealed a large number of genetic loci associated with mental disorders. Genome-wide association studies estimate that the heritability of major depression is approximately 35%,[15] with evidence for sex-specific genetic differences causing higher heritability among women than men,[31] partly explaining gender differences in the incidence (1.4.1.1). The inherited vulnerability for schizophrenia and psychotic

disorders is significantly higher, approximating 80%.[43] Despite the emerging genomic research, the genetic background of anxiety disorders has been relatively neglected.[55]

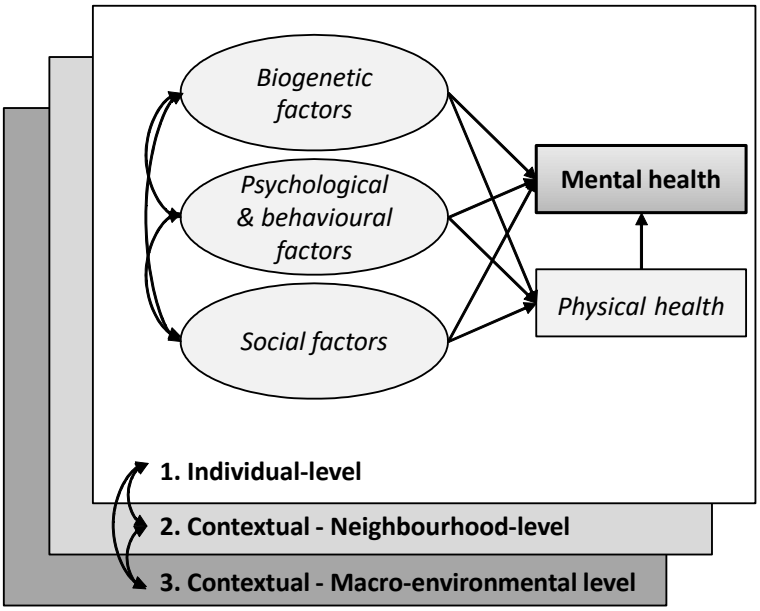


***Figure 1.1*** *Individual determinants of mental health (based on the theoretical model of Engel)*[54]

#### *1.5.1.2 Psychological and behavioural factors*

Psychological factors, such as early socialisation, childhood maltreatment, stressful life events, traumas, discrimination, or being equipped with adaptive or maladaptive coping mechanism can shape the incidence and course of CMDs across the life course,[4,56,57] but also, to a lesser extent, the neurobiology of schizophrenia.[58] Health behaviours such as drug and alcohol use, smoking, physical inactivity or unhealthy diet has been linked to mental health.[13,59] For schizophrenia, there is some evidence reporting higher prevalence among disadvantaged ethnic minorities, especially in the second generation, which cannot be explained by socioeconomic factors; in contrary to CMDs. It is probably linked to psychological processes (e.g. elaborating complex social tasks) interacting with genetic vulnerability.[60]

One of the leading psychological theories on the development and maintenance of mental disorders, is Beck's cognitive model of depression.[32] The central construct of

this theory is the cognitive triad (negative view about world, self and future), a distorted, extreme and negative way of perception and thinking, which is responsible for the emotional, behavioural and physiological symptoms of depression. Earlier schemas, such as childhood experience, shape the dysfunctional attitudes, which, when activated by external stressors, guide the processing of incoming information and lead to cognitive distortions, characterised by the cognitive triad.[61] As it will be pointed out later (1.6.1.1), this theory warrants for cautions interpretation of perceived area measurements.

#### *1.5.1.3 Socioeconomic and social factors*

Mental disorders are strongly determined by social and socioeconomic factors.[6,62] Health inequalities follow a social gradient, where the disadvantaged, poor and less educated suffer more frequently from mental health conditions.[63] A meta-analysis on social determinants of depression found 1.8 times higher odds of depression among individuals with lower socioeconomic status in comparison to the highest socioeconomic group.[64] Elevated rates of anxiety disorders[59] and schizophrenia[43] have also been found in groups with lower socioeconomic position; however, causal pathways for psychotic disorders might differ from CMDs (see 1.6.3). Also, being unemployed or being out of labour force is associated with worse mental health conditions.[65]

Protective social factors, such as social relationships are important to buffer the effects of stress: emotional, instrumental or informational support from family, friends and from broader social networks (e.g. neighbours) have been shown to reduce the risk of depression.[66] In contrary, living alone or being lonely increases the risk of symptoms severity of mental disorders, and causes poorer recovery and worse functional outcomes.[67]

#### *1.5.1.4 Physical health*

Although not necessary part of the classical understanding of diseases risk, physical health conditions should be mentioned at this point. Physical and mental health are strongly intertwined, with not only mental disorders increasing the risk of developing

chronic health problems (e.g. diabetes, high blood pressure, cancer, or cardiovascular diseases)[13] or worsening the clinical outcomes (1.3.1), but vice versa.[15] The relationship might be particularly pronounced among older adults, where the prevalence of chronic conditions is high. Longitudinal evidence suggest that functional limitations might mediate the effect of chronic conditions on depression among elderly.[68]

### 1.5.2 Contextual determinants

Exploring the contextual determinants of (mental) health is an important public health concern, as neighbourhood features and macro-level determinants are modifiable[7] and interventions may reach large population groups without directly intervening on individuals. Moreover, there is evidence showing that changing neighbourhood characteristics may narrow the substantial health inequalities across socioeconomic groups,[69] and so can do country-level social policies.[70] This section first provides a short historical overview on the contextual factors of mental disorders, followed by an introduction to local- and macro-level determinants.

#### *1.5.2.1 Historical perspective*

The notion that social and physical context might have an independent effect on mental health and well-being (i.e. contextual approach) goes back to Durkheim's work on suicide.[49] He suggested that suicide rates signalize social pathology in the community, which is linked to the breakdown of norms and collapse of traditional restraints likely caused by e.g. abrupt economic changes.[71,72] In the previously cited study from Faris and Dunham,[47] the authors found higher rates of schizophrenia in disorganised areas near to the centre of Chicago, in comparison to more residential suburban areas; a difference they explained with social isolation, poverty and substance use.[47,73] A further important earlier contribution is Bronfenbrenner's bio-ecological framework describing the human development as taking place within different contexts.[74] It postulates that children develop within different nested socially organised environments, ranging from proximal (e.g. family) to distal (e.g. policies)

systems, affecting the development of health and wellbeing through direct and indirect interactions between individuals and environments.[74,75]

Since the 1990s, research on the association between social or physical context and health has been emerging, providing evidence on the notion that the place where people grow up, live and age is linked to their health.[49] However, context has several layers, as Bronfenbrenner pointed out;[74] not only features of local areas or neighbourhoods can impact mental health, but also larger macro-level factors may affect mental health directly or by interacting with individual- and/or neighbourhood-level determinants.

#### *1.5.2.2 Neighbourhood effects*

Despite the increasing interest in neighbourhood effects, the overwhelming majority of studies utilises census-derived socioeconomic measures (e.g. poverty, education, unemployment) to explain spatial inequalities in mental health,[7,76,77] providing limited explanation about the nature of spatial inequalities. In order to overcome the 'black box' of neighbourhoods and to reveal processes producing inequalities,[78] there is a need for theoretical underpinning of neighbourhood effects.[79] However, only few studies made an attempt to conceptualise the local determinants of health. One important contribution is from Minh and colleagues,[75] which builds on previous theories such as the bio-ecological framework by Bronfenbrenner,[74] the neighbourhood effects model by Galster[78] and the fundamental causes of diseases by Link and Phelan,[80] when answering how, where and for whom neighbourhood affects human development *(Figure 1.2)*. During the presentation of this model, several neighbourhood characteristics, relevant to the empirical research carried out within this thesis, are introduced.

*Structural mechanism* in the neighbourhood are linked to the 'fundamental causes' of diseases, by building power inequalities and other kind of stratifications across areas; thus, allowing residents to access important resources and buffering social stressors.[75,80] Research has shown that the sociodemographic characteristics of people living in particular areas are linked to mental health: meta-analyses found higher risk

of mental disorders in places with lower socioeconomic status (independently from individual-level socioeconomic status),[26] and protective effects of own ethnic density.[81] Structural mechanism can influence health directly but also through impacting other neighbourhood pathways.[75,82] Structural mechanisms (i.e. income deprivation) are further examined in Chapter 5.

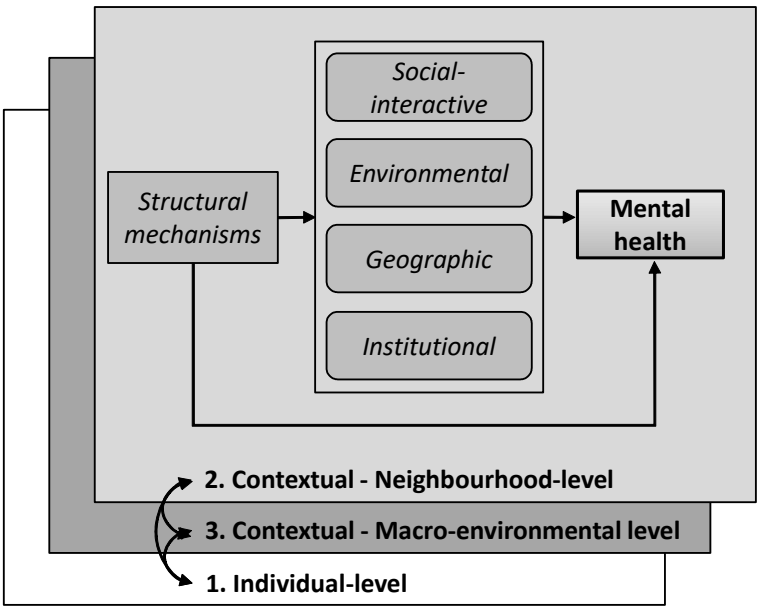


***Figure 1.2*** *Neighbourhood mechanism affecting mental health (based on the theoretical model of Minh et al)[75]*

*Social-interactive mechanisms* relate to the social dimension of communities including commonly referred determinants such as social cohesion, social capital and social disorganisation.[78] Social capital conceptualises the social environment and can be defined as resources available to members of social groups or networks (e.g. trust, social support, information channels, exercise of sanctions).[83] Structural and cognitive social capital may be distinguished, where the former refers to the quantity of social interactions between community members, while the latter (including social cohesion) describes their quality.[83] Social capital affects mental health by buffering the impact of psychosocial stressors and promoting health behaviours.[83] Social disorganisation and neighbourhood disorder (e.g. neighbourhood deterioration,

incivilities, drug use), on the other end, signalise problems, norm violations and danger in the area, affecting health through increased levels of fear, stress as well as social and physical retreat.[28] Importantly, neighbourhood effects may be also mediated by parents and close family environment, impacting children's biological and emotional development.[75,84,85] Social cohesion and neighbourhood disorder are the main focus of Chapter 3.

*Geographical mechanisms* involve neighbourhood effects, which do not arise from the neighbourhood itself but from the larger economic and political context where the neighbourhood is located (see macro-level determinants in 1.5.2.3).[78] Particular areas, for example, might have restricted access to job opportunities or public services due to remoteness and isolation, or due to corruption and incompetence of actors on higher political levels.[78]

*Institutional mechanisms* refer to actions taken by external institutes or persons, affecting neighbourhoods' lives by controlling resources or influencing developments.[78] Area-based stigmatisation by institutions may reduce job opportunities and affect directly the life and health of locals. Also, accessibility to public and private resources and services in the neighbourhood (e.g. public transportation, charities, schools, clinics, local market, cultural services)[86,87] are relevant for social life, and for physical and mental health;[78] mechanisms partly elaborated in Chapter 4.

Finally, *environmental mechanisms* include more tangible, natural or human made features of the neighbourhood, which may affect health outcomes directly.[78] Elevated levels of environmental noise[88] and air pollution[89] has been linked to mental health (see Chapter 4). Also, there is an increased research interest exploring how living close to blue and green spaces can be beneficial for mental health.[90,91] More importantly, Galster[78] groups exposure to crime in this group, which is one of the main focuses of this thesis (Chapter 2, 5 & 6; but also partly Chapter 3 & 4).

#### *1.5.2.2.1 Neighbourhood crime*

Research in criminology consistently shows that crime incidents are not randomly distributed, but concentrated across micro-geographic units or hot spots:[92] the smaller is the spatial unit of analysis the larger is the heterogeneity between units.[93] In the classic study of Sherman et al,[94] 50% of the crime-related calls in Minneapolis were from 3% of the places, with differing magnitude of concentration across types of crimes (e.g. violent, non-violent).

Opportunity theories suggest that there are certain street segment-level criminogenic characteristics (e.g. lack of local guardianship, places of routine activities), which provide opportunities for 'motivated offenders' to commit crime in the present of a 'suitable target'.[93,95] Another significant theoretical explanation for crime incidents is based on the observation that crime is more common in deprived neighbourhoods with more social disorganisation.[96] Also, as Sampson et al[97] have shown, collective efficacy (social cohesion and the willingness of intervene in common good), or more precisely its lack in the community, might mediate the relationship between area disadvantage and crime. While the opportunity theories fail to demonstrate why individuals offend and particular communities are more vulnerable, the social disorganisation theory provides less explanation for the spatial concentration of crime.[93] A recent study tried to bridge these theories by suggesting that physical characteristics of micro-geographic units, embedded in a broader community with more social disorganisation, may help to understand crime patterns.[98] Once crime occurred, it can have significant effects on individual mental health thought direct and indirect pathways[99] (see 1.6.3 and Chapter 2).

It is important to note at this point that particular types of crime may impact mental health on larger geographic scales. Villarreal & Yu[100] argue that while more ordinary crime is embedded in the social and physical structure of the immediate surroundings, organised violence (e.g. drug trafficking) may be linked to macro-level factors, requiring large scales of aggregation. Although these crimes have also the

potential to impact health and increase fear among residents,[100] they are not the objective of this thesis, mainly focusing on Western high-income countries.

#### *1.5.2.3 Macro-level factors*

Exploring only on the individual and neighbourhood-level determinants of mental health cannot explain why prevalence and incidence rates vary across the world but even between neighbouring countries.[3,48] Moreover, it ignores that places and people are shaped by their larger political, economic and social context, often outside of the control of individuals and communities *(Figure 1.3)*.[51,101] Although the effects of societal changes, economic turndowns or recessions on mental health have long been assumed (1.5.2.1), only a handful of empirical and conceptual works are available on this topic (e.g. *political-economy approach* from Bambra).[51,101]

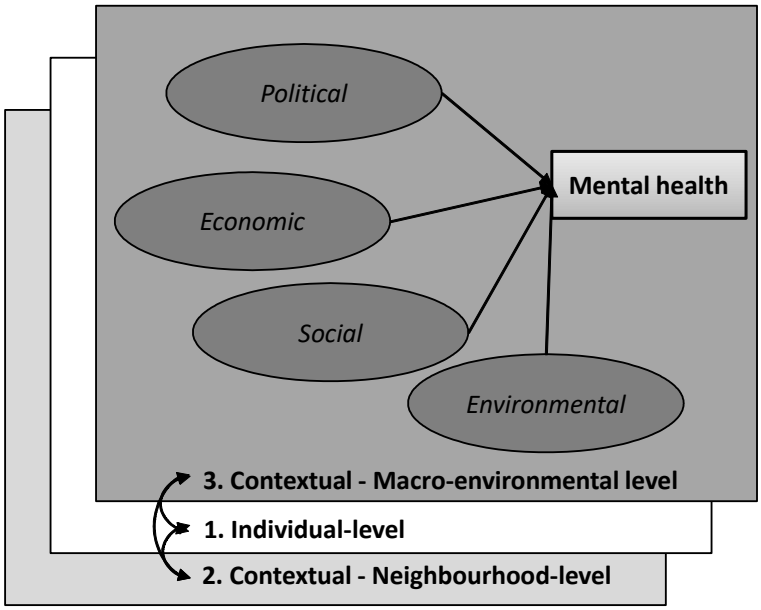


***Figure 1.3*** *Macro-level determinants (based on the theoretical model of Bambra et al)*[101]

For example, there is evidence on how austerity policy and labour market trends during the great recession (beginning 2007/2008) increased mental health problems in Scotland,[102] and also country-level income inequality has been linked to depression.[103] Not only social, economic and political, but also large-scale

environmental factors, such as natural disasters or climate change may affect mental health[104] over and above individual and neighbourhood determinants.

An often applied framework for understanding cross-national health inequalities is the welfare regimes typology from Esping-Andersen.[70,105] It provides systems-based explanations for health inequalities,[48] by linking them to specific social and economic policies. Welfare regimes (e.g. Scandinavian, Bismarckian, Anglo-Saxon, Southern and Eastern European) differ by how they manage economy, provide social protection and income transfer for citizens, which, in turn can produce social and economic inequalities, or buffer the effects of social stress.[70] The welfare regimes theory with further macro-level indicators is elaborated in Chapter 3.

## 1.6 Methodological aspects of research on neighbourhood and mental health

Having described the key literature, the following section presents three methodological aspects, important to consider when studying place and mental health: measuring neighbourhood, measuring mental health and problems arising when examining their relationship. When evidence is available, examples are given from the neighbourhood crime and mental health literature, utilising studies included in the systematic review in Chapter 2. Finally, a last paragraph introduces the life course approach, a novel way of understanding complex place-based mechanisms.

### 1.6.1 Measuring neighbourhood

The literature distinguishes between two main approaches of measuring neighbourhood: subjective and objective measurement. Two empirical chapters utilise the former (Chapter 3 & 4) and two the latter (Chapter 5 & 6).

#### *1.6.1.1 Subjective area measurement*

Subjective measurement of area attributes makes use of human observers to judge neighbourhood features and characteristics. Most commonly, focal survey

participants are asked to rate their residential area, e.g. providing information on the level of perceived crime and violence.[106] This type of measurement has the advantage of taking into consideration how individuals define and perceive their own neighbourhood, which might be crucial for mental health outcomes.[7,107] However, it does not capture features respondents might not be aware of, and findings derived from both self-reported predictors and outcomes are prone to same source bias (i.e. correlated measurement errors),[7] reverse causation and non-measured psychological mechanism influencing reporting behaviour (see more in 7.5.2.2). For example, it is not only plausible that individuals with depression observe their area as more threatening indicating higher crime rates and more danger, but a distorted perception is per se a depressive symptom, as understood within the cognitive model of depression (1.5.1.2).[32]

Crime perception of study respondents may be aggregated within geographic units[108] or responses from an independent survey can be derived to provide a more 'objective' assessment.[109] Also, an alternative approach (systematic social observation) can employ trained rates to evaluate specific neighbourhood features, which can overcome the same source bias.[7] Still, aggregated measurements are prone to biases related to objective area measurements.

#### *1.6.1.2 Objective area measurement*

The objective measurement of neighbourhood features includes techniques mainly rooted in the use of census data and/ or other routinely collected information, and in the application of Geographic Information System. Providing the population rate/ ratio of individuals or entities within a given geographic unit is the most common way of assessing determinants related to structural mechanisms (see area income deprivation measurement in 5.4.2). On the other hand, Geographic Information System techniques are being increasingly used in health geography for calculating spatial distance to resources or stressors, and for characterizing attributes of built environment.[7] Measuring objective crime draws on both techniques: police or other agency-recorded and georeferenced crime incidents can be either aggregated within

certain geographic units utilising administrative boundaries (e.g. census tract),[106] or aggregated within buffer zones calculated around participants' residential home (e.g. 1-km network buffer).[82] Unsurprisingly, objective measurement of crime has also several disadvantages (e.g. drawing area boundaries, insufficient crime reporting behaviour), which is further discussed in 7.5.2.2.

The correlation between perceived and objective neighbourhood crime is surprisingly low,[106] but conceivable given the number of possible biases involved in their measurement. Moreover, studies highlighted generally stronger neighbourhood-mental health associations when using subjective, rather than objective measurements.[106,110,111] Although it is theoretically plausible that neighbourhood perception partly mediates the effect of objective characteristics on mental health,[112] limited longitudinal evidence points towards independent pathways.[113]

### 1.6.2 Measuring mental health

In comparison to physical health, conceptualising and measuring mental health is a particular challenge for epidemiological research.[114] Descriptive and analytical studies in psychiatric epidemiology have two main methods to produce reliable information on individual mental health status: conducting in-person assessments by utilising diagnostic or screening scales, or deriving service use data from the health care system. Two empirical chapters made use of screening scales available in cohort studies (Chapter 3 & 4) and two of mental health service use data (Chapter 5 & 6).

#### *1.6.2.1 In-person assessment*

The majority of available information on the prevalence and aetiology of mental disorders originates from large population surveys assessing mental disorders by utilising structured diagnostic interviews or screening scales. Structured diagnostic interviews were principally developed for clinical use and systematically test symptoms of mental disorders against specific criteria based on diagnostic manuals (ICD or DSM [Diagnostic and Statistical Manual of Mental Disorders]). They (e.g. M.I.N.I. or Structured Clinical Interview for DSM) provide the gold standard of

mental health assessment by indicating specific diagnoses; however, utilising them is a lengthy process requiring trained administrators.[115]

Screening scales, such as the Center for Epidemiologic Studies Depression Scale (CES-D)[116] or EURO-D,[117] are often designed for population surveys and comprise only a handful questions on current symptomatology to ease data collection and lower participant burden. Although screening scales provide cut-off scores indicating a validated threshold for clinically relevant levels of symptoms, they can only measure symptomatology and do not indicate specific diagnosis.

#### *1.6.2.2 Service use data*

Information on mental health may be derived from service use data routinely collected in primary care (e.g. prescribed psychotropic medications by general practitioners' surgeries), or in services linked to secondary or tertiary care (e.g. admission to psychiatric wards in general hospitals or to specialist facilities).[118] At arrival in the health care system with mental health conditions, usually an assessment takes place, which may utilise structured diagnostic interviews, screening scales, or other non-structured clinical interviews; largely varying across facilities and at different levels of health care provision. As the systematic review in Chapter 2 highlights, studies on neighbourhood crime and mental health are overwhelmingly based on screening scales[82,106] with few examples using diagnostic interviews[119] or utilising mental health service use.[120,121]

### 1.6.3 Causal pathways between neighbourhoods and mental health

If there is an association between neighbourhood crime and mental health, theoretically, several explanations can be hypothesised. Two common interpretations are discussed in more detail in the following section: neighbourhood crime causing mental health problems (*social causation*), and individuals with mental disorders moving towards higher crime areas (*health selective migration/ social drift*). However, other contextual factors, for example area deprivation, might affect both mental

health and neighbourhood crime,[82] confounding their relationship; also, individuals with mental disorders are more likely to commit violent crime.[122]

#### *1.6.3.1 Causation hypothesis*

The causation hypothesis puts forward that neighbourhoods influence health outcomes through their various social and physical features. Originally developed to explain the effect of life events on health, the stress process model from Pearlin[123] can be translated into the neighbourhood context by providing an explanation on how individual/neighbourhood stressors ('source of stress') and individual/ neighbourhood resources ('mediating resources') affect health ('manifestation of stress'). Besides (1) becoming a victim of violence or witnessing crime, (2) neighbourhood crime can impact mental health through increased social stress, with differing effects among more or less susceptible individuals (e.g. based on sociodemographic characteristics, childhood experiences, health problems). Moreover, (3) area-level crime can affect resources used to cope with acute or chronic stressors (e.g. health behaviour, social cohesion).[99,124] Therefore, understanding differential vulnerability (i.e. exposure, susceptibility and capacity of response) across communities[53] are important predisposition of tackling neighbourhood effects.

#### *1.6.3.2 Health-selective migration*

Health-selective migration or social drift implies that moving to adverse neighbourhoods can be driven by mental and physical health conditions. The few studies exploring health-selection suggest that individuals with poor health status might follow downwards social and geographical mobility:[125] pre-existing mental and physical health conditions may determine social and socioeconomic status, which, in turn, leads to moving to affordable but more disadvantaged areas.[126] Although there is comparably more research on the causation hypothesis, moving downwards to less favourable neighbourhoods among individuals with mental disorders is likely to be a valid explanation, especially for severe mental health conditions with higher heritability,[43] such as for psychotic disorders.[60,64,127] However, causation and self-

selection are not mutually exclusive interpretations; they can interact over the life course and even across generations.[64,126]

#### *1.6.3.3 Implications for study design*

In epidemiology, cause is defined as an event, condition or characteristic, which precedes the occurrence of an outcome; without the cause, the outcome would have not occurred or would have occurred in a later time.[128] Empirical investigations exploring the associations between context and mental health are mainly based on cross-sectional studies,[7,28,76,77] which are not able to prove one of the most important criteria of this definition, the temporal ordering between exposure and outcomes. As longitudinal investigations are better able to mitigate the risk of reverse causation providing stronger evidence of a causal relationship, they constitute the empirical body of this thesis (Chapter 3-5).

However, identifying causal contextual effects is particularly challenging even in longitudinal studies. First, neighbourhoods are socially, demographically and ethnically stratified, as posits the compositional approach. To estimate unbiased neighbourhood effects, there is a need for perfect specification of individual selection in into areas, which paradoxically eliminates meaningful neighbourhood effects.[129] Second, neighbourhood characteristics are endogenous and arise as 'emergent properties' of the social interactions between the residents, which is particularly true for crime, emerging as a product of criminogenic characteristics and social disorder (1.5.2.2.1). Therefore, instead of using observational data, experimental designs are advocated to better understand causal neighbourhood effects.[7,129] While randomised controlled trials are often unethical or controversial, natural and quasi-experiments may fill the gap by exploring how naturally occurring events or policies/ interventions impact health outcomes as a result of changing exposure, in the absence of researcher's manipulation.[130] Natural and quasi-experiments are particularly useful to inform policy, but require large and good quality data on exposure and outcome.[130] This thesis brings an example for a natural experiment on the effect of changing neighbourhood-level crime on mental health (Chapter 6).

### 1.6.4 Life course of places

The recognition that human lives do not only take place in the cross-sectional dimension of here and now, but significant developmental changes evolve over time, is becoming a prominent theory in social, behavioural and medical sciences.[131,132] The life course approach in epidemiology studies the long-term biological, behavioural and psychosocial pathways linking physical and social exposures to health conditions and disease risks over time. These processes operate across the individual's entire lifespan, from foetal period through childhood and adolescence until late adulthood, but also across generations.[133,134] Exposure to physical and social stressors can influence health on interactive or additive ways: (1) *Critical and sensitive periods* postulate that there are time windows during the life course, when exposures may result in specific disorders or increase the risk of certain health conditions. (2) The *accumulation model* assumes that adverse exposures or health damaging behaviours accumulate (in a correlated or not correlated way) over time and gradually increase the risk of illnesses.[134]

The interdisciplinary framework of life-course approach has been applied to assess the impact of several individual-level characteristics on mental health: there is evidence on the prolonged effects of family social environment,[135] childhood illnesses[136] and childhood maltreatment.[56,57] Similar to individual determinants, place-based associations may vary across the life course, so that health-damaging or health-promoting neighbourhoods can have prolonged effects on mental health. Also, not only individuals change over time, but also places develop (e.g. gentrification, post-industrial decline) in response to social, economic and political influences (1.5.2.3).[51]

However, there is very limited evidence on the life course effects of places on mental health, and no studies have examined the association with neighbourhood crime. The few available studies indicate that exposure to neighbourhood deprivation during sensitive periods, such as in childhood[137] or in times of life course transitions (e.g. adolescence to young adulthood),[138] may have a stronger impact on mental health, or can have long-lasting effects reaching until late adulthood. In contrary, there is some

evidence highlighting that neighbourhood deprivation at more contemporaneous ages have the strongest association with mental health.[139] Moreover, life course individual vulnerability can evolve from adverse exposures in a developmentally sensitive period interacting with concurrent contextual stressors,[140] for which Chapter 4 provides an example.

## 1.7 Contribution to the literature

This chapter began with a short introduction on the public health relevance of mental health (1.3), followed by the description of three clinically important mental disorders (1.4). In contrary to individual-level determinants of mental health, contextual factors are less explored (1.5), and studies focusing on the effect of residential features are challenged by several methodological issues, such as measuring context and mental health, and the causal pathways between them (1.6). This work builds on three main theoretical constructs: (a) on the relational approach to understand spatial inequalities arising from differential exposure and differential susceptibility, (b) on frameworks of embedded and intertwined contextual mechanism (e.g. bio-ecological approach), and (c) on the life course perspective placing all this into the timeframe of human development.

### 1.7.1 Rational and objectives

The main research question of this thesis is how, where and for whom neighbourhood impacts mental health by addressing methodological limitations and interpreting results in the aforementioned theoretical framework. More precisely, the following chapters explore the longitudinal association between neighbourhood stressors, especially crime, and the risk of depression, anxiety and psychosis during follow-up, while considering individual-level characteristics and other contextual determinants at different scales (local versus macro). Neighbourhood-level crime is the main exposure of interest in this work, with two chapters focusing on perceived crime as part of a multi-item questionnaire (i.e. neighbourhood disorder in Chapter 3,

neighbourhood nuisances in Chapter 4), two on objectively recorded crime (Chapter 5 & 6), and one on both (Chapter 2). Specifically, the objectives are *(Figure 1.4)*:

1. To identify the existing literature on the association between objective and perceived area-level crime and mental health across the life course, to estimate their global relationship, and to assess whether particular design or study characteristics impacts findings.

Based on research gaps identified in this systematic review, the following objectives were formulated:

2. To explore whether perceived neighbourhood disorder (including crime) and lack of social cohesion equally relate to depression in later life across different high-income countries; and if not whether macro-level social, economic, political and environmental determinants may explain varying effects.
3. To examine whether the associations between perceived neighbourhood nuisances (including crime), access to neighbourhood services and depression in later life are determined by early childhood stressors, such as socioeconomic conditions, adverse experiences and health problems.
4. To explore whether objectively measured crime in the neighbourhood is linked to mental health service use, indicated as prescriptions for anxiolytics, antidepressants and antipsychotics medication; and whether associations are modified by age, gender and socioeconomic status.
5. To assess whether exposure to changing levels of objective area-level crime is linked to self-reported and service use data on mental health, and whether these associations vary across residential mobility and age; providing information on potential causal pathways.

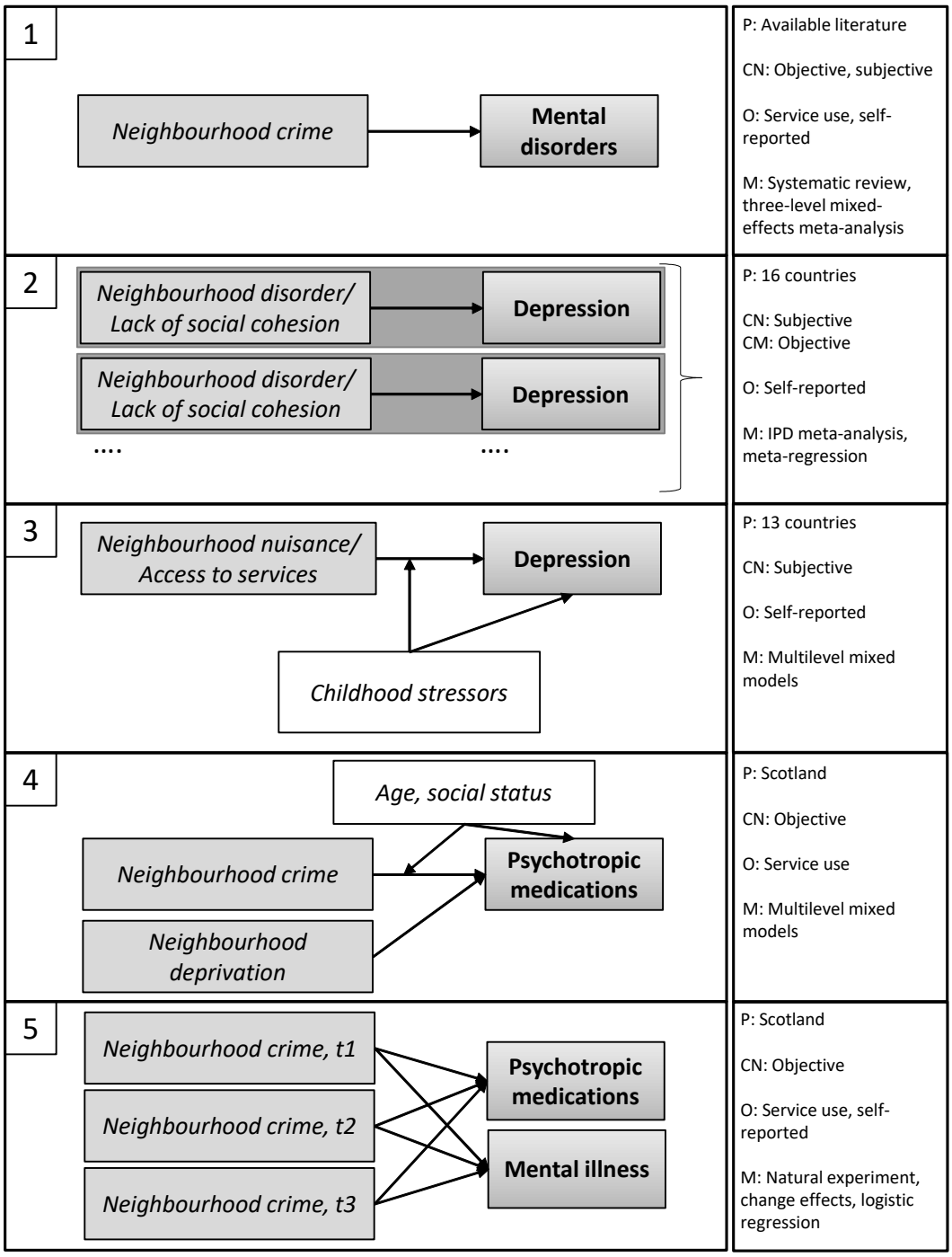


***Figure 1.4*** *Research objectives, highlighting associations, study populations (P), contextual determinants at neighbourhood (CN) and macro-level (CM), outcome measurements (O) and applied methods (M)*

### 1.7.2 Thesis structure

This thesis is based on five paper manuscripts, addressing the previously outlined objectives in a mixture of cross-national and Scotland-based studies utilising survey

data and linked administrative datasets. After this introductory chapter on key literature and methodology (Chapter 1), Chapter 2 provides systematic information on objective and subjective measures of area-level crime and mental health. Based on identified research gaps, Chapter 3 and 4 explore mental health and perceived neighbourhood associations utilising ageing cohorts from western high-income countries; Chapter 5 and 6 objectively measure area exposures in Scotland. Finally, Chapter 7 closes the dissertation by bringing together findings, discussing strengths and limitation, and highlighting opportunities for prevention, policy, and research.

Four out of five chapters have been already published: Chapter 3 in the American Journal of Epidemiology, Chapter 4 in Preventive Medicine, Chapter 5 in the American Journal of Preventive Medicine, and Chapter 6 in the Journal of Epidemiology and Community Health. Prior each chapter, there is a cover page, serving as linking material and providing information on publication status and authors' contributions. In general, while co-authors substantially contributed at each stage, I led the studies, developed the project design, conducted the data analyses, and drafted the first manuscripts. To ease the identification of cited literature, reference lists can be found at the end of each chapter. Supplementary materials linked to the empirical work are at the end of the thesis.

This thesis has been founded by the European Commission's Horizon 2020 research framework, within the LONGPOP project (Methodologies and Data mining techniques for the analysis of Big Data based on Longitudinal Population and Epidemiological Registers; grant number 676060), which enabled me to carry out part of the work at the Center for the Interdisciplinary Study of Gerontology and Vulnerability, University of Geneva. Research presented in Chapter 3 & 4 benefitted largely from this cooperation, making use of on-site expertise on longitudinal modelling and life course research.

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# CHAPTER 2

# 2. A systematic review and meta-analysis of neighbourhood crime and mental health

## 2.1 Chapter overview

This chapter provides an up-to-date evidence base on the link between perceived and objectively measured area-level crime and different mental health conditions (anxiety, depression, psychosis, and psychological distress). By doing so, it further elaborates the context of this thesis and identifies potential research gaps aimed to fill in the upcoming empirical chapters. Moreover, as no systematic review and meta-analysis is available to date on this topic, and generally few meta-analyses in the field of neighbourhood effects, this chapter aimed to fill an important research gap with policy implications.

The chapter in its current form is ready for submission in journal with mental health focus. After the pilot searches, but prior to finishing title and full-text screening, a detailed review protocol has been published in PROSPERO (CRD42019141371):

> *Baranyi G, Di Marco MH, Russ T, Dibben C, Pearce J. The ecological effect of crime on mental health: a systematic review and meta-analyses. PROSPERO 2019 CRD42019141371 Available from: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42019141371*

Referred supplementary material in this chapter can be found in Appendix One.

**Title**

The impact of local crime on mental health: a systematic review and meta-analysis

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*Author's contribution*: GB, CD, TCR, and JP conceived, planned, and oversaw the study. GB and MHDM searched the literature, applied inclusion and exclusion criteria; disagreements between reviewers were resolved by consensus with JP. GB extracted data and conducted quality assessment, MHDM checked the extracted information. GB developed the methodology and conducted the statistical analyses. GB drafted the manuscript; all authors reviewed, commented on, and approved it.

## 2.2 Abstract

**Background** Living in high crime areas may increase the risk of mental health problems through direct and indirect pathways, although systematic evidence is missing. We systematically evaluated the literature to estimate the association between local crime and different mental health conditions.

**Methods** For this systematic review and meta-analysis, we searched 11 electronic databases, grey literature and reference lists to identify relevant studies published before March 28, 2019. Quantitative investigations were included if they reported confounder-adjusted associations between objective or perceived crime and anxiety, depression, psychosis or psychological distress in non-clinical samples across the life course. Effect measures were first converted into Fisher's z-s, pooled with three-level random-effects meta-analyses, and then for reporting purposes transformed into Pearson's correlation coefficients. Univariate and multivariate mixed-effects models were used to explore between-study heterogeneity. PROSPERO protocol: CRD42019141371.

**Findings** We identified 50 studies reporting associations between neighbourhood crime and residents' mental health. Pooled associations were observed for depression (r=0.044 95% CI 0.029-0.059), psychological distress (0.036, 0.017-0.056) and anxiety (0.058, 0.004-0.111), but not at conventional levels of statistical significance for psychosis (0.034, -0.010-0.078). For depression and psychological distress, studies utilizing perceived crime and cross-sectional design reported stronger associations, with variability across age groups. After adjustment for these characteristics, neighbourhood crime was still linked to depression and weakly to psychological distress.

**Interpretation** Local crime is an important contextual determinant of mental health. Area-based crime interventions and service allocation to high crime areas may have public mental health benefits.

**Funding** Horizon 2020 programme of the European Union; Alzheimer Scotland.

## 2.3 Introduction

Mental health problems are major contributors to disability and suffering,[1] affecting 30% of the global population at least once during their lifetime.[2] Over and above individual and household-level factors, there is a growing understanding that social and physical features of the living environments may contribute to the complex multifactorial aetiology of mental disorders.[3-5] A possible key contextual stressor is local crime and violence. Increased crime rates are more common in disadvantaged and low income areas,[6] with signs of socially disorganisation and low collective efficacy (i.e. social cohesion among neighbours with effective control to regulate members maintaining desired common goals).[6] Moreover, crime incidents are particularly concentrated around micro-geographic units, such as street segments, where criminogenic characteristics (e.g. lack of local guardianship, suitable targets) provide opportunities for offending.[7]

Local crime can impact mental health through direct and indirect pathways.[8] Becoming a victim or witnessing crime in the community, has long been shown to increase the risk of developing mental disorders.[3,8-10] There is less consensus, however, on the indirect or ecological ways in which neighbourhood crime 'gets under the skin' in the absence of direct exposure. First, living in a high crime area is a chronic stressor and may be linked to mental health through physiological processes affecting the hypothalamic-pituitary-adrenal axis[11] and causing systematic inflammation in the body.[12] Second, crime may influence mental health through behavioural and developmental pathways. In high crime areas, avoidance behaviour and thus lower physical activity is more common,[13] and so are maladaptive coping strategies in response to chronic stress (e.g. smoking, substance misuse).[8,14] Moreover, parents' neighbourhood crime exposure can affect children's development, and thus later life mental health, through adverse birth outcomes[15] or parenting style.[16] Third, neighbourhood stressors may modify the effect of individual risk factors on mental health,[17] or interact with other contextual determinants (e.g. green space, national policies).[8,18]

Despite the considerable public health relevance, there is no systematic review and meta-analysis available on the indirect impact of local crime on mental health. We aimed to fill this gap by reviewing the literature on area-level perceived and objective crime on mental disorders across different age groups. Establishing the relationship for anxiety, depression, psychosis and psychological distress/ internalising symptoms, and exploring the heterogeneity between studies provides further insights into the complex crime-mental health relationship.

## 2.4 Methods

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines;[19] the research protocol was published on PROSPERO (CRD42019141371).

### 2.4.1 Search strategy and selection criteria

We used a multi-stage search strategy to identify relevant literature on the association between neighbourhood crime and mental health. Searches were executed on the 28th March 2019 and comprised: 11 online databases (ASSIA, CAB Abstracts, Embase, Global Health, IBSS, MEDLINE, PsycINFO, Scopus, Social Services Abstracts, Sociological Abstracts and Web of Science), grey literature (OpenGrey) and screening reference lists of included papers and relevant reviews. We corresponded with authors to clarify methodology or results. Publications from all languages were considered. Database-specific search terms combining free-text strings and subject headings with Boolean operators (AND, OR, ADJn) can be found in appendix *(Supplementary Material 2.1, Supplementary Table 2.1)*.

Quantitative studies meeting the following criteria were included: (1) the sample was recruited from the general population with representative sampling techniques within a given sampling frame; (2) area-level crime was captured as objectively recorded or self-reported crime; (3) mental health outcomes (anxiety, depression, psychosis, psychological distress/internalising symptoms) were assessed with

screening scales, diagnostic instruments or service use data; and (4) confounder-adjusted main effects (at least sex, age and individual-level socioeconomic status or ethnicity) were reported.

We excluded studies when: (1) the sample was based on individuals or their offspring with chronic physical or mental health conditions, as associations might differ in clinical samples;[20] (2) the predictor was (i) personal exposure to community crime, where reviews are already available,[10] (ii) fear of crime or feeling of crime-related safety, because of a high risk of reverse causation with mental disorders,[8] or (iii) the predictor was measured by a composite questionnaire with ≤50% crime-related items; (3) the outcome was operationalised as substance use disorder, mental well-being, perceived stress or non-specified mental illness; (4) univariate associations were reported; or studies were based on ecological data, unless focusing on psychotic disorders, where the prevalence is low. (5) Finally, duplicates without relevant differences in the design or variable operationalisation, as well conference abstracts and papers without original data were excluded. Two reviewers (GB, MHDM) screened all publications independently. Where there was disagreement a third reviewer (JP) was included in the appraisal.

### 2.4.2 Data extraction and quality appraisal

GB extracted, and MHDM cross-checked, the following information from the included studies: first author, year of publication, geographic location, data source, sample size, sample characteristics (age, % of female, % of ethnic minority), sampling technique, baseline response rate, study design (cross-sectional, longitudinal), follow-up time and loss to follow-up for longitudinal studies, crime measurement, geographic extent of exposure, covariates, outcome assessment and risk estimates.

We classified objective and perceived (individual- or aggregated-level) crime measures into violent (e.g. murder, manslaughter, robbery and assault), property (e.g. burglary, larceny, theft, arson, and vandalism) and total crimes; if studies reported effect sizes for multiple single crime types, we pooled them into one of the main

groups using fixed-effects meta-regression.[21,22] Mental health problems were classified into four groups, capturing symptoms or diagnosis related to psychotic (ICD-10 codes F20-F29), affective (F30-F39), and anxiety disorders (F40-F48). A fourth group was designated to combined symptoms of affective and anxiety disorders, also known as psychological distress, or internalising symptoms among people under 18. We considered samples as the main units of analyses, rather than individual studies: for each exposure and outcome combination we extracted a maximum of one cross-sectional and longitudinal (with the longest follow-up) effect estimate per sample.

To account for the geographic extent of crime exposure, we coded areas based on their average population size (≤1,000; 1,001-2,000; 2,001-5,000; 5,001-10,000; 10,001-50,000; and ≥50,001 people). For studies applying buffer zones around participant's residential location, population size was calculated using the average population density of the study area. Mental health assessments were coded whether they applied broader (e.g. symptom scales, medications) or narrower (e.g. diagnosis based on clinical interview, patient registries) criteria. Age groups were recorded as follows: childhood (7-12 years), adolescence (13-18), or adulthood (19+); the latter was subdivided into young adulthood (19-35), middle adulthood (36-60) and late adulthood (61<). Furthermore, we coded whether extracted estimates were adjusted for individual-level crime exposure, presenting the direct crime-mental health pathway; and for area-level socioeconomic status or neighbourhood social processes (e.g. social disorganisation, social cohesion), main predictors of crime incidents. In order to extract comparable effect estimates across all included studies: (i) we selected the most comprehensive model adjusted for all individual characteristics, but without controlling for interactions or other neighbourhood covariates; (ii) we chose the smallest level or aggregation;[23-26] and (iii) when exposure was presented in non-overlapping groups (e.g. tertiles), we extracted the strongest indicative estimate.

Two reviewers (GB, MHDM) assessed study quality using a modified assessment tool for observational studies,[27] including 13 questions capturing study design, exposure and outcome measurement, and statistical approach *(Supplementary Material 2.2)*.

### 2.4.3 Data Analysis

Prior to analyses, effect measures were converted into a common metric, using the *esc* package in R.[28] For binary outcomes, Fisher's *z*-s were directly calculated based on estimates, standard errors and sample sizes; for continuous outcomes, we first computed t-values and then Fisher's *z*-s.[29] Missing information was calculated using standard formulas,[30] and if no indication of precision was reported, we imputed p=0.5 for non-significant and p=0.05 for significant associations. Although we used Fisher's *z*-s in the analysis to prevent biases arising from the skewed distribution of Pearson's correlation coefficients (*r*); findings are reported in *r*-s after transformation.[29]

To account for dependency between estimates derived from the same sample, we fitted three-level meta-analyses — which decompose the total variance into sampling (level 1), between-estimates (level 2) and between-sample variance (level 3)[31] — and added random-effects at the estimate and sample levels. Models were fitted with the restricted maximum-likelihood estimation, pooled effect sizes were calculated with Knapp-Hartung adjustments for confidence intervals, using the *metafor* package in R.[32] Significant Cochrane's Q-statistics indicated heterogeneity between estimates. Intercept only models were run separately for anxiety, depression, psychosis and psychological distress to express their global association with area-level crime.

To explore heterogeneity between estimates, univariate mixed-effects models (meta-regression) were conducted, when at least 10 estimates within the same outcome group were available.[30] The following moderators were added to the main models as fixed effects: % female; age groups; % ethnic minority; geographic extent of exposure; crime measurement; types of crime; study design; adjustment for individual crime exposure, neighbourhood deprivation, social processes; and quality score. If at least 20 estimates were available, significant moderators ($p<0.05$) as well as type of crime measurement and study design (independently from their significance level) were retained for multivariate models. Intercepts in these multivariate models indicated area-level crime associations after adjustments.

Inter-rater agreement between reviewers were expressed with Cohen's Kappa.[30] Publication bias was assessed with funnel plots of estimates against their standard errors with the rank correlation test assessing funnel plot asymmetry.[32] Finally, we conducted four sensitivity analyses: (1) After identifying potential outliers and influential cases, main meta-analyses were rerun without these estimates; (2) To further account for the dependency between effect sizes from the same samples, robust variance estimations were calculated;[31] (3) We reran the main models after excluding studies with >5 neighbourhood covariates, where multicollinearity and/or over-adjustment might be present; (4) Finally, we pooled studies with binary and continuous outcomes separately.[29] For the latter we stayed by Fisher's *z*-s, for binary outcomes we first transformed ORs into RRs[33] and pooled them directly.

### 2.4.4 Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## 2.5 Results

Out of 9,220 unique records, we included 50 studies in the meta-analyses with good agreement rate between reviewers (Cohen's Kappa=0.73) *(Figure 2.1)*.

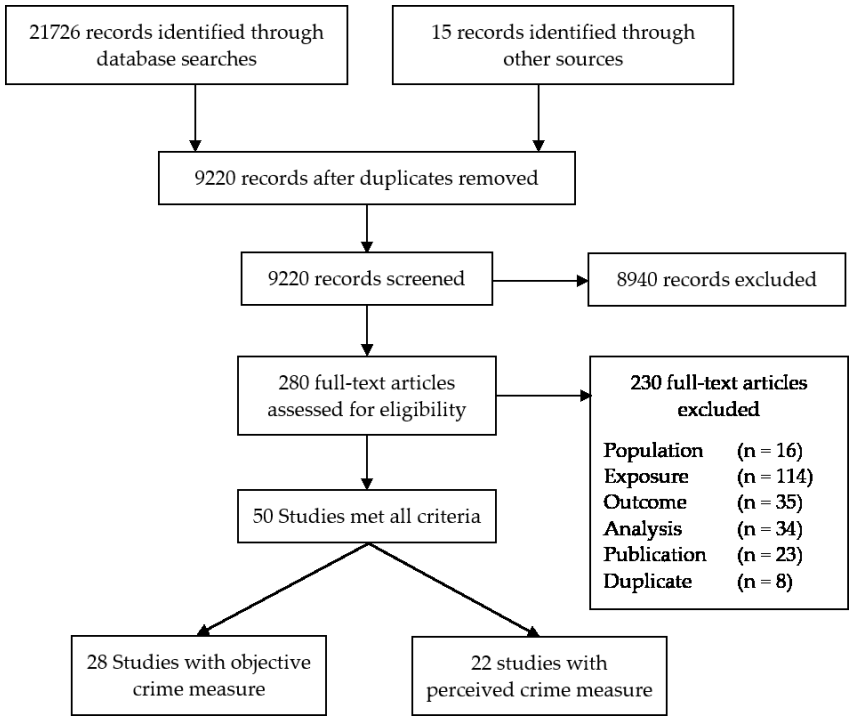


***Figure 2.1*** *Study identification, screening and eligibility test, following the Preferred Reporting Items of Systematic Reviews*

Studies were published between 2002 and 2019 in a wide range of disciplines (e.g. psychology, public health, economics, criminology) and based on over 650,000 individual mental health assessments. Objectively measured crime was used in 28 studies *(Table 2.1)*,[18,20,22-26,34-54] while 22 assessed perceived crime *(Table 2.2)*.[17,21,55-74]

***Table 2.1*** *Studies reporting the association between objectively measured crime and mental health*

| Study | Location | Data sources | Age group | Sample size | Study design | Neighbourhood crime | | Outcome | Control for | | QA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Type | Area unit (with average population categories) | | Area socioeconomic status | Individual crime exposure | |
| **I.** | **Anxiety** | | | | | | | | | | |
| Baranyi et al[34] | Scotland, UK | Scottish Longitudinal Study | Adulthood | 129,945 | L | MC | Data zone (≤1,000) | Anxiolytics prescription | Income | No | 10 |
| Chaix et al[23] | Malmö, Sweden | - | Middle adulthood | 89,285 | C | VC | 500m radius (2,001-5,000) | Diagnosis (ICD-10: F40–F48) | - | No | 9 |
| Weisburd et al[26] | Baltimore, US | - | Adulthood | 2,136 | C | VC | Street segments (≤1,000) | Short Screening Scale for DSM-IV PTSD | - | No | 8 |
| **II.** | **Depression** | | | | | | | | | | |
| Baranyi et al[34] | Scotland, UK | Scottish Longitudinal Study | Adulthood | 129,945 | L | MC | Data zone (≤1,000) | Antidepressants prescription | Income | No | 10 |
| Beck et al[35] | Denver, US | Kaiser Permanente, Denver Health | Adulthood | 165,600 | C | MC | Census tract (2,001-5,000) | Diagnosis (ICD-9: 296.x, 298.0, 300.4, 309.x, 311) | Education, Poverty, Income, Housing tenure, Public assistance, Employment | No | 8/9 |
| Chen & Chen[36] | Urban China | Migration and Quality of Life Survey | Adulthood | 1,250 | C | MC | Urban prefecture (≥50,001) | CESD-8 | GDP | No | 8 |
| Dustmann & Fasani[25] | England, UK | English Longitudinal Study of Ageing | Late adulthood | ~16,600 observations | L | MC | Local Authority (≥50,001) | Modified CESD | Welfare benefiters | No | 10 |
| Generaal et al[20] | The Netherlands | Netherlands Mental Health Survey and Incidence Study-2; Healthy Life in an Urban Setting study; Netherlands Twin Register; New Hoorn | Adulthood | 28,444 | C | MC | Four-digit postal code (2,001-5,000) | CIDI; PHQ-9; HADS-D; CESD-20; BDI-II | SES, Home value, Social security beneficiaries | No | 9/8 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Study; Longitudinal Aging Study Amsterdam; Generations[2] | | | | | | | | | |
| Joshi et al[37] | New York City, US | New York City Neighborhood and Mental Health in the Elderly Study II | Late adulthood | 2,023 | L | VC | 1-km buffer (10,001-50,000) | PHQ-9 | Poverty | No | 10 |
| Meng et al[38] | Montreal, Canada | Montreal South-West Longitudinal Catchment Area study | Adulthood | 1,357 | L | MC | 500-meter buffer (2,001-5,000) | CIDI | Income, Employment | No | 9/8 |
| Norstrand[39] | Philadelphia, US | Community Health Data Base | Adulthood | 983 | C | VC | Census tract (2,001-5,000) | CESD-10 | Income | No | 7 |
| Tracy[40] | Detroit, US | Detroit Neighborhood Health Study | Adulthood | 1,037 | L | VC | City neighborhood (10,001-50,000) | PHQ-9 | - | Yes | 9 |
| Weisburd et al[26] | Baltimore, US | - | Adulthood | 2,136 | C | VC | Street segments (≤1,000) | PHQ-9 | - | No | 8 |
| Wilson-Genderson & Pruchno[41] | New Jersey, US | Ongoing Research on Aging in New Jersey: Bettering Opportunities for Wellness in Life | Late adulthood | 5,688 | C | VC | Census tract (2,001-5,000) | CESD-10 | - | No | 10 |
| **III.** | **Psychosis** | | | | | | | | | | |
| Baranyi et al[34] | Scotland, UK | Scottish Longitudinal Study | Adulthood | 129,945 | L | MC | Data zone (≤1,000) | Antipsychotics prescription | Income | No | 10 |
| Bhavsar et al[52] | London, UK | Lambeth Early Onset | Young adulthood | Person at risk: 267,000; Incidence: 405 | E | MC | Lower Super Output Area (1,001-2,000) | First episode of schizophrenia | Income, Employment; Education | No | 10 |
| Bhavsar et al[53] | London, UK | Outreach and Support in South London | Young adulthood | Person-years at risk: 2,347,022; Incidence: 336 | E | MC | Lower Super Output Area (1,001-2,000) | CAARMS | - | No | 10 |
| Newbury et al[54] | England and Wales, UK | Environmental Risk Longitudinal Twin Study | Adolescence | 2,232 | L | MC | 1-mile buffer (2,001-5,000) | Psychotic experiences | Poverty | No | 10 |

| IV. | Psychological distress/ Internalising symptoms | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alcock et al[42] | Rural England, UK | British Household Survey Panel | Adulthood | 2,200 | L | MC | Lower Super Output Area (1,001-2,000) | GHQ-12 | Income, Employment, Education | No | 12 |
| Ambrey & Shahni[18] | Teheran, Iran | Urban Health Equity Assessment and Response Tool-2 | Adulthood | 19,060 | C | PC | City districts (≥50,001) | GHQ-28 | - | No | 7 |
| Astell-Burt et al[22] | New South Wales, Australia | 45 and Up Study | Late adulthood | 54,844 | L | VC, PC | Statistical Local Area (10,001-50,000) | K10 | - | No | 10 |
| Baranyi et al[34] | Scotland, UK | Scottish Longitudinal Study | Adulthood | 129,945 | L | MC | Data zone (≤1,000) | Anxiolytics or antidepressants prescription | Income | No | 10 |
| Cornaglia et al[43] | Urban Australia | Household, Income, and Labor Dynamics in Australia | Adulthood | 32,594 observations | L | VC, PC | Local Governmental Area (≥50,001) | MCS | Employment, Income | Yes | 11 |
| Dustmann & Fasani[25] | England and Wales, UK | British Household Panel Survey | Adulthood | ~35,000 observations | L | MC | Local Authority (≥50,001) | GHQ-12 | Welfare benefiters | No | 12 |
| Fagg et al[44] | London, UK | Research with East London Adolescents: Community Health Survey | Adolescence | 2,370 | C | MC | Middle Layer Super Output Areas (5,001-10,000) | SDQ | - | No | 8 |
| Goldman-Mellor et al[45] | California, US | California Health Interview Survey | Adolescence | 4,462 | C | VC | Census tract (2,001-5,000) | K6 | Socioeconomic disadvantage | No | 7 |
| Long[46] | Baltimore, US | - | Adulthood | 270 | L | MC | Census block neighbourhoods (2,001-5,000) | STAI/ CESD-6 | Housing tenure, SES | Yes | 12 |
| McCoy et al[47] | Chicago, US | Chicago School Readiness Project; Chicago Head Start | Childhood | 327 | C | MC | Census tract (2,001-5,000) | TRF | Education, Poverty | Yes | 7 |
| Pearson & Breetzke[48] | New Zealand | New Zealand General Social Survey | Adulthood | ~8,550 | C | MC | Census area unit (2,001-5,000) | MCS-12 | Deprivation | Yes | 9 |
| Polling et al[49] | London, UK | South East London Community Health | Adulthood | 1,698 | C | MC | Lower Super Output Area (1,001-2,000) | CIS-R | - | Yes | 9 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stockdale et al[50] | US | Health Care for Communities | Adulthood | 12,716 | C | VC | County (≥50,001) | CIDI-SF | Income, Home ownership | Yes | 7 |
| Villarreal & Yu[24] | Mexico | Mexican Family Life Survey | Adulthood | 30,749 | L | VC | Municipalities (10,001-50,000) | Modified GHQ | - | Yes | 10 |
| White et al[51] | Urban England, UK | British Household Panel Survey | Adulthood | 12,818 | L | MC | Lower Super Output Area (1,001-2,000) | GHQ-12 | Income, Employment, Education | No | 11 |

BDI=Beck Depression Inventory; C=cross-sectional; CAARMS=Comprehensive Assessment of At-Risk Mental States; CESD=Center for Epidemiological Studies Depression; CIDI(-SF)=Composite International Diagnostic Interview (Short Form); CIS-R=Clinical Interview Schedule-Revised; DSM=Diagnostic and Statistical Manual of Mental Disorders; GHQ=General Health Questionnaire; HADS-D=Hospital Anxiety and Depression Scale–Depression; ICD=International Classification of Diseases; K=Kessler Psychological Distress Scale; L=longitudinal; MC=mixed crime; MCS=Mental Component Summary of SF36; PC=property crime; PHQ=Patient Health Questionnaire; PTSD=post-traumatic stress disorder; SDQ=Strengths and Difficulties Questionnaire; STAI=State-Trait Anxiety Inventory; TRF=Teacher's Report Form; VC=violent crime.

***Table 2.2*** *Studies reporting the association between perceived neighbourhood crime and mental health*

| Study | Location | Data sources | Age group | Sample size | Study design | Neighbourhood crime | | Outcome | Control for | | QA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Type | Assessment (individual or aggregated)* | | Area socioeconomic status | Individual crime exposure | |
| ***I.*** **Anxiety** | | | | | | | | | | | |
| Secretti et al[63] | 6 state capitals in Brazil | Brazilian Longitudinal Study of Adult Health | Adulthood | 10,392 | C | MC | Individual: (1) feeling safe walking day or night; (2) violence is a problem; (3) neighbourhood is safe with regard to crimes | CIS-R | - | No | 7 |
| Schriber et al[62] | Northern California, US | California Families Project | Adolescence | 209 | L | MC | Individual: (1) violent crimes (e.g. stabbings, shootings, assaults); (2) taking others' wallets or purses; (3) damaging property; (4) breaking into homes and cars; (5) throwing trash in the streets/ breaking glass; (6) gang fights; (7) drug use and dealing; (8) alcohol use in public; (9) graffiti; (10) groups of people making feel unsafe; (in school and in neighbourhood) | SCARED | - | No | 8 |
| Simning et al[64] | US | National Survey of American Life | Adulthood | 2,820 | C | MC | Individual: (1) problems with muggings, burglaries, assaults or anything else like that | CIDI | - | No | 6 |
| ***II.*** **Depression** | | | | | | | | | | | |
| Baranyi et al[17] | 13 European countries | The Survey of Health, Ageing and Retirement in Europe | Late Adulthood | 10,328 | L | MC | Individual: (1) vandalism, crime | EURO-D | - | No | 9 |
| Forehand & Jones[55] | New Orleans, US | The Family Health Project | Childhood | 117 | C/L | VC | Individual: (1) physical fighting, (2) shootings or knifings, (3) people being killed | CDI | - | No | 8 |
| Jones et al[56] | New Orleans, US | The Family Health Project | Childhood | 137 | C | MC | Individual: (1) gangs; (2) physical fighting; (3) shootings or knifings; (4) people being killed; (5) drug use or drug dealing | CDI | - | No | 5 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Kim[57] | Metropolitan areas of Miami/ Ft. Lauderdale, San Diego, US | Children of Immigrants Longitudinal Study | Adolescence | 2,114 | C | MC | Individual: (1) racial or cultural groups do not get along; (2) little respect for rules, laws and authority; (3) assaults and muggings; (4) delinquent gangs or drug gangs; (5) drug use or drug dealing in the open | CESD-4 | - | No | 6 |
| Lowe et al[58] | Jamaica, St. Vincent, St. Kitts and Nevis, The Bahamas | - | Adolescence | 1,955 | C | MC | Individual: (1) fight with a weapon; (2) youth gang conflict; (3) people hit by police; (4) someone badly hurt; (5) burglary of homes; (6) mugging or robbery; (7) assault by strangers; (8) people afraid to go out after dark; (9) you take a big risk walking alone after dark | BDI-II | - | No | 7/6 |
| Mair et al[59] | New York City, US | Multi-Ethnic Study of Atherosclerosis | Late Adulthood | 548 | L | VC | Aggregated (census tract 2,001-5,000): (1) fight in which a weapon was used; (2) gang fight; (3) sexual assault or rape; (4) robbery or mugging | CESD-20 | - | No | 12/ 11 |
| | | | | | | MC | Aggregated (census tract 2,001-5,000): (1) safe walking day or night; (2) violence is not a problem; (3) neighborhood is safe from crime | | | | |
| Mair et al[60] | Chicago, US | Chicago Community Adult Health Study | Adulthood | 3,105 | C | VC | Individual/ Aggregated (cluster, 5,001-10,000): (1) fight in which a weapon was used; (2) gang fight; (3) sexual assault or rape;(4) robbery or mugging | CESD-11 | - | No | 9/8 |
| Meffert et al[21] | South Africa | South African National Income Dynamics Study | Adulthood | 7,173 | L | MC | Individual: (1) burglary/mugging/ theft; (2) violence between members of the same household; (3) violence between members of different households; (4) gangsterism; (5) murder/shootings/ stabbings | CESD-10 | - | No | 12/ 8 |
| Moore et al[61] | Forsyth County, New York City, Baltimore, St Paul, Los Angeles, Chicago, US | Multi-Ethnic Study of Atherosclerosis | Late Adulthood | 5,475 | L | MC | Individual/Aggregated (1-mile buffer; 10,001-50,000): (1) feel safe walking day or night; (2) violence is not a problem; (3) neighbourhood is safe from crime | CESD-20 | - | No | 11 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Schriber et al[62] | California, US | California Families Project | Adolescence | 209 | L | MC | Individual: (1) violent crimes (e.g. stabbings, shootings, assaults); (2) taking others' wallets or purses; (3) damaging property; (4) breaking into homes and cars; (5) throwing trash in the streets/ breaking glass; (6) gang fights; (7) drug use and dealing; (8) alcohol use in public; (9) graffiti; (10) groups of people making feel unsafe; (in school and in neighbourhood) | CDI-2 | - | No | 8 |
| Secretti et al[63] | 6 state capitals in Brazil | Brazilian Longitudinal Study of Adult Health | Adulthood | 10,392 | C | MC | Individual: (1) feeling safe walking day or night; (2) violence is a problem; (3) neighbourhood is safe with regard to crimes | CIS-R | - | No | 7 |
| Simning et al[64] | US | National Survey of American Life | Adulthood | 2,820 | C | MC | Individual: (1) problems with muggings, burglaries, assaults or anything else like that | CIDI | - | No | 6 |
| Simons et al[65] | Iowa and Georgia, US | Family and Community Health Study | Childhood | 810 | C | VC | Aggregated (clusters, 5,001-10,000): (1) violent arguments; (2) fights with weapons; (3) robbery; (4) gang conflict, (5) sexual assault | DISC-IV | Poverty | Yes | 7 |
| Teychenne et al[66] | Victoria, Australia | Resilience for Eating and Activity Despite Inequality Study | Young adulthood | 4,065 | C | MC | Individual: (1) feeling safe walking day or night; (2) neighbourhood is safe from crime; (3) violence is not a problem | CESD-10 | - | No | 5 |
| Tomita et al[67] | South Africa | South African National Income Dynamics Study | Adulthood | 13593 | C | MC | Aggregated (clusters, NI): (1) burglaries, muggings or thefts; (2) violence between members of the same household; (3) violence between members of different households; (4) gangsterism; (5) murder, shootings or stabbings; (6) drug or alcohol abuse | CESD-10 | - | No | 8 |
| *III.* | **Psychosis** | | | | | | | | | | |
| Kirkbride et al[74] | UK, South London | Aetiology and Ethnicity in Schizophrenia | Adulthood | Person-years at risk: 565,576; | E | MC | Aggregated (ward, 5,001-10,000): (1) graffiti; (2) teenagers hanging around; (3) drunks or tramps on the streets; (4) vandalism and deliberate damage to | SCAN | Deprivation | No | 9 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | and Other Psychoses | | Incidence: 148 | | | property; (5) insults or attacks to do with someone's race or colour; (6) homes broken in to; (7) cars broken in to or stolen; (8) people attacked on the streets | | | | |
| *IV.* | **Psychological distress/ Internalising symptoms** | | | | | | | | | | |
| Bostean et al[68] | US | National Latino and Asian American Survey; Latino sample | Adulthood | 2,524 | C | MC | Individual: (1) feeling safe alone in the at night; (2) people get mugged; (3) people sell/use drugs | K10 | - | No | 7 |
| Delgado et al[69] | Western Andalusia, Spain | - | Adolescence | 2,400 | C | MC | Individual: (1) people sell drugs; (2) some of my friends are afraid to come to my neighbourhood; (3) crimes and hooliganism; (4) fights between street gangs | YSR | - | No | 5 |
| Fauth et al[70] | Chicago, US | Project on Human Development in Chicago Neighborhoods; 9-, and 12-year-olds | Childhood | 1,315 | L | VC | Aggregated (clusters, 5,001-10,000): (1) fight in which a weapon was used; (2) violent argument between neighbours; (3) gang fight; (4) sexual assault or rape; (5) robbery or mugging | CBCL | - | No | 12 |
| Ma et al[71] | Sydney, Australia | - | Adulthood | 562 | C | MC | Individual: (1) high crime rate; (2) crime rate makes it unsafe to go on walks during the day; (3) the crime rate makes it unsafe to go on walks at night | MCS | - | No | 6 |
| Pals et al[72] | Houston, US | - | Adolescence | 1,333 | L | MC | Individual: (1) sexual assaults or rapes; (2) burglaries and thefts; (3) assaults and muggings; (4) organized crime; (5) racial groups not getting along with each other; (6) gangs | Symptoms of anxiety, depressive affect and self-derogation | Economic problems | No | 7 |
| Putrik et al[73] | Maastricht, The Netherlands | - | Adulthood | 9,879 | C | PC | Individual/Aggregated (four-digit postal code (2,001-5,000): (1) bike thefts; (2) thefts from the car; (3) damage to car or thefts from outside the car; (4) car thefts; (5) burglaries | K10 | - | No | 8 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Secretti et al[63] | 6 state capitals in Brazil | Brazilian Longitudinal Study of Adult Health | Adulthood | 10,392 | C | MC | Individual: (1) feeling safe walking day or night; (2) violence is a problem; (3) neighbourhood is safe with regard to crimes | CIS-R | - | No | 7 |

* For studies utilising aggregated reports, area of aggregation with average population size are provided.

BDI=Beck Depression Inventory; C=cross-sectional; CBCL=Child Behavior Checklist; CESD=Center for Epidemiological Studies Depression; CID=Children's Depression Inventory; CIDI=Composite International Diagnostic Interview, CIS-R=Clinical Interview Schedule-Revised; DISC=Diagnostic Interview Schedule for Children; K=Kessler Psychological Distress Scale; L=longitudinal; MC=mixed crime; MCS=Mental Component Summary of SF36; NI=no information; PC=property crime; SCAN=Schedules for Clinical Assessment in Neuropsychiatry; SCARED=Screen for Child Anxiety Related Emotional Disorders; VC=violent crime; YSR=Youth Self-Report.

Meta-analyses indicated an increased risk of depression in higher crime areas (r=0.044, 95% CI 0.029-0.059), with substantial heterogeneity (Cochran's Q=226.720) between the 44 estimates *(Table 2.3)*.[17,20,21,25,26,34-41,55-67] Associations were stronger among young adults (B=0.119, 95%CI 0.047-0.191), in studies utilising individual-level perceived crime (B=0.049, 95%CI 0.020-0.077), and weaker when area-level deprivation was taken into account (B=-0.036, 95%CI -0.064—0.009) *(Table 2.4)*. After retaining all statistically significant predictors and study design in the multivariate mixed-effects models, studies based on young adults (B=0.075, 95%CI 0.006-0.143) and on cross-sectional samples (B=-0.027, 95%CI -0.048—0.007) had stronger crime-depression associations; and there was a trend for an increased association in studies with perceived crime (B=0.040, 95%CI -0.004-0.084). More importantly, in this multivariate model intercept remained significant indicating robust association between neighbourhood crime and depression (r=0.038, 95%CI 0.003-0.074) *(Table 2.4)*.

***Table 2.3*** *Pooled neighbourhood crime effects*

| | Pearson's r | 95% CI lower | 95% CI upper | p-value | Heterogeneity Cochran's Q | Heterogeneity p-value |
|---|---|---|---|---|---|---|
| Anxiety (k=6) | 0.058 | 0.004 | 0.111 | 0.040 | 14.843 | 0.011 |
| Depression (k=44) | 0.044 | 0.029 | 0.059 | <0.001 | 226.720 | <0.001 |
| Psychosis (k=5) | 0.034 | -0.010 | 0.078 | 0.097 | 8.891 | 0.064 |
| Psychological distress (k=28) | 0.036 | 0.017 | 0.056 | <0.001 | 122.666 | <0.001 |

k=number of included estimates.

The pooled association between crime and psychological distress/internalising symptoms was significant (r=0.036, 95%CI 0.017-0.056) *(Table 2.3)* but with high heterogeneity between the 28 estimates (Cochran's Q=122.666).[18,22,24,25,34,42-46,48,49,51,63,68-73] Studies of older adults had stronger associations (B=0.087, 95%CI 0.045-0.129), while those adjusted for area deprivation (B=-0.043, 95%CI -0.075—0.012) and individual crime exposure (B=-0.048, 95%CI -0.089—0.007) had weaker associations *(Table 2.4)*.

Multivariate models including significant moderators, as well as study design and crime measurement, showed stronger associations among older adults (B=0.079, 95%CI 0.031-0.127) and in studies utilizing perceived crime (B=0.036, 95%CI 0.002-0.071), while those based on samples of children showed weaker associations (B=-0.079, 95%CI -0.152—0.006). Finally, the neighbourhood crime intercept remained weakly associated with psychological distress (r=0.025, 95%CI -0.004-0.054) *(Table 2.4)*.

***Table 2.4*** *Univariate and multivariate mixed-effects models*

| | **Depression (k=44)** | | | | **Psychological distress (k=28)** | | | |
|---|---|---|---|---|---|---|---|---|
| | B | 95% CI lower | 95% CI upper | p-value | B | 95% CI lower | 95% CI upper | p-value |
| **Univariate Meta-Regression** | | | | | | | | |
| Sex (% of female in 10) | 0.003 | -0.005 | 0.010 | 0.472 | 0.001 | -0.010 | 0.013 | 0.814 |
| Age groups | | | | | | | | |
| Adulthood | ref | | | | ref | | | |
| Childhood | 0.031 | -0.046 | 0.108 | 0.425 | -0.065 | -0.131 | 0.001 | 0.052 |
| Adolescence | 0.010 | -0.038 | 0.058 | 0.676 | 0.016 | -0.024 | 0.055 | 0.430 |
| Young adulthood | **0.119** | **0.047** | **0.191** | **0.002** | N/A | | | |
| Middle adulthood | -0.012 | -0.090 | 0.065 | 0.750 | N/A | | | |
| Late adulthood | 0.016 | -0.018 | 0.049 | 0.348 | **0.087** | **0.045** | **0.129** | **<0.001** |
| Minority (% in 10) | 0.002 | -0.003 | 0.008 | 0.398 | -0.001 | -0.011 | 0.010 | 0.895 |
| Geographic area (1-6) | -0.004 | -0.013 | 0.004 | 0.321 | 0.005 | -0.008 | 0.018 | 0.415 |
| Crime measurement | | | | | | | | |
| Objective | ref | | | | ref | | | |
| Perceived, individual | **0.049** | **0.020** | **0.077** | **0.001** | 0.030 | -0.013 | 0.074 | 0.163 |
| Perceived, aggregated | 0.024 | -0.008 | 0.056 | 0.141 | -0.010 | -0.078 | 0.058 | 0.761 |
| Crime type | | | | | | | | |
| Property | ref | | | | ref | | | |
| Violent | 0.006 | -0.050 | 0.063 | 0.818 | -0.036 | -0.079 | 0.006 | 0.089 |
| Study design | | | | | | | | |
| Cross-sectional | ref | | | | ref | | | |
| Longitudinal | -0.022 | -0.049 | 0.006 | 0.118 | 0.008 | -0.032 | 0.048 | 0.685 |
| Outcome criteria | | | | | | | | |
| Broad | ref | | | | ref | | | |
| Barrow | -0.009 | -0.045 | 0.027 | 0.622 | 0.013 | -0.054 | 0.081 | 0.684 |
| Adjustment for: | | | | | | | | |
| - crime exposure | 0.004 | -0.066 | 0.073 | 0.919 | **-0.048** | **-0.089** | **-0.007** | **0.022** |
| - area deprivation | **-0.036** | **-0.064** | **-0.009** | **0.012** | **-0.043** | **-0.075** | **-0.012** | **0.009** |
| - area social processes | 0.005 | -0.019 | 0.029 | 0.680 | -0.005 | -0.051 | 0.040 | 0.810 |
| Quality Score | -0.005 | -0.013 | 0.003 | 0.231 | -0.004 | -0.013 | 0.006 | 0.459 |
| **Multivariate Meta-Regression** | | | | | | | | |
| Intercept | **0.038** | **0.003** | **0.074** | **0.036** | 0.025 | -0.004 | 0.054 | 0.085 |
| Age groups | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Adulthood | ref | | | | ref | | | |
| Childhood | 0.015 | -0.066 | 0.095 | 0.714 | **-0.079** | **-0.152** | **-0.006** | **0.035** |
| Adolescence | -0.036 | -0.087 | 0.015 | 0.164 | -0.002 | -0.040 | 0.035 | 0.896 |
| Young adulthood | **0.075** | **0.006** | **0.143** | **0.033** | N/A | | | |
| Middle adulthood | -0.007 | -0.078 | 0.064 | 0.832 | N/A | | | |
| Late adulthood | 0.025 | -0.006 | 0.057 | 0.114 | **0.079** | **0.031** | **0.127** | **0.003** |
| Crime measurement | | | | | | | | |
| Objective | ref | | | | ref | | | |
| Perceived, individual | 0.040 | -0.004 | 0.084 | 0.071 | **0.036** | **0.002** | **0.071** | **0.041** |
| Perceived, aggregated | 0.011 | -0.033 | 0.055 | 0.612 | 0.019 | -0.039 | 0.078 | 0.503 |
| Study design | | | | | | | | |
| Cross-sectional | ref | | | | ref | | | |
| Longitudinal | **-0.027** | **-0.048** | **-0.007** | **0.011** | 0.014 | -0.015 | 0.043 | 0.332 |
| Adjustment for: | | | | | | | | |
| - crime exposure | N/A | | | | -0.009 | -0.036 | 0.018 | 0.475 |
| - area deprivation | -0.009 | -0.047 | 0.029 | 0.635 | -0.019 | -0.050 | 0.011 | 0.207 |

k=number of included estimates.

The meta-analysed results indicated statistically significant pooled neighbourhood crime-anxiety associations (r=0.058, 95%CI 0.004-0.111; Cochran's Q=14.843, p=0.011); and there was a weak link to psychotic problems (r=0.034, 95%CI -0.010-0.078; Cochran's Q=8.891, p=0.064) *(Table 2.3)*. The small number of included estimates precluded further analyses on anxiety (k=6)[23,26,34,62-64] and psychosis (k=5).[34,52-54,74]

Publication bias could only be detected among studies with depression as an outcome (Kendall's tau=0.215; p=0.047; *Supplementary Figure 2.1*). In the sensitivity analyses, after excluding two outlier estimates for depression and one for psychological distress *(Supplementary Figure 2.2)*, pooled associations decreased but remained significant for depression (r=0.036, 95%CI 0.024-0.048) and psychological distress (r=0.058, 95%CI 0.004-0.111); publication bias was no longer present for depression *(Supplementary Table 2.3)*. The main results did not change when robust variance estimations were applied *(Supplementary Table 2.4)*, but slightly increased after excluding studies with >5 adjusted neighbourhood covariates *(Supplementary Table 2.5)*. Finally, when studies with binary and continuous outcome measures were pooled separately, they remained statistically significant for depression (RR=1.09, 95%CI 1.02-1.16; r=0.05, 95%CI 0.03-0.07) and psychological distress (RR=1.22, 95% CI 1.08-1.37; r=0.02, 95% CI 0.01-0.03), and were close to significance level for anxiety (RR=1.25, 95% CI 0.97-

1.62) and psychosis (RR=1.13, 95% CI 0.97-1.31) (forest plots are shown in *Supplementary Figure 2.3. and 2.4*).

## 2.6 Discussion

This systematic review and meta-analysis suggests that residing in high crime areas is linked to mental health problems. Associations were more robust for depression and psychological distress, where further analyses uncovered stronger links in studies utilising individual-level perceived crime assessment and cross-sectional design, and varying vulnerability across the life-course. While we were able to identify an indication of elevated risk of anxiety and psychosis in high crime neighbourhoods, these were based on a few studies.

To our knowledge, this is the first comprehensive systematic review and meta-analysis on the association between neighbourhood crime and mental health, and one of the first ones on the contextual determinants of mental health.[5] Pooled estimates were small, which is common in the literature on area effects[5] but they were comparable in magnitude to well-known public health challenges such as the effect of second-hand smoking on cancer.[75] Considering the large populations living in high crime areas, as well as the high prevalence of mental disorders,[2] these associations present a significant challenge to global mental health. Our results indicated that neighbourhood crime effects may vary between age groups. Although differences were based only on very few studies reporting children's internalising symptoms,[47,70] depression in the young,[66] and psychological distress in late adulthood,[22] they highlight the importance of exploring differential vulnerability to neighbourhood crime exposure across the life course.

Studies often implied causal pathways leading from neighbourhood crime exposure to mental health. However, there is evidence of higher risk of crime victimisation among people with existing mental health problems, especially for women, being more vulnerable.[76] Also, health-selective migration into more socially disadvantaged and/or higher crime areas, as part of a downwards circle of social selection through

unemployment and low income, may be plausible among individuals with particular mental health trajectories. Studies included in our review had varying quality with the majority utilizing observational data and applying cross-sectional design, which are prone to reverse causation. Although higher quality longitudinal investigations confirmed a reduced but significant link between neighbourhood crime and mental health, this review cannot draw conclusions on causal mechanism based on available evidence.

It is plausible that perceived crime, as a more proximal factor, mediates the effect of objective crime on mental health,[8] which may explain the different effect sizes between objective and subjective measurements in our analyses. However, there is not only a modest correlation between perceived and objective crime,[41,45] but also measurement-specific errors which may have affected the findings. Self-reported exposures and outcomes increase the risk of same source bias (i.e. correlated measurement errors),[4,5] and reverse causation (i.e. people with mental health conditions perceive their neighbourhood as more dangerous). On the other hand, outcomes measured using administrative data might under-report crime incidents and administrative areas chosen as units of aggregation are unlikely to coincide with people's self-defined neighbourhood.[4] Criminological research shows that crime is concentrated in a few hot spots (law of crime concentration),[7,26] providing an adequate spatial specificity for assessing crime effects,[26] but also questioning the appropriateness of aggregating into large scales and their potential interpretation. Moreover, studies with objectively measured crime often adjust for other, highly correlated, area-level characteristics (e.g. income deprivation), likely to lead to over-adjustment.

This systematic review applied rigorous selection criteria (for example, we separated perceived crime from measures of neighbourhood disorder and included only confounder-adjusted estimates as a response to earlier critiques[5]), considered biases arising from methodological and sample characteristics, and tested the robustness of findings in a wide range of sensitivity analyses. However, it has limitations. First,

studies had varying quality — with no study achieving the highest appraisal score — and limited geographic coverage (86% of studies were from high-income countries). Second, data on anxiety and psychosis were scarce, and for the latter only two samples utilised individual-level information. Third, crime operationalisation, study design and statistical approach varied across studies; therefore, effect estimate transformation inherently led to less precise findings. Last, although studies assessing the effect of direct crime exposure were excluded from this review, their unmeasured impact likely affected the findings.

Future research should extend the knowledge base by disentangling the complex causal pathways between local crime and mental health utilising high quality longitudinal investigations and quasi- or natural-experimental approaches (e.g. crime reduction policies, changing crime levels).[4] Identifying vulnerable sociodemographic groups and exploring crime effects between different mental disorders (e.g. for rare outcomes utilising administrative datasets) may help to better target policies and interventions. While researchers investigating crime effects might consider using smaller scale geographic units following findings on spatial crime concentration,[7,26] analysing how national-level social, economic and health policies influence the local crime-mental health relationship merits further attention.[77]

Crime in residential areas is a significant public health, social, economic and legal concern, requiring systems-based approaches in intervention and policy. Complex neighbourhood-based programmes (e.g. reducing alcohol availability, area rehabilitation, greening vacant parcels)[78] alongside with macro-level interventions (e.g. reducing harms related to poverty) can better address the determinants of crime[7,8] and may have benefits for public mental health. Allocating universal or targeted mental health preventions in the vicinity of high crime areas present opportunities to reduce the incidence of mental disorders, and can be particularly useful in early ages where skills and coping strategies can be acquired (e.g. in school context).[79] Finally, cooperation between professionals tasked with crime and mental

health prevention and intervention (e.g. spatially targeted policing paired with mental health professionals)[80] could have long-term benefits on population level.

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# CHAPTER 3

# 3. Neighbourhood effects and depression across 16 countries

## 3.1 Chapter overview

The focus of this chapter is on perceived social environment and depression among older adults. It explores how the relationship between neighbourhood and mental health can be modified by macro-level social, political, economic and environmental factors. Two major literature gaps are addressed: First, the majority of studies on neighbourhood and mental health has been conducted in Anglo-Saxon countries, limiting the cross-national generalizability of findings (see 2.6). Second, while it is plausible that there are country-level differences in neighbourhood effects, it has not yet been empirically tested utilising explanatory country-level indicators.

The chapter in its current version has been published in the *American Journal of Epidemiology* and available online as follows:

> *Baranyi G, Sieber S, Cullati S, Pearce J, Dibben C, Courvoisier D. The Longitudinal Association of Perceived Neighborhood Disorder and Lack of Social Cohesion With Depression Among Adults Aged 50 and Over: An Individual Participant Data Meta-Analysis From 16 High-Income Countries. Am J Epidemiol 2019, https://doi.org/10.1093/aje/kwz209 [Epub ahead of print]*

The paper received a favourable invited commentary from Professor Mikael Rostila, Stockholm University/Karolinska Institutet.[1] The commentary provided an in-depth discussion on the welfare regimes concept and further explanations on how specific regimes may impact the effect of social capital on mental health. Moreover, it suggested for future research to examine specific welfare state features, rather than using the crude classification. To adequately answer these recommendations, further analyses were conducted to explore effect modification by country-specific social spending:

> *Baranyi G, Sieber S, Cullati S, Pearce J, Dibben C, Courvoisier DS. Response to Commentary. Am J Epidemiol 2019, https://doi.org/10.1093/aje/kwz208 [Epub ahead of print]*

At the end of this chapter, a short assessment explored the risk of selection bias at unit and item level, as well as multicollinearity between independent variables, easing to address overall strengths and limitations. Due to space restrictions in epidemiological journals, this information was not included in the original publication, but attached to this chapter as an additional material (same for Chapter 4-6).

Referred supplementary material can be found in Appendix Two.

**Reference**

1. Rostila M, Social cohesion, depression and the role of welfare states, *Am J Epidemiol* 2019, https://doi.org/10.1093/aje/kwz207 [Epub ahead of print]

**Title**

The Longitudinal Associations of Perceived Neighbourhood Disorder and Lack of Social Cohesion With Depression Among Adults Aged 50 Years or Older: An Individual Participant Data Meta-Analysis From 16 High-Income Countries

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*Author's contribution*: G. B. developed the project design, conducted the data analysis and drafted the first manuscript. D. S. C. supported design, statistical methods and writing. S. S. prepared the SHARE dataset for analyses. S. S., S. C., J. P. and C. D. contributed to the project design and to the interpretation of the results. All authors reviewed and commented on the manuscript, and approved the final version.

## 3.2 Abstract

Although residential environment might be an important predictor of depression among older adults, systematic reviews point to a lack of longitudinal investigations, and the generalizability of the findings is limited to a few countries. We used longitudinal data collected between 2012 and 2017 in 3 surveys, including 15 European countries and the United States, and comprising 32,531 adults aged 50 years and older. The risk of depression according to perceived neighbourhood disorder and lack of social cohesion was estimated using two-stage individual participant data meta-analysis; country-specific parameters were analysed by meta-regression. We conducted additional analyses on retired individuals. Neighbourhood disorder [odds ratio (OR)=1.25] and lack of social cohesion (OR=1.76) were significantly associated with depression in the fully adjusted models. In retirement, the risk of depression was even higher (neighbourhood disorder: OR=1.35; lack of social cohesion: OR=1.93). Heterogeneity across countries was low and was significantly reduced by the addition of country-level data on income inequality and population density. Perceived neighbourhood problems increased the overall risk of depression among adults aged 50 years or older. Policies, especially in countries with stronger links between neighbourhood and depression, should focus on improving the physical environment and supporting social ties in communities, which can reduce depression and contribute to healthy ageing.

## 3.3 Background

Depression is one of the leading causes of disability worldwide, affecting 1 out of 5 individuals during their lifetime,[1] and it is associated with a large economic burden.[2] Approximately 13.5% of people over the age of 50 years suffer from clinically relevant depressive symptoms,[3] and this percentage rises dramatically among the oldest old (age ≥ 80 years).[4] Because of global ageing, the number of people older than 65 years is expected to grow almost 3-fold by 2050,[5] which will significantly increase the disease burden related to depression. These processes present a range of challenges for social, economic and health-care systems, and require age-specific adaptations to support healthy ageing.[6]

In ageing individuals, psychosocial and health-related determinants become more prominent risk factors for the incidence[7] and recurrence[8] of depression. Because of morbidity, functional decline, and life-course transitions (e.g. retirement), older people tend to spend more time in their local area, which affects the pathways through which physical and social characteristics influence their social and psychological well-being.[6,9] Exposure to adverse neighbourhood conditions, such as vandalism, crime, littering, and heavy traffic, have been found to increase the risk of depression through direct and indirect pathways,[10,11] while social cohesion or social capital buffers individual distress and weakens the risk of depression.[12,13]

Although there is a growing body of literature on neighbourhoods and mental health, relatively few studies have assessed the longitudinal associations for this age group,[9] and evidence is based on a low number of (mainly Anglo-Saxon) economies, limiting the generalizability of the findings. Examining the evidence of possible neighbourhood effects in different settings will provide further insights into the public health significance of the residential environment. In addition, the inclusion of several countries enables the consideration of between-country heterogeneity in neighbourhood effects. Although previous studies have shown that the prevalence of depression[14] and its association with social inequality[15] differs by welfare regime (i.e. typology indicating how states manage their economies and provide social protection

and income transfers; originally introduced by Esping-Andersen[16]), there is no evidence of differential neighbourhood effects. Moreover, because of micro- and meso-level social and environmental factors (e.g. population density, green space, air pollution) have been previously associated with mental health, and also interact with each other,[9] it is feasible that they will modify neighbourhood effects on mental health between countries. An understanding of how country-level social, environmental, or welfare-state differences influence the link between neighbourhood and mental health can help in prioritising public health policies and interventions at the national-level.

Our primary aims in this individual participant data (IPD) meta-analysis were the following. First, we examined the longitudinal associations (2 years) of perceived neighbourhood disorder and social cohesion with depressive symptoms among adults aged 50 years or older, estimating the risk in a wide range of European and North-American countries. Second, using meta-regression, we explored effect modification by type of welfare regime and other macro-level social or environmental indicators in the country-specific neighbourhood effects. In a secondary analysis, we investigated the robustness of our findings for retired individuals, a subgroup, for whom we assumed that there would be stronger associations than in the general sample, since this group tends to spend more time in a residential environment.

## 3.4 Methods

### 3.4.1 Data sources

Data were drawn from 3 representative longitudinal panel surveys of ageing adults: the English Longitudinal Study of Ageing (ELSA),[17] the Health and Retirement Study (HRS),[18] and the Survey of Health, Ageing and Retirement in Europe (SHARE).[19] All of the studies have comparable designs and contain information on noninstitutionalized community-dwelling adults aged 50 years or over (51 years for HRS[18]), as well as details on their partners, irrespective of their age. Participants are followed up approximately every 2 years, with regular refreshment samples being

added to compensate for attrition bias and to balance the age structure. The initial HRS cohort was recruited in the United States in 1992[20] and served as an exemplar for subsequent ageing studies. ELSA, with a representative sample for England, was set up in 2002.[17] The first wave of SHARE was conducted in 2004/2005, and the most recent wave was conducted in 2015; it included 17 European countries and Israel.[19] ELSA, HRS, and SHARE data are harmonized, allowing cross-national comparisons.

Our analytical sample comprised individuals who provided valid measurements of depression at 2 consecutive study waves and answered at least 1 question on perceived neighbourhood characteristics at the baseline wave. We excluded participants if they had depression at baseline, were living in nursing homes, were younger than 50 years, moved to a new residential address between baseline and follow-up, or had missing values for baseline covariates. Because data on the neighbourhood were not usually collected in all waves, we used the most recently available sweeps in compliance with our criteria: for ELSA, wave 7 (2014/2015) and wave 8 (2016/2017); for SHARE, wave 5 (2013) and wave 6 (2015). In the HRS, since 2006 approximately 50% of the sample has been selected for an enhanced face-to-face interview, while the other half is interviewed via telephone; the survey mode alternates in each wave. Neighbourhood perception is part of the psychosocial questionnaire, which is administered after the face-to-face interviews, once every 4 years for the same person.[18] Therefore, in order to have information for the entire HRS sample, we extracted exposure data from 2 consecutive waves (wave 11 in 2012 and wave 12 in 2014) and linked them with matching follow-ups (wave 12 in 2014 and wave 13 in 2016). The rates of attrition between baseline and follow-up were 16% for ELSA, 12% and 16% for the 2 HRS subsamples, and ranged from 15% (Switzerland) to 32% (Luxemburg) in SHARE.

### 3.4.2 Neighbourhood

For the measures of perceived neighbourhood disorder and lack of social cohesion, we used 4 similarly operationalised items asking participants about the "local area, that is, everywhere within a 20 minute walk or about a mile/ [kilometre in SHARE] of

your home." Neighbourhoods were assessed in ELSA and HRS on a 7-point bipolar scale in the self-completion part of the questionnaire, while SHARE applied a 4-point Likert scale in the interview denoting agreement or disagreement with the opposing statement. *A priori,* we assigned 2 items to the neighbourhood disorder domain, capturing 1) vandalism and crime/graffiti and 2) the cleanness of the area. Lack of social cohesion included items on 1) feeling part of the area and 2) receiving help if in trouble. Principal components analysis did not confirm the 2-component structure but indicated 1 underlying score, which provided satisfying internal consistency (Cronbach's $\alpha$: 0.57-0.82). In order to make neighbourhood variables comparable across studies, we first dichotomized all items (SHARE: 0-1 vs. 2-3; ELSA, HRS: 0-3 vs. 4-6) to obtain similar response patterns between cohorts. Scales were computed by calculating the average value of the respective items, which ranged between 0 and 1 with higher numbers indicating more problems and less cohesion in the residential area.

### 3.4.3 Depression

Depressive symptoms were assessed with 2 self-report symptom scales: the Center for Epidemiological Studies Depression (CES-D) Scale[21] and the EURO-D Scale.[22] The CES-D was implemented in ELSA and HRS, and the EURO-D was implemented in SHARE. The original CES-D Scale, containing 20 items, was developed to detect depressive symptomatology in the general population during the week preceding the interview.[21] In ELSA and HRS, a short version of the CES-D was used, with 8 items asking respondents whether (in the past week) they had felt depressed, felt that everything was an effort, had restless sleep, were happy, were lonely, enjoyed life, felt sad, or could not get going. The EURO-D Scale consists of 12 items measuring the presence of depression, pessimism, wishing for death, guilt, sleep, interest, irritability, appetite, fatigue, concentration, enjoyment and tearfulness in the last month.[22] Both scales have high internal consistency and test-retest reliability, provide a valid measurement of depression, and show high correlation within the same population.[22,23] Binary answers, indicating the presence or absence of depressive

symptoms, were summed, with scores increasing scores indicating higher levels of depressive symptoms. For approximation of a clinically significant level of depressive symptoms, a cutoff score of ≥3 was applied for CES-D,[23] and a cutoff score ≥4 was applied for the EURO-D;[22,23] these thresholds were also used in a recent comparative study.[24]

### 3.4.4 Baseline covariates

We adjusted for several sociodemographic and health-related confounders measured at baseline, that were relevant to the neighbourhood-depression association.[10,12,25,26] In addition to sex (male, female), age (because of non-linear relationship with depression, this variable was categorized as 50-59, 60-69, 70-79, and ≥80 years), and immigration (born in the country of interview or not), we included 3 indicators of socioeconomic status: educational attainment, total equalized household net wealth, and economic activity. For education, we used the International Standard Classification of Education classification from the harmonized data sets and grouped the highest educational attainment into 3 categories: primary (levels 0 and 1), secondary (levels 2- 4) and tertiary (levels 5 and 6). Household nonpension net wealth included financial, physical and housing wealth after all debt had been subtracted. We calculated an equalized measure by dividing the household sum by the square root of benefiting members,[27] and categorized it into country-specific tertiles (low, medium, or high wealth). Economic activity described whether the respondent was working (employed, self-employed), retired, or out of the labour force (homemaker, unemployed, permanently sick or disabled). We included information on partnership (married or cohabiting vs. neither) and on current smoking (yes, no). A binary variable described whether the respondent reported at least 2 out of 7 physician-diagnosed chronic diseases or conditions (arthritis, cancer, cardiovascular disease, diabetes, high blood pressure, lung disease and stroke). Finally, a measure of functional limitations indicated whether the respondent had at least 1 disability affecting Activities of Daily Living or Instrumental Activities of Daily Living.[28]

### 3.4.5 Country-level indicators

Countries were grouped into 5 types of welfare regimes based on an expanded classification[15] of Ferrera's typology,[29] which is considered a state-of-the-art typology and is often used in cross-national surveys.[15] The 1) Scandinavian welfare regimes (Denmark, Sweden) are described as having universal coverage and generous social transfers; the 2) Bismarckian regimes (Austria, Belgium, France, Germany, Luxembourg, Switzerland) have earnings-related benefits administered by the employer and familialism; the 3) Anglo-Saxon regimes (England, Israel, United States) have minimum welfare provisions and a strong emphasis on the market;[15] the 4) Southern European regimes (Italy, Spain) are characterized as "rudimentary," with services ranging from generous to limited and with high reliance on the family;[15,29] and, the 5) Eastern European regimes consist of postcommunist countries (Czech Republic, Estonia, Slovenia) which have experienced shifts towards marketization from more universalist communist welfare states.[15]

Macro-level social and environmental indicators were extracted from the World Bank Database (https://data.worldbank.org/) for the closest year of data collection *(see Supplementary Table 3.1)*: gross domestic product at purchasing power parity per capita (in current international dollars), Gini index of income inequality (from 0 to 100; with higher values indicating more inequality), population density (number of people per $km^2$), urbanization rate (percentage of the population that is urban), forest coverage (percentage of land area), and annual mean air pollution level (particulate matter less than or equal to 2.5 in μg in diameter, measured in $\mu g/m^3$). Before including these variables in the models, we standardized all external raw data. Correlations between indicators are shown in *Supplementary Table 3.2*.

### 3.4.6 Statistical analysis

We conducted a two-stage IPD meta-analysis to estimate the overall associations between perceived neighbourhood characteristics and depression.[30] First, we fitted separate logistic regression models for each country, including perceived

neighbourhood characteristics as a continuous independent variable, to obtain odds ratios (OR) for depression with 95% confidence intervals (CI). Second, we derived effect estimates and their variance and pooled them using meta-analysis. Heterogeneity between countries was quantified with the $I^2$ statistics, indicating the percentage of variance explained by individual countries.[31] Because the heterogeneity was low ($I^2$ < 25%), we fitted fixed-effects models with inverse variance pooling, assuming a single underlying true association across countries.[30] We present results from 2 sets of models: The first set of models controlled for age and sex, and the second set adjusted for all confounders (age, sex, country of birth, education, wealth, economic activity, partnership status, current smoking, chronic diseases or conditions, and functional limitations). Prior to the main analyses, we tested the linearity assumption by imputing neighbourhood variables in categorical form into the models, which was confirmed by the stepwise increasing gradients. Interaction models did not reveal significantly different neighbourhood associations among male and female participants; therefore, no sex-stratified results were prepared.

Although heterogeneity was relatively low, we still examined whether the between-country variation in the risk estimate might be explained by sample (sample size, percentage of female participants) or country characteristics (e.g. welfare regime, Gini index, air pollution). We first retained log odds and their standard errors from the fully adjusted logistic models and then performed univariable random-effects meta-regression. Models were fitted by the restricted maximum likelihood method and corrected with the Hartung-Knapp variance estimator.

Because multicentre studies can be analysed in various ways,[32] in the sensitivity analyses we derived risk estimates pooled by 1) two-stage IPD with random-effects models, and estimated with 2) one-stage IPD with random intercepts (multilevel logistic models), and 3) one-stage IPD with fixed country effects (logistic models). Although we expected only small differences,[30] we report results from the two-stage IPD meta-analysis as the main results, because in multilevel models at least 30 countries would be required to accurately estimate the country-level parameters.[33]

Findings on neighbourhood disorder and lack of social cohesion are presented in the Results section of the text, while findings from analyses of the composite neighbourhood problems score are shown in the Appendix *(Supplementary Tables 3.3 and 3.4, Supplementary Figure 3.1)*. We provided stage one results of the IPD meta-analysis (i.e. covariate adjusted logistic models by countries) for the composite neighbourhood problems score in *Supplementary Table 3.3*.

All analyses were performed using STATA 13 (StataCorp LLC, College Station, Texas).

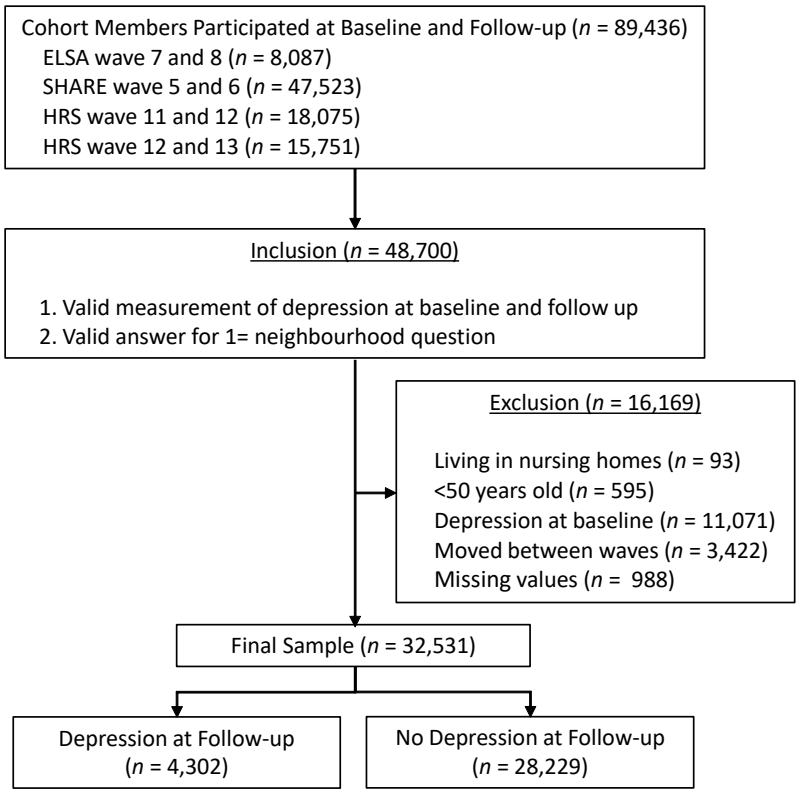


***Figure 3.1*** *Selection of participants from 3 studies (the English Longitudinal Study of Ageing [ELSA], the Health and Retirement Study [HRS] and the Survey of Health, Ageing and Retirement in Europe [SHARE]) for a pooled data set on neighbourhood perception and depression. The pooled data set contained information assessed in 16 different countries between 2012 and 2017. Note that the HRS collects information on neighbourhood perception from half of the sample in each study wave. Because the survey mode alternates between waves, we extracted and merged data from both subsamples.*

## 3.5 Results

After application of all inclusion and exclusion criteria *(Figure 3.1)*, the pooled analytical sample contained 32,531 participants from 16 countries: Austria (n = 1,448), Belgium (n = 1,875), the Czech Republic (n = 1,645), Denmark (n = 1,491), England (n = 4,634), Estonia (n = 1,713), France (n = 1,250), Germany (n = 1,819), Israel (n = 561), Italy (n = 1,157), Luxemburg (n = 456), Slovenia (n = 1,144), Spain (n = 1,742), Sweden (n = 1,640), Switzerland (n = 1,310), and the United States (n = 8,646). *Table 3.1* shows the characteristics of study participants by survey. For the total sample, 55.3% were female, and the mean age was 66.7 years. Over half of the sample (56.8%) was retired at the time of data collection. Although household wealth was defined in terms of 3 equally large categories within countries, in the analytical data set there was underrepresentation of individuals from the low wealth group, partly because of censoring of depression cases at baseline. After 2 years, the incidence of depression was 13.2% with large country variation ($P < 0.001$), ranging between 8.1% (Denmark) and 22.7% (Estonia).

***Table 3.1*** *Baseline[a] and Follow-up[b] Characteristics (%) of Adults Aged 50 Years or Older (n=32,531) From 3 Surveys Included in a Study of neighbourhood Perception and Depression, 2012–2017.*

| **Characteristics[c]** | **ELSA** (n=4,634) | **HRS** (n=8,646) | **SHARE** (n=19,251) | **Pooled Data** |
|---|---|---|---|---|
| Gender | | | | |
| Male | 46.3 | 42.0 | 45.5 | 44.7 |
| Female | 53.7 | 58.0 | 54.5 | 55.3 |
| Age | | | | |
| 50-59 | 18.2 | 26.2 | 28.4 | 26.4 |
| 60-69 | 43.3 | 30.2 | 37.1 | 36.1 |
| 70-79 | 29.1 | 31.1 | 24.8 | 27.1 |
| 80< | 9.3 | 12.6 | 9.7 | 10.4 |
| Country of birth | | | | |
| Born in the country | 94.1 | 88.6 | 89.5 | 89.9 |
| Born outside | 5.9 | 11.4 | 10.5 | 10.1 |
| Educational attainment | | | | |
| Primary | 19.2 | 12.8 | 17.3 | 16.4 |
| Secondary | 46.2 | 60.1 | 55.9 | 55.6 |
| Tertiary | 34.6 | 27.1 | 26.8 | 28.0 |

| | | | | |
|---|---|---|---|---|
| Equalized household wealth | | | | |
| Low | 26.1 | 22.4 | 30.8 | 27.9 |
| Medium | 35.7 | 36.2 | 33.4 | 34.5 |
| High | 38.2 | 41.4 | 35.8 | 37.6 |
| Economic activity | | | | |
| Employed | 30.4 | 35.4 | 29.6 | 31.3 |
| Retired | 62.6 | 49.7 | 58.7 | 56.8 |
| Out of labor force | 7.0 | 14.9 | 11.7 | 11.9 |
| Partnership status | | | | |
| In a couple | 77.1 | 68.5 | 63.9 | 67.0 |
| Alone | 22.9 | 31.5 | 36.1 | 33.0 |
| Current smoking | | | | |
| No | 91.6 | 89.5 | 82.8 | 85.9 |
| Yes | 8.4 | 10.5 | 17.2 | 14.1 |
| Chronic diseases or conditions | | | | |
| Less than two | 76.9 | 41.5 | 76.3 | 67.2 |
| Two or more | 23.1 | 58.5 | 23.7 | 32.8 |
| Functional limitations | | | | |
| No | 83.4 | 90.6 | 90.7 | 89.6 |
| At least one | 16.6 | 9.4 | 9.3 | 10.4 |
| Neighbourhood disorder[d,e] | 0.13 (0.004) | 0.12 (0.003) | 0.15 (0.002) | 0.14 (0.002) |
| Lack of social cohesion[d,f] | 0.09 (0.003) | 0.13 (0.003) | 0.08 (0.001) | 0.09 (0.001) |
| Composite neighbourhood score[d,g] | 0.11 (0.003) | 0.13 (0.003) | 0.11 (0.001) | 0.12 (0.001) |
| Depression at follow up[h] | | | | |
| Yes | 10.4 | 10.4 | 15.2 | 13.2 |
| No | 89.6 | 89.6 | 84.8 | 86.8 |

Abbreviations: ADL, Activities of Daily Living; ELSA, English Longitudinal Study of Aging; HRS, Health and Retirement Study; IADL, Instrumental Activities of Daily Living; ISCE, International Standard Classification of Education; SHARE, Survey of Health, Ageing and Retirement in Europe.

[a] Baseline measures: ELSA (2014/2015), HRS (2012, 2014), SHARE (2013).

[b] Follow-up measures: ELSA (2016/2017), HRS (2014, 2016), SHARE (2015).

[c] Proportions may not sum to 100, because of rounding.

[d] Values are expressed as mean (standard error).

[e] The neighbourhood disorder measure captured perceived 1) vandalism and crime/graffiti and 2) cleanness of the residential area; values ranged between 0 and 1.

[f] Lack of social cohesion included 1) not feeling part of the neighbourhood and 2) not receiving help if in trouble; values ranged between 0 and 1.

[g] The composite neighbourhood score comprised all 4 perceived neighbourhood characteristics; values ranged between 0 and 1.

[h] The Center for Epidemiological Studies Depression Scale[21] was implemented in ELSA and HRS, and the EURO-D Scale[22] was implemented in SHARE.

The IPD meta-analyses models showed significantly elevated ORs of clinically relevant depressive symptoms by neighbourhood disorder (OR=1.44, 95% CI: 1.28, 1.61) and lack of social cohesion (OR=1.99, 95% CI: 1.75, 2.26) after adjustment for gender and age *(Supplementary Figure 3.2)*. In the fully adjusted models *(Figure 3.2)*,

the pooled OR for neighbourhood disorder was 1.25 (95% CI: 1.11, 1.41), with individual ORs ranging between 0.52 and 2.11 and significantly higher than 1 in the Czech Republic, Denmark and the United States. Lack of social cohesion had a pooled OR of 1.76 (95% CI: 1.54, 2.01) *(Figure 3.3)*, with individual ORs ranging from 0.91 to 5.36, and significantly elevated in Belgium, the Czech Republic, Estonia, France, Germany, Slovenia, England, and the United States. Meta-regression indicated stronger associations between lack of social cohesion and depression in more equal countries ($\beta$ = -0.174, $P$ = 0.01), as measured by Gini index. Furthermore, there was a tendency for associations between lack of social cohesion and depression to be stronger in countries with higher levels of air pollution ($\beta$ = 0.152, $P$ = 0.09) *(Table 3.2)*.

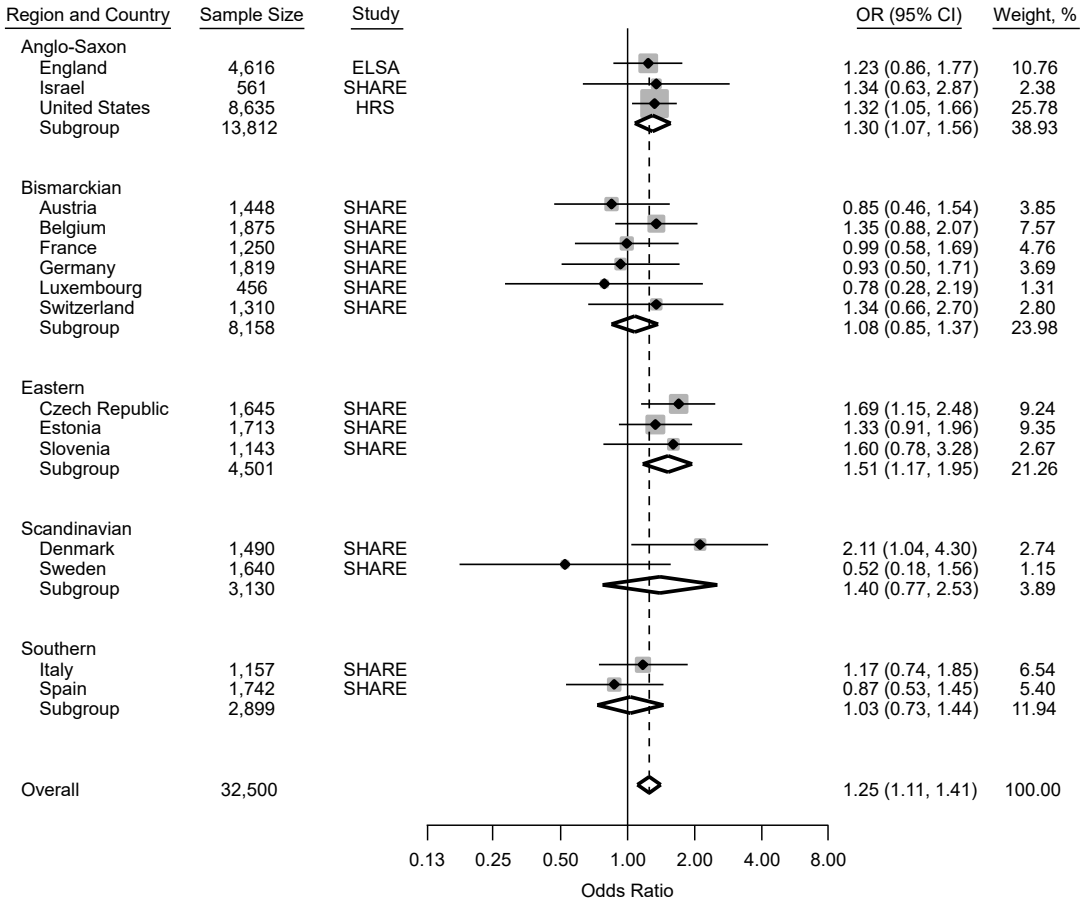


***Figure 3.2*** *Country-specific and pooled associations of perceived neighbourhood disorder with depression among adults aged 50 and over in 16 high-income countries between 2012 and 2017. Models are adjusted for age, gender, country of birth, education, wealth, economic activity, partnership status, current smoking, chronic diseases or conditions and functional limitations; countries are grouped by welfare regimes. The size of each grey square is proportional to the relative weight of the sample in the meta-analysis; diamonds represent the pooled estimates. Odds ratios (OR) > 1 indicate increased, while OR < 1 decreased risk of depression. The overall $I^2$ was 0.0% ($P$ = 0.53). CI, Confidence Interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; SHARE, Survey of Health, Ageing and Retirement in Europe.*

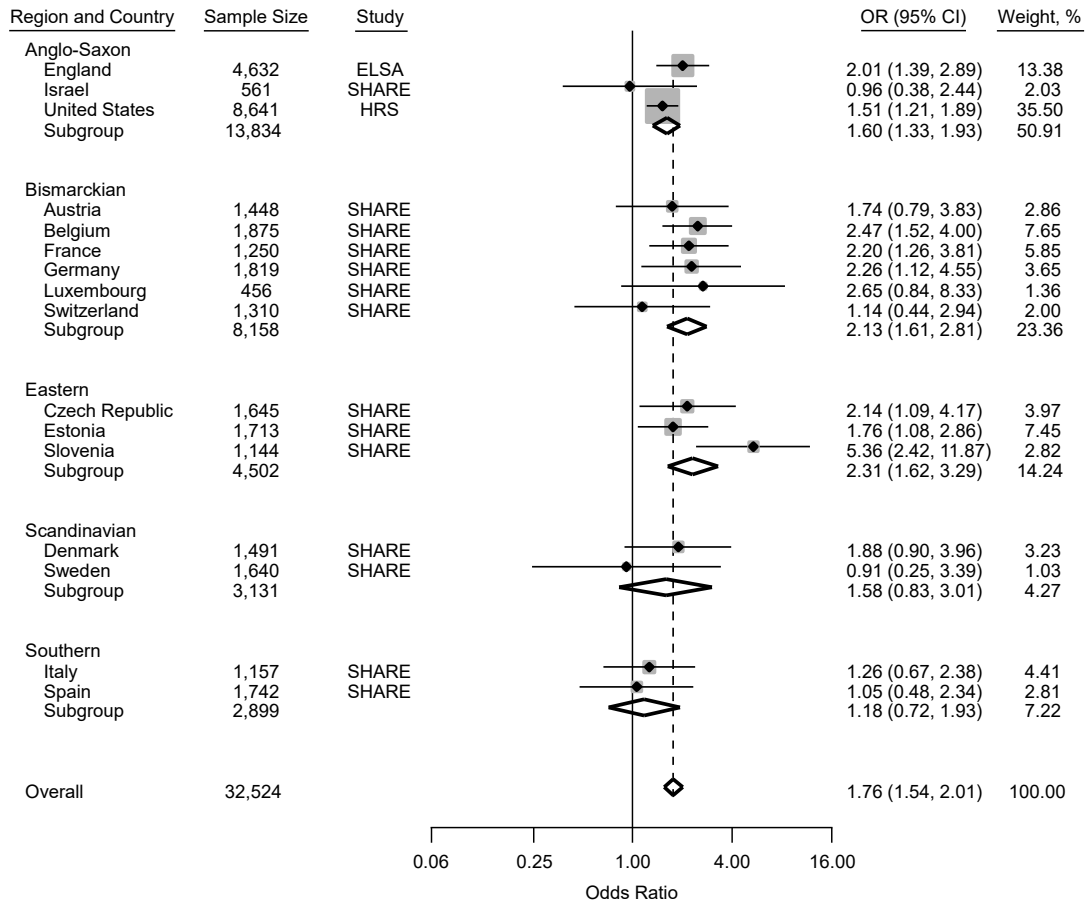


***Figure 3.3*** *Country-specific and pooled associations of perceived lack of social cohesion with depression among adults aged 50 and over in 16 high-income countries between 2012 and 2017. Models are adjusted for age, gender, country of birth, education, wealth, economic activity, partnership status, current smoking, chronic diseases or conditions and functional limitations; countries are grouped by welfare regimes. The size of each grey square is proportional to the relative weight of the sample in the meta-analysis; diamonds represent the pooled estimates. Odds ratios (OR) > 1 indicate increased, while OR < 1 decreased risk of depression. The overall $I^2$ was 23.7% (P = 0.19). CI, Confidence Interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; SHARE, Survey of Health, Ageing and Retirement in Europe.*

We repeated the analyses for retired individuals. In the sex and age adjusted models, neighbourhood disorder had an OR of 1.48 (95% CI: 1.28, 1.72), while the OR of lack of social cohesion was 2.06 (95% CI: 1.73, 2.45) *(Supplementary Figure 3.3)*. Although the pooled ORs decreased after adjustment for all covariates, they remained higher in this subsample than in the full sample. The pooled OR of neighbourhood disorder was 1.35 (95% CI: 1.16, 1.57)—10% higher when including only participants at retirement compared with all participants aged 50 years or older. The pooled OR of lack of social cohesion was 1.93 (95% CI: 1.61, 2.30), indicating 17% higher odds of

depression during retirement *(Supplementary Figure 3.4)*. Meta-regression analyses found significantly elevated risk of depression by lack of social cohesion in more equal countries (β = -0.188, *P* = 0.04) and in countries with higher population density (β = 0.194, *P* = 0.04) *(Table 3.2)*. There was a tendency for associations between neighbourhood disorder and depression to be weaker in countries with more forest coverage (β = -0.175, *P* = 0.099), and for associations between lack of social cohesion and depression to be stronger in countries with higher levels of air pollution (β = 0.205, *P* = 0.07).

***Table 3.2*** *Associations of Perceived Neighborhood Disorder and Lack of Social Cohesion With Depression in 16 High-Income Countries (Meta-Regression Analysis), 2012–2017*

| Country-level indicators[a] | Neighbourhood disorder | | | Lack of social cohesion | | |
|---|---|---|---|---|---|---|
| | β | SE | P | β | SE | P |
| **Aged 50 and over** | | | | | | |
| Sample size | 0.021 | 0.038 | 0.60 | -0.059 | 0.047 | 0.23 |
| % of female participants | 0.098 | 0.060 | 0.13 | -0.044 | 0.094 | 0.65 |
| GDP PPP per capita | -0.065 | 0.088 | 0.47 | -0.052 | 0.128 | 0.69 |
| Gini index | -0.026 | 0.054 | 0.64 | -0.174 | 0.061 | 0.01 |
| Population density | 0.002 | 0.059 | 0.97 | 0.089 | 0.073 | 0.24 |
| % of urban population | 0.016 | 0.074 | 0.84 | -0.064 | 0.104 | 0.55 |
| % of forest coverage | -0.062 | 0.080 | 0.45 | 0.055 | 0.110 | 0.63 |
| Air pollution ($PM_{2.5}$) | 0.044 | 0.062 | 0.49 | 0.152 | 0.083 | 0.09 |
| Welfare regime | [b] | | | [c] | | |
| **In retirement** | | | | | | |
| Sample size | 0.054 | 0.056 | 0.35 | -0.097 | 0.063 | 0.15 |
| % of female participants | 0.084 | 0.083 | 0.33 | -0.186 | 0.121 | 0.15 |
| GDP PPP per capita | 0.061 | 0.114 | 0.60 | -0.003 | 0.158 | 0.99 |
| Gini index | 0.019 | 0.070 | 0.79 | -0.188 | 0.082 | 0.04 |
| Population density | 0.044 | 0.078 | 0.58 | 0.194 | 0.087 | 0.04 |
| % of urban population | 0.133 | 0.094 | 0.18 | 0.096 | 0.123 | 0.45 |
| % of forest coverage | -0.175 | 0.099 | 0.099 | -0.102 | 0.125 | 0.43 |
| Air pollution ($PM_{2.5}$) | 0.038 | 0.078 | 0.64 | 0.205 | 0.102 | 0.07 |
| Welfare regime | [d] | | | [e] | | |

Abbreviations: GDP PPP, Gross Domestic Product in Purchasing Power Parity (in current international $); $PM_{2.5}$, Particulate matter of ≤ 2.5 μm in diameter; SE, Standard Error.

[a] Raw data was standardized before meta-regression, with the exception of welfare regime.

[b] Associations did not differ by welfare regime; F(4,11) = 1.29; *P* = 0.33.

[c] Associations did not differ by welfare regime; F(4,11) = 1.73; *P* = 0.21.

[d] Associations did not differ by welfare regime; F(4,11) = 1.18; *P* = 0.37.

[e] Associations did not differ by welfare regime; F(4,10) = 0.71; *P* = 0.60.

The pooled neighbourhood associations were robust and did not significantly differ when estimated in one-stage IPD meta-analysis (random or fixed country effects) or in random-effects two-stage IPD meta-analysis *(Supplementary Table 3.4)*. Analyses that used the composite neighbourhood problems score produced risk estimates comparable to those calculated for lack of social cohesion (full sample: 1.74, 95% CI: 1.49, 2.03; in retirement: 1.96, 95% CI 1.60, 2.40) *(Supplementary Figure 3.1)*. Similarly to the main analysis, we found stronger associations between neighbourhood problems and depression in more equal countries ($\beta$ = -0.160, P = 0.04). In the subsample of retirees, there was a tendency toward weaker associations between neighbourhood problems and depression in countries with more forest coverage ($\beta$ = -0.248, *P* = 0.095), and towards stronger associations in countries with higher population density ($\beta$ = 0.202, *P* = 0.07) *(Supplementary Table 3.4)*.

## 3.6 Discussion

This cross-national longitudinal study provides evidence for a link between perceived neighbourhood disorder, and lack of social cohesion and depression among adults aged 50 years or older. These findings are based on analyses of data from 3 representative panel surveys including 32,531 participants across 16 high-income countries. Risk estimates were 10-17% higher, on average, in a subsample containing only retired individuals than in the total sample. We identified low country-level variation between risk of depression by neighbourhood problems, which could be partly explained by macro-level indicators such as income inequality, population density, forest coverage and air pollution.

Our findings are in line with those of previous cross-sectional studies,[9] and longitudinal studies exploring the possible effect of perceived neighbourhood disorder[10,11,26] and social cohesion/ social capital[12,13,25,34] on the risk of depression in older age. As people age and then retire, the geographical extent of their mobility space tends to decrease, and they often become more reliant on their community and local services.[9] At the same time, depression trajectories widen by neighbourhood

quality in ageing individuals,[12] leading to stronger associations between neighbourhood and depression among retired individuals.

These findings suggest that the broader social, economic, and environmental context of a country might modify the association between neighbourhood characteristics and depression. In Southern European countries, neighbourhood disorder and lack of social cohesion did not increase the risk of depression, while in Eastern European and Anglo-Saxon countries we often found strong and significant associations. Type of welfare regimes did not statistically explain differences, which may have been due to the low number of countries in each welfare-regime group. However, other unexplored social norms and cultural values predicting the source of social support (community vs. family and close relatives) and ways of coping with residential stressors might be better predictors of modification of the relationship.

Meta-regression analysis estimated stronger risks of depression by lack of social cohesion, when people were living in economically more equal countries. Egalitarian countries tend to have better health outcomes, which might be linked via social capital or other aspects of social organization.[35] Perceived lack of social cohesion in more equal economies, therefore, violates the normative rules of the society and the general expectation of people regard to their neighbourhoods and neighbours. This perceived discrepancy between reality and expectations might cause insecurity and lead to higher levels of psychological distress. There was also weak evidence for a modifying role of air pollution in the link between social cohesion and depression, which seems to be important in more polluted countries, where social cohesion can buffer the distress induced by air pollution.[36] In addition to income inequality and air pollution, findings among retired individuals revealed that in countries where people live in closer proximity to each other, lack of social cohesion predicted depression more strongly. The value of the immediate community increases with higher population density, especially for individuals who are more reliant on their surroundings. Finally, neighbourhood disorder tended to be associated with higher risk of mental health problems in countries with less forest coverage. Exposure to nature may be

protective for mental health by reducing the hazardous effect of environmental distress[37] caused by (for example) neighbourhood disorder, traffic noise, or air pollution.

This study had several strengths. We report here (for the first time, to our knowledge) pooled risks of depression for neighbourhood disorder and lack of social cohesion among adults aged 50 years or older based on data from several high-income countries, many of them (e.g. Southern and Eastern European countries) often neglected in research. The presented analyses were based on longitudinal data with baseline and follow-up measures of outcome, placing this among the few prospective studies in the neighbourhood literature. Effect estimates from 16 different countries were pooled together by IPD meta-analyses, taking into account demographic, socioeconomic, and health confounders. Moreover, we have provided possible explanations for country-level differences in the risk of depression by neighbourhood problems.

The study also had limitations. First, the exposure, outcome, and covariates were all self-reported measures. Although we excluded possible depression cases at baseline to avoid the potential for underlying depression to distort the perceptions of neighbourhood or covariates, we could not completely rule out reverse causation or an unmeasured psychological mechanism (e.g. reporting behaviour) leading to biased estimates.[38] Second, despite the high correlation between outcome measures, they have relevant differences:[23] The CES-D Scale tends to have stronger associations with social and demographic factors than the EURO-D, indicating a more extreme pool of cases, and it captures a shorter time interval (1 week vs. 1 month). Third, there was a significant number of missing values for neighbourhood perception. Although the sample size was not related to the variation between effect parameters, nonresponse bias might have influenced the results. Missing values for neighbourhood originated from the survey method in ELSA and HRS (e.g. leave-behind questionnaire), while in SHARE only part of the sample (household respondents) was asked about their residential area, providing very different reasons

for missingness in the pooled data set. Fourth, because neighbourhood perception was not assessed in each wave, we could not include the same year of baseline and follow-up for all surveys, which meant that it is possible that unknown macroeconomic or societal changes may have affected the results. Fifth, several European and North American countries were not included in this study, due to either the lack of data or insufficient data harmonization. We cannot exclude the possibility that the absence of these countries may have influenced the study's findings.

Future research should make use of comparable multicentre surveys (e.g. Gateway to Global Aging Data) and extend its focus to low- and middle-income countries. Although there are cross-sectional multicentre studies on residential environment and health available in different country settings,[39] longitudinal evidence is needed to better understand how macro-level social and environmental indicators shape neighbourhood effects. In addition, using objectively measured neighbourhood exposure would overcome possible bias related to the use of self-report measures. Neighbourhood environment is a significant determinant of mental health and has the potential to reduce the negative effects of socioeconomic inequalities on health.[39] Moreover, it is modifiable and therefore offers policy-makers opportunities for intervention to enhance health among older adults.[6] Policies, especially in countries with a stronger link between neighbourhood and depression, should focus on improving the physical qualities of residential areas and supporting social ties in communities, which can reduce mental health problems and related disability and make positive contributions to healthy ageing.

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ELSA: The data were made available through the UK Data Archive. The English Longitudinal Study of Ageing was developed by a team of researchers based at University College London, the National Centre for Social Research and the Institute for Fiscal Studies. The data were collected by the National Centre for Social Research. The funding was provided by the National Institute of Aging in the United States, and a consortium of UK government departments coordinated by the Office for National Statistics.

HRS: The Health and Retirement Study is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and conducted by the University of Michigan. This analysis uses Early Release data (for wave 2016), which have not been cleaned and may contain errors that will be corrected in the Final Public Release version of the dataset.

SHARE: This paper uses data from SHARE Waves 5 and 6 (10.6103/SHARE.w5.610, 10.6103/SHARE.w6.610), see Börsch-Supan et al. (2013) for methodological details (19). The SHARE data collection has been funded by the European Commission through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812), FP7 (SHARE-PREP: GA N°211909, SHARE-LEAP: GA N°227822, SHARE M4: GA N°261982) and Horizon 2020 (SHARE-DEV3: GA N°676536, SERISS: GA N°654221) and by DG Employment, Social Affairs & Inclusion. Additional funding from the

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## 3.8 Response to Invited Commentary

**Title**

Baranyi et al. Respond to "Depression and Welfare States"

**Authors**

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*Author's contribution*: G.B. developed the two main topics of the response, conducted the analyses and prepared the first draft. All authors contributed to the interpretation of the results, commented on the manuscript, and approved the final version.

Dr Mikael Rostila's insightful commentary[1] on our work[2] emphasises the analytical potential of the welfare state concept and furthers the interpretation of our findings. We extend this debate by 1) exploring whether specific aspects of welfare states are linked to neighbourhood effects and 2) arguing for greater attention to life-course perspectives on cross-level interactions between upstream and downstream contextual determinants of health.

Though examining welfare regimes can be interesting because they represent broad concepts of welfare policy, we agree with Rostila that research examining macro-level mechanisms underpinning health inequalities should pay greater attention to specific welfare characteristics.[1] To illustrate this point, we tested whether total and older age-specific public expenditures on social protection (percentage of Gross Domestic Product) modified the associations between neighbourhood and depression in our data, focusing only on retired individuals. Using the same analytical approach as that outlined in our paper,[2] and country-level data from the Organisation for Economic Co-operation and Development database (https://data.oecd.org), we found trend-wise cross-level interactions: Increasing total public spending strengthened the association between lack of social cohesion and depression ($\beta = 0.210$, $P = 0.05$); and higher pension spending weakened the association between neighbourhood disorder and depression ($\beta = -0.150$, $P = 0.09$) *(Table 3.3)*.

***Table 3.3*** *Associations of Perceived Neighbourhood Disorder and Lack of Social Cohesion With Depression Among Retired Individuals in 16 High-Income Countries, by Country-Level Public Social Expenditure (Univariate Meta-Regression Analysis), 2012–2017*

| Country-level public social expenditure[a] | Neighbourhood disorder | | | Lack of social cohesion | | |
|---|---|---|---|---|---|---|
| | β | SE | P | β | SE | P |
| Older adults in retirement | | | | | | |
| Total social spending | -0.110 | 0.084 | 0.21 | 0.210 | 0.098 | 0.05 |
| - pension spending | -0.150 | 0.082 | 0.09 | 0.113 | 0.107 | 0.31 |
| - spending on incapacity | 0.050 | 0.104 | 0.64 | 0.064 | 0.133 | 0.64 |
| - health spending | -0.013 | 0.087 | 0.88 | 0.102 | 0.122 | 0.42 |
| - social benefits to households | -0.144 | 0.096 | 0.16 | 0.159 | 0.123 | 0.22 |

Abbreviations: SE, Standard Error.

[a] Expressed in % of Gross Domestic Product;[6] raw data was standardized before meta-regression.

While the second finding points towards elderly-related social protection buffering against the detrimental effects of neighbourhood problems, the first may indicate that social spending is often directed towards working adults and children, thus leaving older people feeling more left alone. Although exploring the link between specific social policies and neighbourhood inequalities is a significant question, research should take into account major caveats of cross-country analyses (e.g. small sample size, differences in the underlying populations or implementation of policies).

Although these additional findings provide some tentative insights into the mechanisms connecting welfare regimes and mental health, the results also point to some important areas for further investigation. In particular, for a deeper understanding of how macro-level context influences neighbourhood social processes and health, it is important to examine contextual exposures over the *full* life course.[3] Residential characteristics have long been associated with mental health and there is also emerging evidence that neighbourhood conditions throughout life predict late life mental health, either by intervening in sensitive developmental periods (e.g. early childhood) or by accumulating over time.[3,4]

Macro-level context might also have long-lasting health implications. We found strong associations between social cohesion, neighbourhood disorder and depression in Central and Eastern European countries (the Czech Republic, Estonia and Slovenia).[2] Although our findings indicated a stronger link, on average, between neighbourhood and depression among retired individuals, the opposite was found for Central and Eastern European countries, with greater associations being seen in adults who were still in the workforce (for lack of social cohesion OR = 2.54, 95% CI: 1.22, 5.30). This cohort was in their thirties during the early 1990s postcommunist political and economic transition. As Rostila points out, the presence of social ties in a neighbourhood increases the likelihood of accessing informal welfare and support,[1] which might be important during rapid societal and economic changes requiring adaptation and adjustment. Growing up in a communist regime and experiencing the transition to capitalism during young adulthood might have had long-term effects on

social adaptation and mental health. More research making use of historical contextual data is needed to comprehend the complex effect of the evolution of welfare states.

Simultaneously considering various levels of aggregation[1] and adapting the life course framework to context can contribute to "scaling up" the determinants of health in epidemiological research.[5] This would not only help us to understand how different levels of contexts interact by influencing human health but also provide new and important policy insights.

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This publication reflects only the author's view and that the Research Executive Agency of the European Commission is not responsible for any use that may be made of the information it contains.

Conflict of interest: none declared.

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## 3.9 Assessment of bias

*Non-measurement error at unit-level*

Baseline response rates differed in the included surveys, with the highest proportion of obtained interviews in HRS (70-82%; depending on the cohorts),[1] followed by ELSA (70%)[2] and SHARE (62%);[3] and with declining response rates in the new refreshment samples over time.[1-3] As reported in the chapter, also attrition rates between baseline and follow-up varied across countries, with higher attrition in SHARE (23.4%; ranging between 14.9 and 31.5%) in comparison to HRS (14.1%) and ELSA (16.4%).

*Non-measurement error at item-level*

The main source of missing values was neighbourhood perception, providing different reasons of missingness across surveys. In HRS and ELSA, items assessing neighbourhood perception were part of the leave-behind questionnaire left at the end of the interview for respondents to return by mail.[1,2] In SHARE, neighbourhood questions were part of the face-to-face interview; however, only main household respondents were asked.[4] Irrespective from exposure and outcomes, missing data on covariates were negligible in magnitude in the pooled dataset (<3%). Complete case analysis, the preferred method in this thesis, gives unbiased findings if outcome does not predict being a complete case after taking into consideration covariates.[5] Post-hoc logistic regression indicated that missingness were not explained by depression (p=0.380), so that complete case analysis was unbiased and multiple imputation was not required.

Applying inclusion and exclusion criteria resulted in a large drop in the sample size (see *Figure 3.1*). To assess representativeness of the final sample, sample proportions by variables in the original *(Figure 3.1. – top box)* and analytic *(Figure 3.1. – bottom box)* ELSA, HRS and SHARE samples are provided in *Supplementary Table 3.5*. Results indicated that respondents in the analytical samples had higher socioeconomic status and better overall health status. A drop in sample size was particularly large in Israel and Italy.

*Multicollinearity*

Collinearity between independent variables was explored with variance inflation factors (VIF), which did not indicate high correlation (VIF<10; 1/VIF>0.1) between variables *(Supplementary Table 3.7).*

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# CHAPTER 4

# 4. Childhood stressors, neighbourhoods and depression in later life

## 4.1 Chapter overview

This chapter focuses on the question whether childhood experiences affect the associations between perceived physical environment and depression among older adults by filling two research gaps: First, few longitudinal studies are available with longer follow-ups (>2 years), especially regarding the two main exposures in this chapter: perceived neighbourhood nuisances (including crime) and access to neighbourhood services. Second, little is known about vulnerable population groups where neighbourhoods might have stronger effects. Although early childhood is a sensitive period for human development, limited information is available whether exposure to stressors in this age may have long-term effects on how people react to their residential environment.

This chapter in its current form has been published in *Preventive Medicine* and available as follows:

> *Baranyi G, Sieber S, Pearce J, et al. A longitudinal study of neighbourhood conditions and depression in ageing European adults: Do the associations vary by exposure to childhood stressors? Prev Med 2019; 126: 105764.*

At the end of the chapter, a short assessment explores the risk of bias, easing to address overall strengths and limitation at the end of the thesis. Referred supplementary material can be found in Appendix Three.

**Title**

A longitudinal study of neighbourhood conditions and depression in ageing European adults: Do the associations vary by exposure to childhood stressors?

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*Author's contribution*: GB and SC developed the research design and prepared the first draft of the study. GB and SS conducted the data analysis. All authors supported the research design, reviewed and commented on the manuscript, and approved the final version.

## 4.2 Abstract

Emerging literature emphasises the association between neighbourhood conditions and late life depression. Childhood experiences, crucial for life course development of mental health, may modify how neighbourhood affects subsequent depression. This study assessed the longitudinal associations of access to services and neighbourhood nuisance with depression among older adults, and tested whether these associations varied by exposure to childhood stressors. Data were drawn from the cross-national Survey of Health, Ageing and Retirement in Europe, a prospective cohort study between 2004/2005 and 2015, representative for European adults over the age of 50. Individual perceptions of neighbourhood were measured at baseline; childhood stressors, defined as socioeconomic conditions, adverse experiences and health problems, were collected retrospectively. Multilevel logistic regression estimated the risk of depression (n=10,328). Access to services were negatively (OR=0.78, 95% CI 0.68-0.90) and neighbourhood nuisance positively (OR=1.36, 95% CI 1.18-1.56) associated with the probability of depression during follow-up. We found interactions between neighbourhood and childhood socioeconomic conditions, but not with adverse experiences and health problems. While older adults who grew up in better childhood socioeconomic conditions benefited more from living in a residential area with good access to services, they were at higher risk of developing depression when residing in areas with more neighbourhood nuisances. Older adults' mental health can benefit from better access to public transportation and neighbourhood amenities, while physical and social problems in the local area increase the risk of depression. Importantly, socioeconomic circumstances in early life may influence vulnerability to neighbourhood effects in older age.

## 4.3 Introduction

Depression is one of the most common threats to mental health in late life, causing emotional suffering and dramatically reduced quality of life over the age of 55.[1,2] The aetiology of depression in older adults differs from younger populations with medical comorbidities and functional impairments gaining more importance.[3] Age-specific material and psychosocial factors, such as lower income, loss of status, critical life events, or living in residential care settings, also contribute to higher risk of depression in this age group.[4,5]

Due to limited mobility, functional decline and life course changes (i.e. retirement), the activity spaces of older adults become increasingly restricted to their immediate surroundings, making them particularly vulnerable to neighbourhood stressors and dependent on local resources.[6,7] The majority of studies in this field are cross-sectional,[7] which can hardly establish causal links between neighbourhood and mental health. The few existing longitudinal investigations, however, point to elevated risk of depression among those residing in areas with higher poverty,[8] more neighbourhood problems (such as crime, noise, littering and drug use)[9-12] or higher air pollution.[13] Limited evidence is available on the effects of access to transportation and neighbourhood services, which suggests lower risk of depression by the presence of essential amenities.[7,14,15]

Exploring differential vulnerability to neighbourhood exposures across the life course might further our understanding of the mechanisms affecting the development of depressive symptoms and help to identify policy opportunities for addressing health inequalities among older populations.[16] Individual, (e.g. marital status,[9] social support[17]), and area-based factors (e.g. social cohesion in the community[18]) have been shown to buffer the adverse effects of neighbourhood disadvantage. Although there is an increasing interest in the mental health impact of childhood circumstances,[19-21] the moderating role of these conditions on the relationship between neighbourhood and mental health is poorly understood. There is evidence for increased risk of

depression among adults residing in high crime neighbourhoods with previous exposure to childhood trauma.[22] However, the lasting effect of adversity may depend on the level of hardship.[23] While no or high levels of lifetime adversity is associated with higher vulnerability, moderate levels might lead to resilience (i.e. the process of positively adapting to adversities and recovering from negative life events).[23,24]

There is a lack of prospective data in the literature and little evidence exist on whether common childhood stressors (e.g. disadvantaged socioeconomic conditions) modify the effects of residential area on depression among older adults. The current study, therefore, assessed longitudinal associations of neighbourhood nuisances and access to services with depression among older European adults. Moreover, it examined whether childhood stressors, defined as socioeconomic disadvantage, adverse experiences and health problems, modify the neighbourhood - mental health relationship.

## 4.4 Methods

### 4.4.1 Study design and participants

The Survey of Health, Ageing and Retirement in Europe (SHARE) is a cross-national European panel study, representative for the community-dwelling population aged 50 and over.[25] Since 2004/2005, individuals have been followed-up regularly, approximately every second year; the latest available sweep (wave 6) was conducted in 2015 in 18 countries. Our analyses made use of all waves at the time of data analysis. Non-institutionalised respondents between the age of 50 and 96 were included in the sample, if they provided valid answers on neighbourhood characteristics and depression at baseline (waves 1 or 2), participated in the life history assessment (wave 3, SHARELIFE), and had at least one assessment of depressive symptoms during the follow-up (waves 4-6). As the same neighbourhood questions were asked in wave 1 and 2, we extracted for each participant the latest available information and defined the respective wave as baseline. Survey participants remained part of the analytic dataset, as long as they stayed at the same

residential address; if residential movement occurred during follow-up, we censored participant's observations from all consecutive waves. The SHARE study was approved by the relevant research ethics committees in the participating countries, and all participants provided written informed consent.

### 4.4.2 Neighbourhood conditions

Neighbourhood was assessed with four binary questions, capturing the characteristics of the area immediately surrounding the participants' place of residence. Multiple correspondence analysis indicated two underlying dimensions behind the four items: two items focused on access to services ("*sufficient supply of facilities such as pharmacy, medical care, grocery and the like within reasonable distance*"; "*sufficient possibilities for public transportation*") and two on neighbourhood nuisances ("*pollution, noise or other environmental problems*"; "*vandalism or crime*"). Dimensions were statistically independent from each other ($p<0.001$), while items belonging to the same dimensions showed moderate tetrachoric correlation ($r_{tetAccess}=0.52$ and $r_{tetNuisances}=0.66$). Scores were computed by summarizing the corresponding binary items and dichotomising them (yes, no).

### 4.4.3 Depression

The EURO-D scale from waves 1, 2, 4, 5 and 6 was used for the measurement of current depressive symptoms. The instrument consists of 12 binary items capturing the presence of depression, pessimism, wishing for death, guilt, sleep, interest, irritability, appetite, fatigue, concentration, enjoyment and tearfulness in the preceding month. This scale has adequate internal consistency and criterion validity in older populations.[26,27] The score ranged from 0 to 12, with higher values indicating more depressive symptoms. We used the cut-off score of ≥4 to detect clinically significant levels of depressive symptoms.[26]

### 4.4.4 Childhood stressors

SHARELIFE retrospectively collected information on participants' life history, which we used to compute three composite measures of childhood stressors. Childhood socioeconomic conditions (CSCs) at the age of 10 were measured using 4 questions, indicating (1) the occupational position of the main breadwinner based on skill levels (low, high); (2) number of books at home (<10, ≥10); (3) home overcrowding (measured by household size and number of rooms available); and (4) housing quality based on the presence or absence of basic amenities (fixed bath, cold running water supply, hot running water supply, inside toilet, central heating). After dichotomising the answers, we computed a common score with five categories labelling the social condition of the family ranging from 'most disadvantaged' to 'most advantaged'.[28]

Adverse childhood experiences (ACEs) were defined as traumatic or stressful conditions in the children's immediate environment occurring until the age of 15. The following variables were used: (1) child in care; (2) parental death; (3) parental mental illness; (4) parental drinking problem; (5) period of hunger; and (6) property taken away. Dichotomised answers have been summed up and classified into 3 categories, indicating 'no ACE', '1 ACE', and '2 or more ACEs'.

Finally, childhood health problems (CHPs) before the age of 15 were measured with the following non-mutually exclusive items: (1) hospitalization for longer than one month; (2) multiple hospitalizations; (3) childhood illnesses (e.g. asthma, polio); and (4) serious childhood health conditions (e.g. epilepsy, leukaemia). We calculated a binary variable indicating 'no CHP' versus '1 or more CHPs'.

### 4.4.5 Covariates

Demographic variables included age [in ten years, centred at the midpoint of the sample's age range (73 years)], age-squared (to examine accelerated change over ageing), birth cohorts (1919-1928, 1929-38, 1939-45, after 1945), gender and born in the country of interview (yes, no). Highest educational attainment (primary or lower, secondary, tertiary) was measured using on the International Standard Classification

of Education. We computed equalized household net wealth as an indicator of socioeconomic status by dividing household non-pension net wealth by the square root of benefiting members. Low, medium and high wealth groups with equal number of participants were classified within each participating country. Further covariates included labour market status (employed, out of the labour force, retired, unemployed), living in status (in couple, alone) and restrictions (yes, no) in Activities of Daily Living (ADL) and in Instrumental Activities of Daily Living (IADL).[29] While sociodemographic and health covariates were measured at baseline, we computed a composite index for health behaviour (alcohol consumption, physical inactivity, smoking and unhealthy diet[30]) using the mode of their values across waves.

### 4.4.6 Statistical analyses

Multilevel logistic regression analyses estimated the effect of perceived neighbourhood conditions on the risk of depression, presented in Odds Ratios (OR) with 95% Confidence Intervals (CI). Considering the clustered nature of the SHARE dataset, i.e. observations (level 1) are nested in individuals (level 2), and individuals in countries (level 3), we used multilevel models to take into account the dependency of repeated measurements within the same level.

The first set of models examined the associations between neighbourhood and depression. In Model 1 (M1), we adjusted for the effects of age, age-squared, birth cohorts and gender. M2 further controlled for all other individual factors (born in the country, education, equalized household net wealth, living status, labour market status, ADL, IADL and health behaviours). While M1 and M2 were conducted separately for access to services (M1a, M2a) and for neighbourhood nuisance (M1b, M2b), in M3 we included both factors in the fully adjusted model in order to assess their independent associations with depression. In M4, we additionally adjusted for baseline levels of depression to test a more causal pathway between neighbourhood (wave 1 or 2) and depression (waves 4-6). For all main models, intra-class correlation (ICC) were calculated indicating group resemblance within countries.

The second set of models explored the associations between childhood stressors and depression, and assessed interaction effects with neighbourhood exposures; all models were run separately for CSCs, ACEs and CHPs. After we estimated the effects of the childhood stressors on depression (M5), while adjusting for all aforementioned individual covariates and baseline levels of depression, interaction terms were added to the models, separately for access to services (M6a) and for neighbourhood nuisance (M6b). In the last model (M7), we considered interaction terms for both neighbourhood variables simultaneously.

We conducted supplementary and sensitivity analyses to further explore the robustness of our findings. First, instead of using the binary indicators of depression we conducted multilevel linear regression imputing continuous EURO-D scores. Second, in order to test, whether urban-rural difference attenuates neighbourhood effects, we repeated all analyses by including a variable on the type of residence (rural, urban). Third, we reran the main analyses in a subsample (n=7928) who were free of depression at baseline. Fourth, we explored whether results evolve with ageing by including an interaction term between age and neighbourhood; when appropriate between age, neighbourhood and childhood conditions.

All models were controlled for participant attrition since inclusion in SHARE (no attrition, dropped out, deceased) and conducted in R Studio.

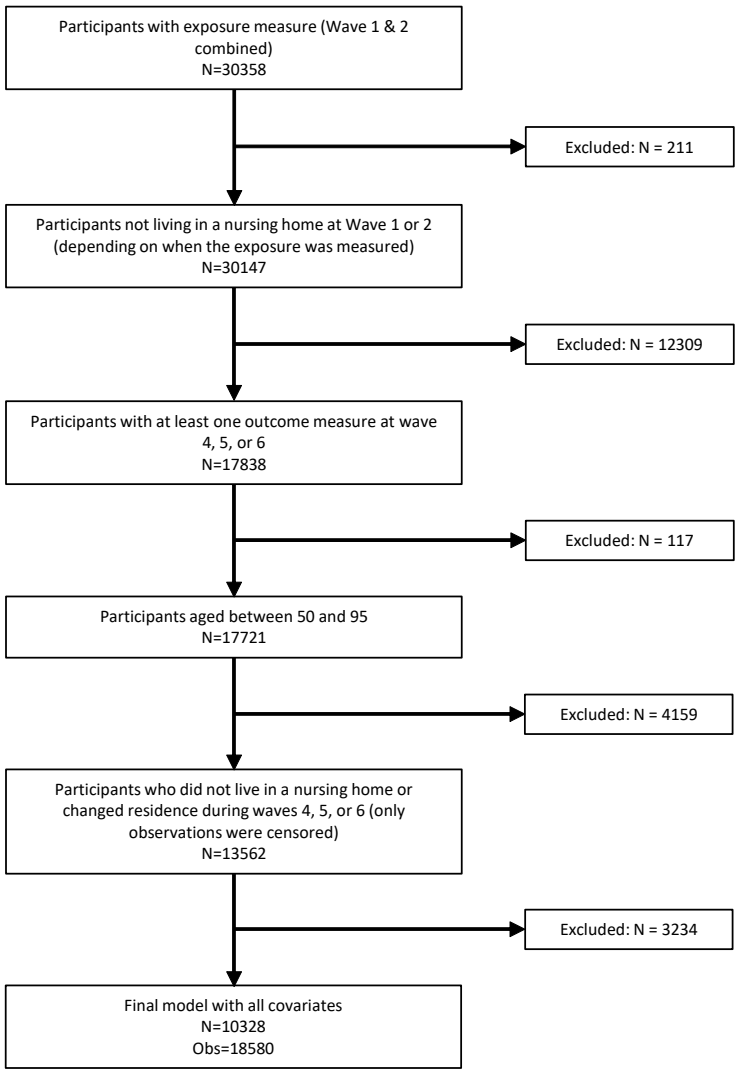


***Figure 4.1*** *Flowchart indicating sample selection into the analytic sample, Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015*

## 4.5 Results

The final analytical sample comprised 10328 participants with 18580 observations during follow-up, living in 13 different European countries (Austria, Belgium, Czech Republic, Denmark, France, Germany, Greece, Italy, The Netherlands, Poland, Spain, Sweden, and Switzerland) *(Figure. 4.1)*. The majority of the sample was female (56.4%) and the average age was 68.6 at baseline. 70.7% of the participants described having sufficient access to services and a similar proportion (71.2%) did not report any signs of neighbourhood nuisance *(Table 4.1)*. 63.2% had never reported being suffering from

clinically relevant levels of depressive symptoms; 23.2% had depression at baseline and an additional 13.6% developed during follow-up.

***Table 4.1*** *Descriptive statistics of the analytic sample (n=10,328), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015*

| **Variable** | | **n (%)** |
|---|---|---|
| Gender | Male | 4,502 (43.6) |
| | Female | 5,826 (56.4) |
| Age at baseline (mean [SD]) | | 68.6 (9.1) |
| Birth cohorts | 1919 and 1928 | 845 (8.2) |
| | 1929 and 1938 | 2,504 (24.2) |
| | 1939 and 1945 | 2,448 (23.7) |
| | After 1945 | 4,531 (43.9) |
| Attrition during follow-up | No dropout | 9,044 (87.6) |
| | Dropped out | 806 (7.8) |
| | Deceased | 478 (4.6) |
| Born in the country | Yes | 9,769 (94.6) |
| | No | 559 (5.4) |
| Highest educational attainment | Primary | 2,837 (27.4) |
| | Secondary | 5,294 (51.3) |
| | Tertiary | 2,197 (21.3) |
| Equalized household net wealth | Low | 2,957 (28.6) |
| | Medium | 3,504 (33.9) |
| | High | 3,867 (37.4) |
| Health Behaviours index (mean [SD]) | | 0.3 (0.3) |
| Living status | Living alone | 3,189 (30.9) |
| | Living in a couple | 7,139 (69.1) |
| Labour market status | Employed | 3,482 (33.7) |
| | Out of the labour force | 1,674 (16.2) |
| | Retired | 4,826 (46.7) |
| | Unemployed | 346 (3.4) |
| ADL | Any restriction | 718 (7.0) |
| | No restrictions | 9,610 (93.0) |
| IADL | Any restrictions | 1,079 (10.4) |
| | No restrictions | 9,249 (89.6) |
| Access to services | Yes | 7,305 (70.7) |
| | No | 3,023 (29.3) |
| Neighbourhood nuisances | Yes | 2,971 (28.8) |
| | No | 7,357 (71.2) |
| Childhood socioeconomic conditions | Most disadvantaged | 1,804 (17.5) |
| | Disadvantaged | 2,474 (24.0) |
| | Middle | 3,445 (33.4) |
| | Advantaged | 2,003 (19.4) |
| | Most advantaged | 602 (5.8) |
| Adverse childhood experiences | No | 7,946 (76.9) |

| | | |
|---|---|---|
| | 1 adverse childhood experience | 1,948 (18.9) |
| | 2 or more adverse childhood experiences | 434 (4.2) |
| Childhood health problems | No | 7,565 (73.2) |
| | 1 or more childhood health problems | 2,763 (26.8) |
| Depression at baseline | Yes | 2,401 (23.2) |
| | No | 7,927 (76.8) |
| Depression at follow-up | Yes | 2,657 (25.7) |
| | No | 7,671 (74.3) |
| Countries | Austria (455, 4.4%), Belgium (1,174, 11.4%), Czech Republic (701, 6.8%), Denmark (972, 9.4%), France (686, 6.6%), Germany (693, 6.7%), Greece (866, 8.4%), Italy (969, 9.4%), The Netherlands (839, 8.1%), Poland (716, 6.9%), Spain (802, 7.8%), Sweden (817, 7.9%), Switzerland (638, 6.2%) | |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; SD, standard deviation.

Good access to services was significantly associated with lower risk of depression (OR=0.82, 95% CI 0.73-0.93) in the initial model (M1a), which only slightly changed after adjusting for all socioeconomic and health covariates (M2a: OR=0.86, 95% CI 0.76-0.98) *(Table 4.2)*. Similarly, the presence of neighbourhood nuisances increased the risk of depression in the initial (M1b: OR=1.43, 95% CI 1.27-1.62) and in the fully adjusted model (M2b: OR=1.38, 95% CI 1.22-1.56). When simultaneously considering both neighbourhood variables in a fully adjusted regression (M3), the effects of access to services and neighbourhood nuisances did not materially change, confirming independent and robust effects on depression. In M4, we adjusted for baseline levels of depression: participants with sufficient access to services had 22% lower odds for reporting depression during the follow-up, while any signs of neighbourhood nuisance in the residential area increased the risk of depression with 36% *(Table 4.2)*. Country differences explained approximately 3.5-3.7% of the total variation in the initial models ($ICC_{country}$).

***Table 4.2*** *Depression by neighbourhood conditions among 10,328 older European adults (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015*

| Variable | Access to services | | Neighbourhood nuisances | | M3: Access and nuisances | M4: Control for baseline depression |
|---|---|---|---|---|---|---|
| | M1a: Initial | M2a: Fully-adjusted | M1b: Initial | M2b: Fully-adjusted | | |
| Age (centred, in 10 years) | 1.58 (1.32-1.89) | 1.41 (1.17-1.69) | 1.60 (1.34-1.92) | 1.42 (1.18-1.70) | 1.43 (1.19-1.72) | 1.48 (1.21-1.81) |
| Age$^2$ (centred, in 10 years) | 1.30 (1.20-1.42) | 1.28 (1.17-1.40) | 1.32 (1.21-1.44) | 1.29 (1.18-1.41) | 1.29 (1.18-1.41) | 1.34 (1.21-1.47) |
| Gender (ref: Female) | 0.30 (0.26-0.34) | 0.34 (0.30-0.39) | 0.30 (0.26-0.34) | 0.35 (0.30-0.39) | 0.35 (0.30-0.40) | 0.44 (0.38-0.51) |
| Birth cohorts (ref: After 1945) | | | | | | |
| 1919 and 1928 | 0.79 (0.47-1.33) | 0.61 (0.36-1.03) | 0.78 (0.46-1.30) | 0.60 (0.36-1.02) | 0.59 (0.35-1.00) | 0.54 (0.30-0.96) |
| 1929 and 1938 | 1.18 (0.87-1.61) | 0.99 (0.72-1.35) | 1.18 (0.86-1.60) | 0.99 (0.72-1.36) | 0.97 (0.70-1.33) | 0.96 (0.67-1.37) |
| 1939 and 1945 | 1.15 (0.93-1.43) | 1.01 (0.81-1.26) | 1.15 (0.93-1.43) | 1.01 (0.81-1.26) | 1.02 (0.82-1.27) | 1.00 (0.78-1.27) |
| Attrition during follow-up (ref: No attrition) | | | | | | |
| Dropped out | 1.09 (0.85-1.39) | 0.99 (0.78-1.27) | 1.06 (0.83-1.36) | 0.99 (0.77-1.27 | 0.98 (0.77-1.26) | 1.00 (0.76-1.32) |
| Deceased | 2.27 (1.70-3.02) | 1.76 (1.32-2.34) | 2.27 (1.70-3.02) | 1.76 (1.32-2.35) | 1.77 (1.33-2.36) | 1.91 (1.38-2.64) |
| Born in the country (ref: No) | | 0.65 (0.51-0.83) | | 0.66 (0.52-0.84) | 0.66 (0.52-0.84) | 0.74 (0.56-0.98) |
| Education (ref: Primary) | | | | | | |
| Secondary | | 0.81 (0.70-0.94) | | 0.79 (0.68-0.91) | 0.80 (0.69-0.92) | 0.71 (0.61-0.83) |
| Tertiary | | 0.77 (0.64-0.93) | | 0.75 (0.62-0.91) | 0.76 (0.63-0.92) | 0.68 (0.55-0.83) |
| Equalized household net wealth (ref: Low) | | | | | | |
| Medium | | 0.84 (0.73-0.97) | | 0.86 (0.75-0.99) | 0.85 (0.74-0.98) | 0.92 (0.78-1.08) |
| High | | 0.71 (0.62-0.83) | | 0.73 (0.63-0.84) | 0.72 (0.62-0.84) | 0.80 (0.68-0.94) |
| Health Behaviours index | | 4.62 (3.65-5.84) | | 4.60 (3.64-5.81) | 4.60 (3.64-5.82) | 4.30 (3.33-5.57) |
| Living status (ref: Living alone) | | 1.04 (0.91-1.18) | | 1.05 (0.93-1.19) | 1.04 (0.92-1.18) | 1.17 (1.02-1.35) |
| Labour market status (ref: Employed) | | | | | | |
| Out of the labour force | | 2.05 (1.69-2.50) | | 2.03 (1.67-2.48) | 2.04 (1.67-2.48) | 2.31 (1.85-2.87) |
| Unemployed | | 2.00 (1.46-2.74) | | 1.98 (1.45-2.71) | 1.98 (1.44-2.70) | 1.96 (1.37-2.80) |
| Retired | | 1.62 (1.34-1.95) | | 1.60 (1.33-1.93) | 1.60 (1.32-1.93) | 1.85 (1.50-2.28) |
| ADL (ref: No restrictions) | | 1.94 (1.55-2.42) | | 1.93 (1.54-2.41) | 1.91 (1.53-2.39) | 1.55 (1.19-2.00) |

| | | | | | | |
|---|---|---|---|---|---|---|
| IADL (ref: No restrictions) | | 2.06 (1.71-2.49) | | 2.08 (1.72-2.51) | 2.05 (1.70-2.48) | 1.53 (1.23-1.91) |
| Access to services (ref: No) | 0.82 (0.73-0.93) | 0.86 (0.76-0.98) | | | 0.84 (0.74-0.95) | 0.78 (0.68-0.90) |
| Neighbourhood nuisances (ref: No) | | | 1.43 (1.27-1.62) | 1.38 (1.22-1.56) | 1.40 (1.23-1.59) | 1.36 (1.18-1.56) |
| Baseline depression (wave 1 or 2) | | | | | | 8.41 (6.93-10.21) |
| $ICC_{country}$ | 3.66% | 1.61% | 3.50% | 1.54% | 1.45% | 0.00% |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; CI, confidence intervals; OR, odds ratios.

Childhood stressors were significantly associated with depression in the fully adjusted models (M5). In comparison to the most disadvantaged CSCs, those who grow up in disadvantaged, middle, advantaged and in the most advantaged conditions, showed better mental health outcomes as older adults *(Table 4.3)*. Similarly, having reported one or two and more ACEs increased the risk of depression *(Supplementary Table 4.1)*, and so did one or more CHPs *(Supplementary Table 4.2)*.

Interaction models revealed significant modification of neighbourhood effects by CSCs *(Table 4.3)*. Living in an area with good access to public transportation and basic amenities was particularly beneficial for those coming from middle (OR=0.60, 95% CI 0.41-0.89), advantaged (OR=0.55, 95% CI 0.35-0.87) and most advantaged CSCs (OR=0.42, 95% CI 0.21-0.83) (M6a). Furthermore, reporting presence of neighbourhood nuisances in the residential area increased the risk of depression for older adults coming from less disadvantaged families (M6b). In comparison with the most disadvantaged CSCs, disadvantaged (OR=1.78, 95% CI 1.17-2.71), advantaged trend-wise (OR=1.25, 95% CI 0.98-2.48) and most advantaged (OR=2.16, 95% CI 1.07-4.35) childhood conditions predicted depression when living in areas with neighbourhood nuisances. These interaction effects remained fairly constant when all interaction terms were considered within the same model (M7) *(Table 4.3)*.

***Table 4.3*** *Interaction effects of childhood socioeconomic conditions and neighbourhood conditions on depression among 10,328 older European adults (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015*

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | 0.81 (0.70-0.93) | 1.16 (0.86-1.56) | | 1.07 (0.79-1.45) |
| Neighbourhood nuisances (ref: No) | 1.35 (1.17-1.55) | | 0.94 (0.68-1.30) | 0.86 (0.62-1.19) |
| CSCs (ref: Most disadvantaged) | | | | |
| Disadvantaged | 0.80 (0.65-0.97) | 0.92 (0.66-1.28) | 0.66 (0.52-0.84) | 0.70 (0.50-0.99) |
| Middle | 0.57 (0.47-0.70) | 0.88 (0.64-1.21) | 0.54 (0.43-0.68) | 0.67 (0.48-0.94) |
| Advantaged | 0.50 (0.40-0.64) | 0.81 (0.55-1.18) | 0.44 (0.34-0.58) | 0.61 (0.41-0.90) |
| Most advantaged | 0.47 (0.33-0.66) | 0.98 (0.54-1.77) | 0.37 (0.25-0.55) | 0.51 (0.27-0.95) |
| Access to services x CSCs | | | | |
| Access x Disadvantaged | | 0.88 (0.59-1.32) | | 0.87 (0.58-1.31) |
| Access x Middle | | 0.60 (0.41-0.89) | | 0.68 (0.46-1.00) |
| Access x Advantaged | | 0.55 (0.35-0.87) | | 0.61 (0.39-0.95) |
| Access x Most advantaged | | 0.42 (0.21-0.83) | | 0.60 (0.30-1.20) |
| Neighbourhood nuisances x CSCs | | | | |
| Nuisances x Disadvantaged | | | 1.78 (1.17-2.71) | 1.98 (1.29-3.03) |
| Nuisances x Middle | | | 1.25 (0.84-1.88) | 1.41 (0.94-2.13) |
| Nuisances x Advantaged | | | 1.56 (0.98-2.48) | 1.77 (1.11-2.82) |
| Nuisances x Most advantaged | | | 2.16 (1.07-4.35) | 2.47 (1.23-4.99) |

All models were adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression.
Abbreviations: CI, confidence intervals; CSC, childhood socioeconomic conditions; OR, odds ratios

We did not find any evidence for effect modification by ACEs and CHPs *(Supplementary Table 4.1 and 4.2)*. In the first sensitivity analysis, we tested the robustness of our findings by using continuous measures of depression. Although the main *(Supplementary Table 4.3)* and interaction effects *(Supplementary Table 4.4)* of access to services were slightly attenuated, the overall pattern of the findings did not change. Similarly, adjusting for rural-urban differences lessened the interaction effects of access to services and CSCs, but they remained close to the significance level *(Supplementary Table 4.5 and 4.6)*. In the subsample with no depression at baseline, the main effect of neighbourhood nuisances remained preserved; the association with access to services was only in the initial model significant *(Supplementary Table 4.7)*. Although the interaction coefficients had the same direction and pattern as in the main sample, the reduced power and large standard errors due to decreased sample size likely led to overlapping confidence intervals *(Supplementary Table 4.8)*. Finally, the supplementary analyses including age slopes for neighbourhood found a weak evidence for decreasing effect of neighbourhood nuisance on depression by ageing, which was attenuated after adjustment for baseline level of depression *(Supplementary Table 4.9 and 4.10)*.

## 4.6 Discussion

This study examined the longitudinal associations between perceived neighbourhood conditions and depression in older European adults and tested whether this relationship varied by exposure to childhood stressors. Our findings showed independent effects of neighbourhood conditions: living in an area with good access to services reduced by 22% the odds of developing depression during the follow-up, whereas being exposed to neighbourhood nuisances increased the odds by 36%. Less advantaged CSCs, ACEs and CHPs were associated with depression. While ACEs and CHPs did not modify the associations between neighbourhood exposure and mental health, we found differential vulnerability by CSCs. Older adults who grew up in better circumstances benefited more from living in a

residential area with good access to local services, but they were also at higher risk of developing depression when residing in areas with more neighbourhood nuisances; suggesting early childhood determination of place-based protective and risk factors on late life mental health.

### 4.6.1 Study strengths and limitations

Our findings are based on a large population-based sample of more than 10000 older adults from 13 European countries and present longitudinal findings over a 10-year period, which place this study among the very few long-term examinations in this field offering a prospective design.[7,15] Moreover, to our knowledge this is one of the first studies exploring the modifying effects of different childhood stressors on the neighbourhood-mental health link in this age group. However, it has also important limitations warranting for cautious interpretation. First, both predictor and outcome were assessed through self-report measures and thus can be subject to same source bias.[31] Although we tried to mitigate against reverse causation (i.e. depression leads to less favourable perception of the neighbourhood) by adjusting for baseline levels of depression, we could not exclude the possibility of other non-measured conditions, such as psychological disposition, distorting the associations.[32] Subjective measures of neighbourhood conditions often show stronger associations with health outcomes than objective characteristics.[32] Although the latter can better capture area features respondents might not be aware of, they are not able to take into account the substantial variation in how individuals define their own neighbourhoods.[33] Subjective perception might be the mediating pathway between objective neighbourhood characteristics and mental health.[32] Second, early childhood stressors were collected retrospectively; therefore, they may be affected from recall bias. Although retrospectively measured ACEs might potentially overestimate the effect of childhood on subjective outcomes,[34] CSCs and CHPs showed good level of internal and external consistency in the SHARE study.[35] Third, attrition during follow-up presents a possible bias to the representativeness of the findings. Although, in all models we included a variable indicating attrition during follow-up, our study design

required respondents to participate in at least 3 out of 6 waves, which led to a substantial drop in the sample size.

### 4.6.2 Comparison with the literature

Our study provided longitudinal evidence of the protective effects of good access to public transportation, pharmacy, medical care and grocery. As the mobility of older adults is often restricted, sufficient availability of and access to local services can provide basic and essential daily resources, help to maintain physical and mental health, and support social participation;[7,14] presenting opportunities for public health interventions. Previous research suggested adverse effects of neighbourhood problems on mental health among older adults,[7,9,10] which we were able to confirm in the SHARE study using subjective measures of pollution, noise, vandalism and crime. Possible neuropathological mechanisms contributing to higher risk of depression might lead through direct (e.g. elevated level of proinflammatory cytokines in the blood caused by air pollution,[13] distress induced by exposure to noise or crime[9,12]) or indirect (e.g. declining physical and social activities in the local area) pathways.

In line with findings highlighting the impact of early life experiences on mental health,[19-21] CSCs, ACEs and CHPs predicted late life depression. Exposure to stressors in this age might meet a so-called sensitive period, a time-limited developmental window when experiences and external exposures may alter developmental processes and influence prospective health.[19,36] ACEs and CHPs did not modify the effect of neighbourhood, which was particularly unexpected for ACEs, where interaction has been already shown.[22] However, ACEs were defined as intrafamilial events in our analysis, while the previous study focused on interpersonal trauma (e.g. abuse, neglect).[22]

CSCs predicted how neighbourhood influences depression. Living in an area with sufficient access to services was only beneficial for older adults, if they grew up in neutral or advantaged families; older people who experienced disadvantaged childhood circumstances did not benefit from better neighbourhood resources.

According to the pathway hypothesis, children with different socioeconomic background are channelled into pathways leading to divergent adult circumstances and health outcomes,[37] which, because of low social mobility, accumulates advantages and disadvantages, further widening health inequalities throughout the life course.[38] Childhood socioeconomic conditions did not only predict who could benefit from neighbourhood resources, but also influenced individual reactions for neighbourhood stressors. Previous research highlighted two distinct mechanisms for how childhood stressors may interact with later stressors, depending on the toxicity of exposure.[24] Severe adversities in early life can make individuals more vulnerable to psychopathology when exposed to subsequent stressors.[24] The stress sensitisation hypothesis in neighbourhood context has been confirmed in a US study showing elevated rates of depression among childhood trauma survivors living in high crime neighbourhoods as adults.[22] However, moderate levels of childhood stressors may contribute to resilience and help to build up resources and coping mechanism which can buffer the effect of future stressors.[24,39] This stress inoculation hypothesis provides a framework for our findings on the interaction of CSCs and neighbourhood nuisances, where participants with most disadvantaged CSCs did not indicate increased risk of depression when residing in adverse areas. An alternative explanation would emphasise the mental health consequences of downward intergenerational mobility,[40] i.e. coming from better childhood circumstances but ending up in adverse neighbourhood conditions.

### 4.6.3 Conclusion

Our longitudinal results provide valuable insights into how childhood stressors can modify the effects of neighbourhood on mental health among older adults, differently for protective and risk factors. Childhood is an important life stage where early experiences, exposure to stressors and living conditions can shape future coping mechanisms and resources relevant for healthy ageing. Future research on neighbourhood effects should prioritise the implementation of the life course approach to better understand differential vulnerability to neighbourhood conditions

and confirm our findings by using prospective childhood measures and objectively measured area characteristics. Furthermore, providing access to neighbourhood amenities and public transportation, as well as reducing environmental problems in the residential area, present public health opportunities to support healthy ageing. Policy makers may consider opportunities mitigating childhood stressors through supporting low-income families and investing in early childhood development and education, which can minimise the health impact of childhood socioeconomic inequalities.

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## 4.8 Assessment of bias

*Non-measurement error at unit-level*

Baseline response rates were on average 62% in the first, and 61% in the second SHARE wave.[1] There was a high attrition rate (>40%) during the 6 to 10-year follow-up of the study *(Figure 4.1)*, which clearly affected the representativeness of the sample. Although household net wealth was defined as 3 equally large group at baseline, in the analytic sample 10% more individuals remained from the high in comparison to low wealth groups *(Table 4.1)*.

*Non-measurement error at item-level*

Neighbourhood questions in SHARE wave 2 were asked in the main interview from household respondents, but were part of the drop-off questionnaire in wave 1. There was a substantial amount of missing covariates in the analytic sample (n=3234; <24% of the sample) *(Figure 4.1)*, overwhelmingly (>80%) caused by missing retrospective assessment of childhood stressors. As childhood stressors were assessed in wave 3 and not in baseline, missingness for these variables were mainly due to sample attrition (i.e. non-measurement error at unit level). The remaining missing covariates (<5% of the sample) were linked to non-measurement error at item-level. Post-hoc logistic regression indicated that being a complete case could not be explained by depression after considering covariates (p=0.136); so that complete case analysis was unbiased, and multiple imputation was not required.[2]

*Multicollinearity*

Collinearity between independent variables was explored with variance inflation factors (VIF). Although there was a high correlation between age, age-squared and age cohorts (VIF>10; 1/VIF<0.1), multicollinearity did not affect other variables and the mean VIF was moderate (VIF=3.33) in the fully adjusted model (*Supplementary Table 4.11*).

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# CHAPTER 5

# 5. Neighbourhood crime and prescribed psychotropic medications

## 5.1 Chapter overview

After exploring the associations between perceived neighbourhood conditions (including crime) and depression, the following two chapters focus on objectively measured neighbourhood characteristics and different mental health conditions. More precisely, Chapter 5 investigates the longitudinal relationship between neighbourhood income deprivation, neighbourhood crime and the initiation of new anxiolytics, antidepressants and antipsychotics medication in Scotland. Three main research gaps were addressed: First, by scaling down and focussing on crime events in small areas (data zones with 500-1000 residents), this chapter aimed to address the spatial specificity of crime. Second, very few studies are available on the association between neighbourhood crime and anxiety- and psychosis-related outcomes (2.6); therefore, this chapter aimed to provide condition-specific associations. Third, little is known about effect heterogeneity; exploring vulnerability across sociodemographic groups would address this gap.

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> *Baranyi G, Cherrie M, Curtis S, et al. Neighborhood Crime and Psychotropic Medications: A Longitudinal Data Linkage Study of 130,000 Scottish Adults. Am J Prev Med 2020;58(5):638–647.*

At the end of the chapter, a short assessment explores the risk of bias, easing to address overall strengths and limitation at the end of the thesis. Referred supplementary material can be found in Appendix Four.

**Title**

Neighbourhood Crime and Psychotropic Medications: A Longitudinal Data Linkage Study of 130,000 Scottish Adults

**Authors**

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*Author's contribution*: GB designed the study, conducted data analyses, interpreted the results and prepared the first draft. JP and CD participated in the study design, in the interpretation of the findings and commented on the manuscript. MC and SC contributed to the interpretation and revised the manuscript.

## 5.2 Abstract

**Introduction**: Although neighbourhood crime has been associated with mental health problems, longitudinal research utilising objective measures of small-area crime and mental health service use is lacking. This study examines how local crime is associated with newly prescribed psychotropic medications, in a large longitudinal sample of Scottish adults, and explored whether the relationships vary between sociodemographic groups.

**Methods**: Data from the Scottish Longitudinal Study, a 5.3% representative sample of the population, were linked with police recorded crime in 2011 for residential locality, and with psychotropic medications from 2009-2014, extracted from the prescription dataset of National Health Service Scotland. Individuals receiving medication during the first 6 months of observation were excluded; the remaining sample was followed for 5.5 years. Covariate-adjusted, multilevel mixed-effects logistic models estimated associations between area crime and prescriptions for antidepressants, antipsychotics and anxiolytics (analysed in 2018/2019).

**Results**: After adjustment for individual and neighbourhood covariates, findings on 129,945 adults indicated elevated risk of antidepressants (OR=1.05, 95% CI: 1.00-1.10) and antipsychotics (OR=1.20, 95% CI: 1.03-1.39), but not anxiolytics (OR=0.99, 95% CI: 0.93-1.05) medication in high crime areas. Crime showed stronger positive association with antidepressants among individuals (especially women) aged 24-53 years in 2009, and with antipsychotics among men aged 44-53 years in 2009. Skilled workers and people from lower non-manual occupations had increased risk of medications in high crime areas.

**Conclusions**: Local crime is an important predictor of mental health, independent of individual and other contextual risk factors. Place-based crime prevention and targeting vulnerable groups may have benefits for population mental health.

## 5.3 Introduction

Mental disorders are major contributors to global disease burden, affecting approximately 30% of the population at least once during their lifetime.[1] In addition to research on individual-level risk factors, growing attention is being paid to the wider determinants of mental health inequalities. Research has shown that the urban environment is linked with common mental disorders[2] and psychotic illnesses,[3] and this relationship may be explained by local differences in both social and physical conditions,[4] including income deprivation, crime or social cohesion.[5-7]

Although the majority of the research on contextual risks is focused on the association with area-based poverty, evidence is more limited regarding the causal pathways linking neighbourhood deprivation to mental disorders.[8] A possible mediator may be the elevated levels of crime in disadvantaged areas.[8, 9] The available evidence suggests that victimisation and witnessing violence directly effects psychiatric disorders.[10, 11] Indirectly, crime and violence in the community may increase the threat of victimisation, inducing chronic stress and fear of crime, making residents more vulnerable to psychiatric conditions.[12] Protective factors buffering the effect of stressors may be lacking in unsafe areas as people engage less in health-promoting physical and social activities.[12]

Although associations between residing in high crime neighbourhoods and mental health problems have been reported,[8, 12-14] the literature has several shortcomings. First, though substantial research focuses on depression, it is less clear whether the effect of crime varies by psychiatric conditions. Second, there is a lack of studies utilising longitudinal designs with objective measures,[8, 14] which is critical to avoid reverse causation and same source bias.[15] Third, crime tends to be spatially concentrated;[9] studies using large geographic scales[14] are unlikely to provide sufficient spatial specificity. Finally, few studies have investigated the link between crime levels and mental health service use,[16-18] and there is limited evidence on medication use, the most common treatment of mental disorders.[19] The primary aim of this study is to estimate the longitudinal associations between neighbourhood

crime and prescribed psychotropic medications, in a large nationally representative sample of Scottish adults. Furthermore, the study explores how the inclusion of area-level socioeconomic disadvantage changes this relationship, identifies vulnerable groups by age, gender and social grade, and tests whether different types of psychiatric conditions were more sensitive to varying crime levels.

## 5.4 Methods

### 5.4.1 Study sample

Data were drawn from the Scottish Longitudinal Study (SLS), a 5.3% nationally representative sample of the Scottish population linking administrative and statistical data sources.[20] Based on 20 semi-random birthdays,[20] the sample captures individuals present at any of the 1991, 2001 and 2011 Censuses. For the purpose of this study, a subset of the original SLS sample was extracted, including adults aged ≥16 years in 2001 Census, present in both 2001 and 2011 Censuses and not living in communal establishments in 2011. The core SLS sample contains individual socio-demographic characteristics. Data on prescribed medications (available between 2009 and 2014) were linked to the sample using personal identifiers, while area-level crime and income deprivation (recorded in 2010/2011) were linked using 2011 Census data zones. To avoid confounding due to inclusion of individuals with long-standing mental illness, participants with prescribed psychotropic drugs during the first 6 months of the available prescription data were excluded. The remaining sample was followed until the end of December 2014 *(Supplementary Figure 5.1)*. Ethical approval for the research was given by the Public Benefit and Privacy Panel for Health and Social Care, National Health Service (NHS) Scotland (application number eDRIS 1516-0398) and by the Research Ethics and Integrity Committee, University of Edinburgh (GeoSciences_2018_189).

### 5.4.2 Measures

The Scottish National Prescription Information System holds all NHS prescriptions, prescribed, dispensed and reimbursed in the community across Scotland.[21] Prescriptions for three main types of psychotropic drugs were linked to SLS members. Antidepressants (British National Formulary 4.3) are used mainly for treating depression but also for anxiety disorders and eating disorders;[22] antipsychotics and related drugs (British National Formulary 4.2) are prescribed for psychotic and related disorders but also for unresponsive depression and anxiety;[22, 23] and finally anxiolytics (British National Formulary 4.1.2) provide short-term relief of severe anxiety *(Supplementary Table 5.1)*.[22] As some tricyclic antidepressants can be prescribed in lower dosage for neuropathic pain or headaches,[22] free-text dose instructions, extracted by the data owners with data-mining techniques,[24] were used to exclude low dosage (≤30mg/day) of amitriptyline and nortriptyline from the dataset. Three study outcomes were defined as having been prescribed at least one new medication during the 5.5 years of follow-up for: antidepressants, antipsychotics, and anxiolytics.

Crime and income deprivation indicators were extracted from the 2012 release of the Scottish Index of Multiple Deprivation, available for data zones, including approximately 500-1,000 household residents per unit. The crime domain consists of police recorded and geo-referenced crimes or offenses (crimes of violence, sexual offenses, domestic housebreaking, vandalism, drugs offenses, common assault) aggregated during the 2010-2011 financial year.[25] Income deprivation captures the proportion of the population receiving financial support from the state because of to low income (i.e. Income Support or Income-based Employment and Support Allowance; Job Seekers Allowance; Guarantee Pension Credit; Tax Credit Families on low incomes).[25] Police recorded crime and number of individuals with social benefits were divided by the respective population estimates and reported as ranks between the most and least disadvantaged areas. High, moderate and low groups were defined for crime and income deprivation by dividing the 6,505 data zones into three

equal groups *(Figure 5.1)*, which were moderately correlated in the sample ($r_S$=0.64, $p$<0.001).

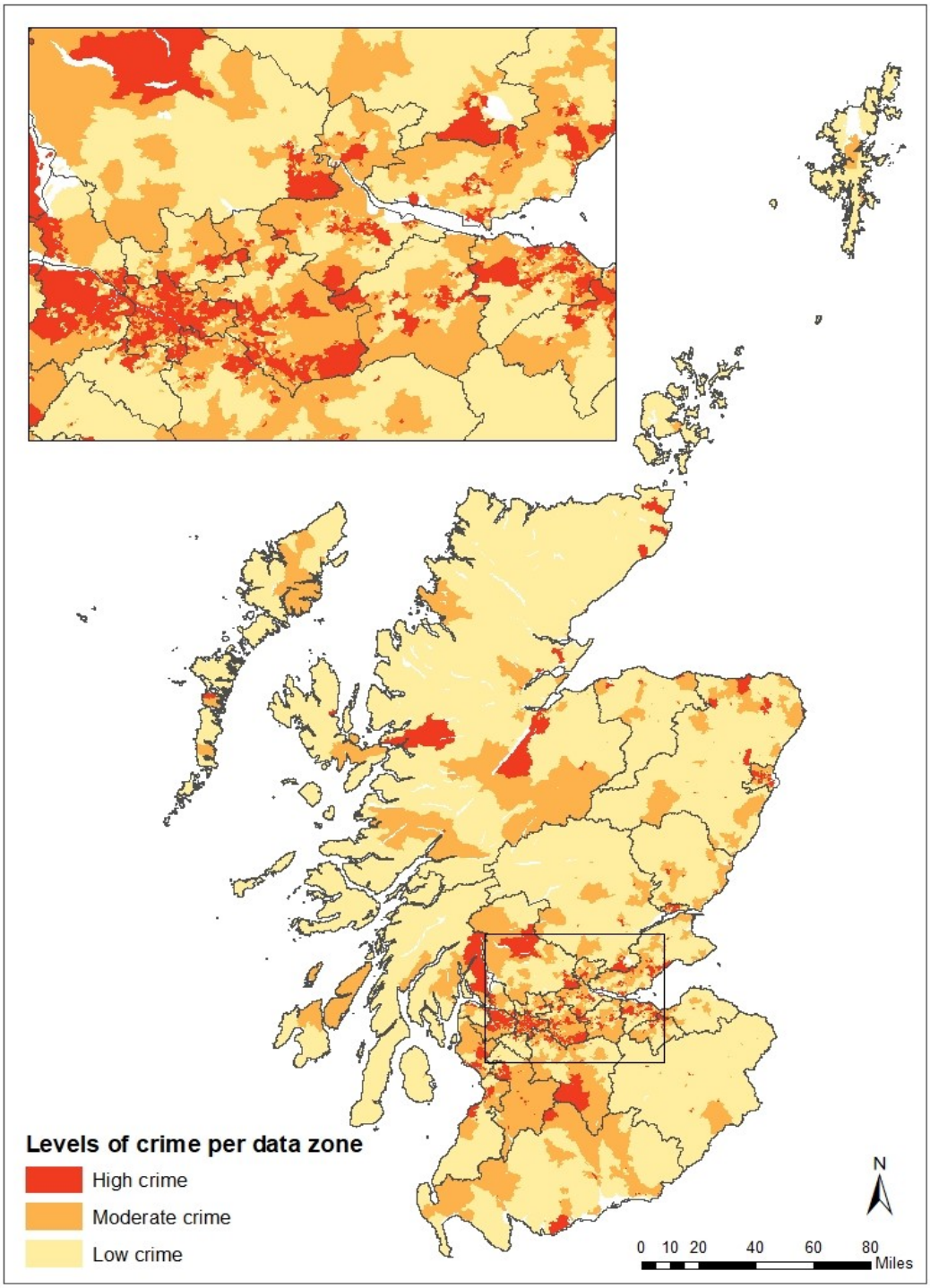



***Figure 5.1*** *Levels of crime in 6,505 data zones grouped into 32 Local Authorities across Scotland (source: Scottish Index of Multiple Deprivation 2012). Data are presented for the whole country and for the Central Belt of Scotland.*

Demographic variables were reviewed for consistency between the 2001 and 2011 Censuses, and comprised information on sex (female, male), age at baseline (24–33, 34–43, 44–53, 54–63, 64–73, 74–83, and ≥84 years in 2009) and ethnicity (white, non-white, missing). Other individual covariates were extracted from the 2011 Census; for which missing values have been imputed by the 2011 Census team.[26] Social grade based on occupation ranged from higher professional groups to the lowest grade workers. Highest educational attainment provided information on qualifications classified into five groups ranging between 'no qualification' and 'higher educational degree'. Employment (employed, out of labour market, retired, unemployed), marital status (married, single, separated, divorced, widowed), living status (alone, with others) and the presence of long-term illness, disease or condition (yes, no) other than mental health problems were also included in the analyses *(Supplementary Table 5.2)*. Finally, deciles of population density per data zone were used to adjust for levels of urbanisation.

### 5.4.3 Statistical analysis

Multilevel mixed-effects logistic regressions with random intercept were fitted by calculating estimations based on QR decomposition. To adjust for unexplained variability between geographic clusters, individual observations were nested into 32 Scottish Local Authorities. Local Authorities have similarities in terms of social care provision, and labour market characteristics[27] and overlap the 14 Scottish Health Boards, responsible for population health and health care service delivery.[22] The very low prevalence of antipsychotic medication precluded the use of smaller geographic units.[28] Fixed effects were expressed with odds ratios (OR) and 95% confidence intervals (CI), likelihood ratio test detected non-zero random-effects variance.[29]

In the main analyses, three hierarchical models were presented for the three medication groups; each model included data zone level crime as the main predictor of interest. Model 1 controlled for sex and age. Model 2 adjusted for all additional individual covariates (ethnicity, social grade, educational attainment, employment status, marital status, living status, and long-term illness, disease or condition) and

population density. The final model (Model 3), presented for the entire sample and stratified by sex, explored whether crime had an additional association over and above area-level income deprivation (see conceptual diagram in *Supplementary Figure 5.2*). As little evidence is available on the varying effect of crime across the life course and by different social groups, interactions were explored with 1) sex-age and 2) social grade. Finally, adjusted predictive margins of interaction terms were estimated with Bonferroni corrections, while fixing all covariates at their means and taking into account the random structure of the data. Predicted probabilities were visualised in plots.

Three sets of sensitivity analyses were carried out. First, new episode of antidepressants, antipsychotics or anxiolytics medication were defined, when at least six prescriptions from the same medication cluster were dispensed during follow-up. Second, as conditions with antidepressants and anxiolytics use may largely overlap, main results were provided for the outcome of having been prescribed at least one 'antidepressant or anxiolytic' medication. Third, to minimize the risk of health selection into high crime neighbourhoods, models were repeated including only individuals who stayed in the same data zone during the entire study period (01/01/2009-31/12/2014). Information on continuous residential location were derived by SLS staff from the NHS GP postcode database.

All analyses were conducted in 2018/2019 within the SLS safe setting in Edinburgh, UK, using STATA 13.

## 5.5 Results

After excluding individuals with medications during the first six months of the study period, the analytic sample size comprised 129,945 adults from the original sample of over 150,000. A small majority were female (51%) and the average age was 51.3 years in 2009. During follow-up, 22% of the sample received at least one new prescription for antidepressants, 2% for antipsychotics and 11% for anxiolytics. These proportions

differed significantly between groups of sample members categorised by crime tertiles of their residential area ($p$<0.001) *(Table 5.1)*.

***Table 5.1*** *Individual and small area characteristics by crime levels among 129,945 Scottish adults (%)*

| Variable | Low crime (n = 47,655) | Moderate crime (n = 45,193) | High crime (n = 37,097) |
|---|---|---|---|
| Sex | | | |
| Male | 49 | 49 | 48 |
| Female | 51 | 51 | 52 |
| Age groups in 2009, years | | | |
| 24–33 | 12 | 15 | 20 |
| 34–43 | 20 | 19 | 19 |
| 44–53 | 24 | 22 | 20 |
| 54–63 | 21 | 19 | 17 |
| 64–73 | 14 | 14 | 13 |
| 74–83 | 8 | 8 | 8 |
| ≥84 | 2 | 2 | 2 |
| Ethnicity | | | |
| White | 97 | 96 | 95 |
| Non-white | 1 | 1 | 1 |
| Missing | 2 | 2 | 3 |
| Social Grade | | | |
| AB | 27 | 19 | 12 |
| C1 | 32 | 30 | 27 |
| C2 | 22 | 24 | 24 |
| D | 17 | 23 | 31 |
| E | 1 | 3 | 6 |
| Education | | | |
| No qualification | 21 | 29 | 38 |
| Level 1 | 20 | 22 | 23 |
| Level 2 | 13 | 12 | 11 |
| Level 3 | 11 | 10 | 9 |
| Level 4 | 36 | 27 | 19 |
| Employment status | | | |
| Employed | 65 | 62 | 57 |
| Retired | 28 | 28 | 27 |
| Out of labour force | 6 | 7 | 11 |
| Unemployed | 2 | 3 | 4 |
| Marital status | | | |
| Married | 69 | 59 | 47 |
| Single | 15 | 20 | 28 |
| Separated | 3 | 3 | 4 |
| Divorced | 7 | 8 | 11 |
| Widowed | 8 | 9 | 10 |

| | | | |
|---|---|---|---|
| Living status | | | |
| With others | 86 | 82 | 75 |
| Alone | 14 | 18 | 25 |
| Long-term illness, disease or condition | | | |
| No | 79 | 77 | 75 |
| Yes | 21 | 23 | 25 |
| Area population density (mean[SD]) | 4.4 (2.7) | 5.7 (2.8) | 6.4 (2.7) |
| Area income deprivation | | | |
| Low | 71 | 28 | 7 |
| Moderate | 27 | 48 | 27 |
| High | 2 | 24 | 66 |
| At least one new prescription | | | |
| Antidepressants | 19 | 22 | 26 |
| Antipsychotics | 1 | 1 | 2 |
| Anxiolytics | 10 | 11 | 12 |

Source: Scottish Longitudinal Study. AB, Higher or intermediate managerial, administrative or professional grade; C1, Supervisory, clerical and junior managerial, administrative and professional; C2, Skilled manual workers; D, Semi-skilled and unskilled manual workers; E, State pensioners, casual and lowest grade workers, unemployed with state benefits only.

Compared with those in low crime areas, individuals living in neighbourhoods with moderate or high crime showed a significantly higher risk of having a new prescription for antidepressants during follow-up *(Table 5.2)*. Associations were weaker but still significant after adjustments for covariates and population density (moderate crime: OR=1.07, 95% CI 1.03-1.10; high crime: OR=1.17, 95% CI 1.13-1.21). In the final model, antidepressant medication was more common among female participants and the risk decreased in older age groups *(Supplementary Table 5.3)*; after controlling for income deprivation, residing in high crime areas was associated with 5% higher odds (95% CI: 1.00-1.10) of antidepressant prescriptions *(Table 5.2)*. There were higher odds of new antipsychotic medications in high compared to low crime areas, even after adjustments for individual covariates and population density (OR=1.27, 95% CI 1.13-1.44) *(Table 5.2)*. In the fully-controlled model, the risk of antipsychotics prescription was higher among men and in older age groups *(Supplementary Table 5.3)*. While living in high crime neighbourhoods increased the odds of new medication by 20% (95% CI: 1.03-1.39), which was attributable to the male subsample (OR=1.31, 95% CI: 1.06-1.62), income deprivation was not associated

with antipsychotics prescription *(Table 5.2)*. Finally, new anxiolytic medication was associated with moderate (OR=1.09, 95% CI: 1.04-1.14) and high (OR=1.17, 95% CI: 1.12-1.23) crime rates in the model with age and sex controlled. However, this association was not significant after further model adjustments, leaving only income deprivation as an area-level predictor *(Table 5.2, Supplementary Table 5.4)*.

Effect modification for the association with area crime levels was found by age and sex, and by social grade. Crime had a stronger association with new antidepressants among individuals who were aged 24-53 years in 2009 (in particular women), and with antipsychotics among men aged 44-53 years in 2009. With ageing, the associations disappeared and even became negative for antidepressants and anxiolytics, indicating lower likelihood of medication in high crime areas *(Figure 5.2 for male and Figure 5.3 for female participants)*. Furthermore, models indicated higher risk of new medications in moderate and high crime neighbourhoods for individuals in middle social grades: for antidepressants medication among 'skilled manual' workers, for antipsychotics medication among those belonging to the 'supervisory, clerical and junior managerial, administrative and professional' group *(Supplementary Figure 5.3)*.

***Table 5.2*** *Associations between crime, area income deprivation and new psychotropic prescriptions (n=129,945)*

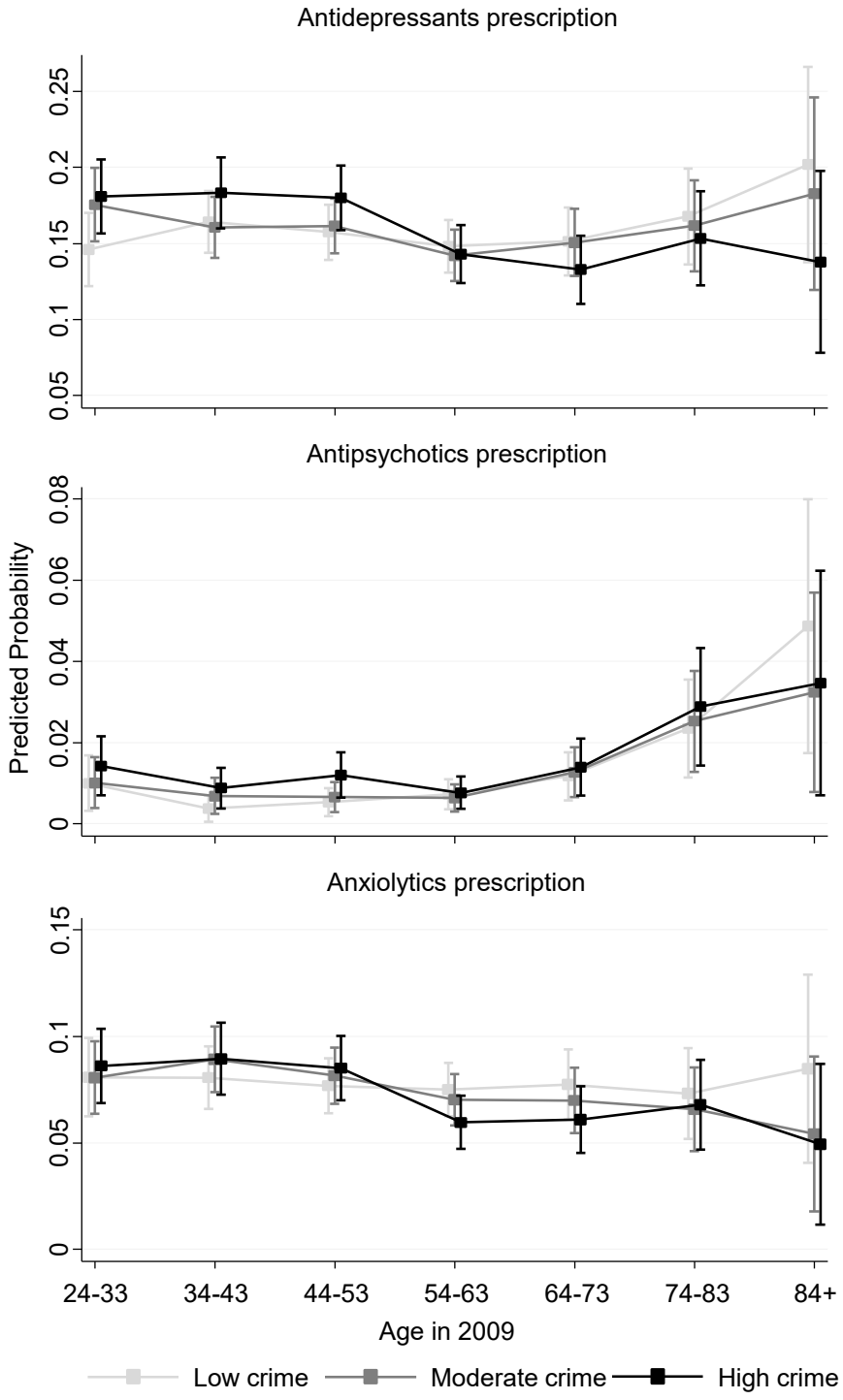
| Variable | | Model 1[a] | Model 2[b] | Model 3[c] | Model 3: Male | Model 3: Female |
|---|---|---|---|---|---|---|
| **Antidepressants** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.17 (1.13-1.21)** | **1.07 (1.03-1.10)** | 1.01 (0.97-1.04) | 1.01 (0.95-1.07) | 1.00 (0.96-1.05) |
| | High | **1.43 (1.38-1.48)** | **1.17 (1.13-1.21)** | **1.05 (1.00-1.10)** | 1.05 (0.98-1.12) | 1.04 (0.98-1.10) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.11 (1.07-1.15)** | **1.09 (1.03-1.15)** | **1.12 (1.07-1.18)** |
| | High | | | **1.23 (1.17-1.29)** | **1.15 (1.07-1.24)** | **1.27 (1.19-1.35)** |
| $ICC_{Local\ Authority}$ | | 0.34 (0.19-0.61) | 0.25 (0.13-0.47) | 0.23 (0.12-0.44) | 0.21 (0.08-0.48) | 0.20 (0.09-0.42) |
| **Antipsychotics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.15 (1.03-1.29)** | 1.04 (0.92-1.17) | 1.00 (0.88-1.14) | 1.04 (0.86-1.25) | 0.96 (0.82-1.15) |
| | High | **1.62 (1.45-1.82)** | **1.27 (1.13-1.44)** | **1.20 (1.03-1.39)** | **1.31 (1.06-1.62)** | 1.10 (0.89-1.35) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | 1.08 (0.95-1.22) | 1.06 (0.88-1.28) | 1.09 (0.91-1.30) |
| | High | | | 1.12 (0.96-1.32) | 1.15 (0.91-1.45) | 1.07 (0.86-1.33) |
| $ICC_{Local\ Authority}$ | | 1.97 (1.04-3.70) | 2.17 (1.17-4.02) | 2.21 (1.19-4.07) | 2.64 (1.30-5.27) | 2.26 (1.03-4.92) |
| **Anxiolytics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.09 (1.04-1.14)** | 1.02 (0.98-1.07) | 1.00 (0.95-1.05) | 0.99 (0.91-1.07) | 1.00 (0.94-1.07) |
| | High | **1.17 (1.12-1.23)** | 1.03 (0.98-1.08) | 0.99 (0.93-1.05) | 0.96 (0.87-1.06) | 1.00 (0.92-1.08) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.06 (1.01-1.12)** | *1.07 (0.99-1.16)* | *1.06 (0.99-1.13)* |
| | High | | | **1.09 (1.02-1.16)** | 1.09 (0.98-1.20) | *1.08 (1.00-1.17)* |
| $ICC_{Local\ Authority}$ | | 0.33 (0.18-0.61) | 0.34 (0.18-0.64) | 0.34 (0.18-0.64) | 0.34 (0.14-0.79) | 0.38 (0.20-0.74) |

*Note*: Boldface indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Estimates are expressed in OR with 95% CI. ICC, Intraclass Correlation Coefficient.
Source: Scottish Longitudinal Study

[a] Model 1: Adjusted for sex and age.

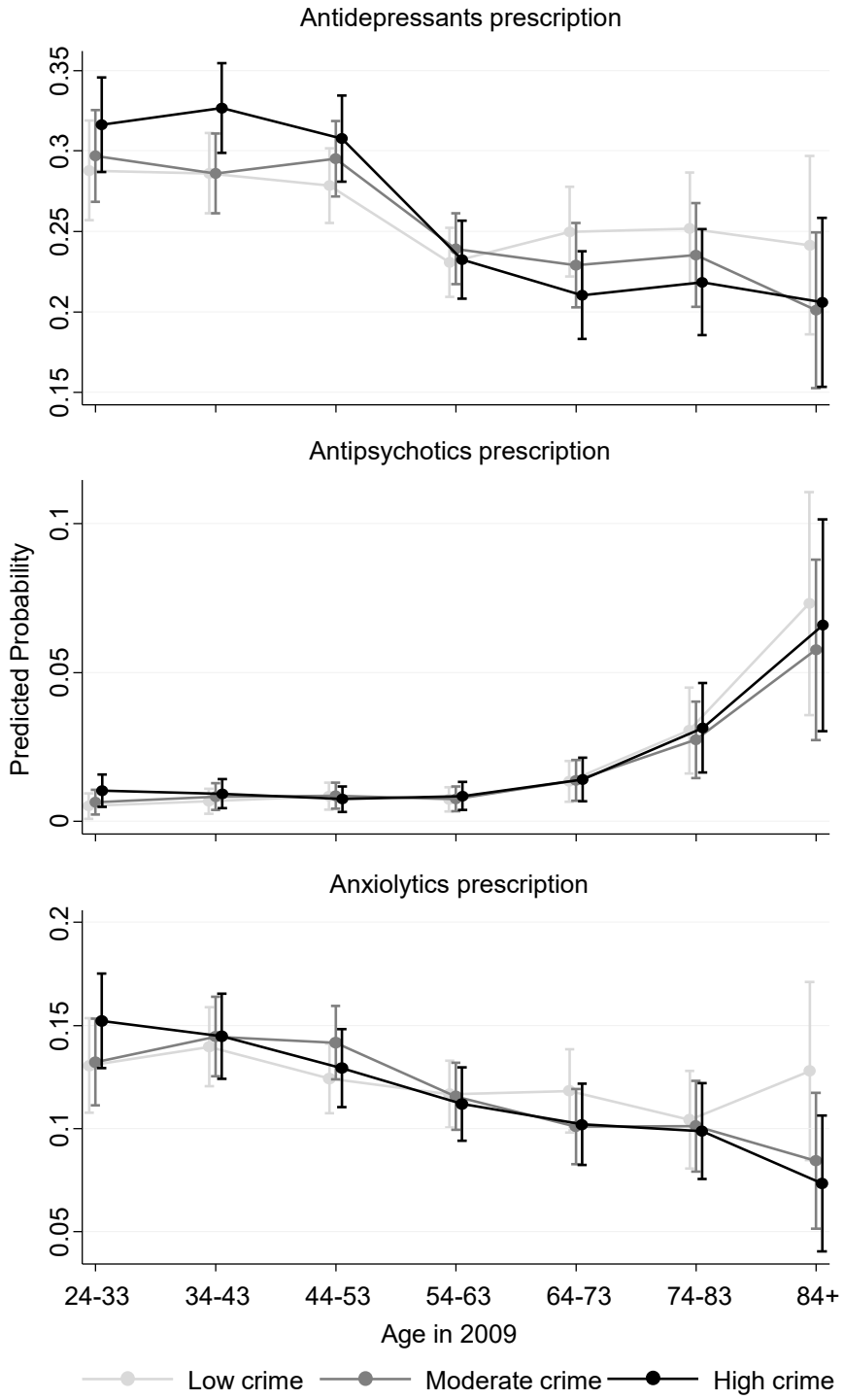
[b] Model 2: Model 1 + adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition, and area population density.

[c] Model 3: Model 2 + adjusted for area income deprivation.




Source: Scottish Longitudinal Study

***Figure 5.2*** *Adjusted predictions for new psychotropic prescriptions by age groups and crime levels in males. Note: Models were adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition, area population density and area income deprivation; and corrected for multiple comparison (Bonferroni correction).*




Source: Scottish Longitudinal Study

***Figure 5.3*** *Adjusted predictions for new psychotropic prescriptions by age groups and crime levels in females.* Note*: Models were adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition, area population density and area income deprivation; and corrected for multiple comparison (Bonferroni correction).*

In supplementary analysis, the odds of receiving at least six antidepressant medications during follow-up by crime levels were comparable to the main findings, whereas the associations with anxiolytics and antipsychotics became stronger. The odds of being prescribed at least six antipsychotics during follow-up tripled in high crime areas (Model 3: OR=1.57, 95%: 1.22-2.03) in comparison with the main results, and were similarly pronounced among male and female participants *(Supplementary Table 5.5)*. Findings for 'antidepressant or anxiolytics' medication were comparable to the results for antidepressants *(Supplementary Table 5.4 and 5.6)*. Finally, analyses based on individuals who stayed at the same address during the entire study period yielded findings comparable to the main models *(Supplementary Table 5.7)*.

## 5.6 Discussion

This study suggests that crime in the residential area increases the risk for initiation of prescriptions for psychotropic medications. In addition to the relatively strong link to income deprivation, higher local crime rate slightly increased the likelihood of having antidepressant prescriptions. This was mainly attributable to higher vulnerability among individuals aged 24-53 years in 2009. Only crime levels, and not income deprivation, predicted the risk of antipsychotic prescriptions, and the association was particularly pronounced among men aged 44-53 years in 2009. There was no association between crime and anxiolytics medication. Among individuals with middle social grades, those living in higher crime areas had elevated risk of antidepressants and antipsychotics medications.

Although the general findings on the increased risk of mental disorders in high crime areas are consistent with previous evidence utilising cross-sectional and longitudinal data on self-reported mental health,[8, 13, 14, 18] this study highlights differing relationship by medication types. For antidepressants the association with crime was accompanied by a strong link with area poverty, indicating that other area-based mechanism, in addition to crime, might operate in disadvantaged neighbourhoods to affect these conditions.[8] The relationship between crime and antipsychotic drugs was

four-times stronger than for antidepressant medications, whereas no other area-level association was related. Although no previous person-level evidence is available, this result is in line with an ecological investigation from London, UK on the incidence of first episode schizophrenia,[18] highlighting the predominance of community exposure to crime and violence in the aetiology of psychoses, over other contextual determinants. In addition to previously outlined pathways, the strong link between antipsychotics and neighbourhood crime in the current sample, particularly among middle-aged men, might be related to increased drug use in high crime areas,[12] which has been linked to psychosis incidence.[30] Also, non-adherence to antipsychotic medications may vary across crime levels, explaining higher risk of new prescriptions in high-crime neighbourhoods. With regards to service use for anxiety disorders, income deprivation rather than crime may explain spatial patterning in disadvantaged neighbourhoods, supporting results in a previous study using inpatient and outpatient contact in Malmö, Sweden.[17] However, the relationship among crime, mental health and mental health service use is particularly complex. Not only can exposure to crime influence mental health problems, but individuals with existing psychiatric conditions are at higher risk of victimisation,[31] and more likely to commit violent offenses.[32] Furthermore, though findings reported here indicated decreasing effect sizes of crime from antipsychotic to anxiolytic prescriptions, the treatment gap widens from psychotic to depressive and anxiety disorders.[33, 34] This dose-response relationship between the severity of condition and probability of treatment suggests that there may be greater underestimation of the real effect of crime on mental health when utilising anxiolytic and antidepressant medications.

Stronger relationships between neighbourhood crime and mental health problems for those in middle social grades can be explained by the combined effects of lack of personal resources and lower adaptation to chronic neighbourhood stressors. People with higher social positions may be better equipped with material and social resources[35] protecting them from the detrimental effect of crime. By contrast, adaptation to chronic stressors (e.g. based on previous exposures) or saturation of

contextual effects over and above individual risk could provide an explanation for non-significant effects in lower social grades. Contrary to other literature,[8] this study found that, amongst older adults, the use of antidepressants and anxiolytics was less likely as crime level increased, whereas the positive association with area income deprivation remained. Although declining mobility in older age may increase the exposure to neighbourhood nuisances affecting mental health, there is also evidence of lower engagement in physical activity and walking in unsafe neighbourhoods in this age group.[36] It is plausible that elevated local crime may further restrict individuals from leaving their home to consult a health practitioner, independent of their mental health status. However, psychotropic medications in this age group should be interpreted with caution as they may indicate physical and neurological comorbidities;[22, 37] also, higher mortality in violent areas[38] may result in a more selected and resilient older populations than in low crime areas.

### 5.6.1 Limitations

This longitudinal data-linkage study benefited from a large-scale nationally representative sample, comprising detailed individual-level information on personal attributes.[20] Prescriptions are routinely collected and quality checked by NHS Scotland, which provides comprehensive health care, funded through general taxation, and is almost universally used by patients seeking health services in the whole population.[21] As prescriptions have to be submitted to NHS Scotland by dispensers for reimbursement, it has an exceptional high level of completeness enabling longitudinal data linkage: General practitioners account for more than 95% of total prescribing in the primary care, and 98.7% of their prescriptions had personal identifiers in 2014.[21]

However, several limitations need to be considered. First, the outcome measure was derived from service use. Access to primary health care or mental health stigma may vary by neighbourhoods. Furthermore, prescribing behaviour between primary healthcare providers can be spatially patterned,[39] independent from health and social care differences on Local Authority level (which has been taking into consideration

in this study). Second, psychotropic drugs are a proxy for psychiatric disorders, and can be prescribed for other conditions. A substantial number of patients with dementia receive antipsychotic and antidepressant prescriptions even in the complete absence of depression or psychosis.[23, 40] Third, prescriptions prior 2009 are not available.[21] Despite excluding individuals with ongoing medication and controlling for residential movements during the study, it still remains plausible that individuals with psychiatric history, especially with psychoses,[6] were already selected in high crime areas. Future longitudinal research should explore the complex spatial-temporal associations between crime and mental disorders by utilising longer follow-ups and repeated measurements.

### 5.6.2 Conclusions

Using objective, small area-level measures this study provided prospective evidence that neighbourhood crime is associated with new antidepressant and antipsychotic medication independent of area deprivation, urbanisation and a range of individual characteristics. Targeting high crime areas with crime prevention or area-based interventions (e.g. rehabilitating deprived areas, mitigating deteriorated housing or greening vacant parcels) may reduce crime,[41] which can be beneficial for mental health. It may also be prudent for health care planners to enhance mental health services in the vicinity of violent areas,[13] providing prevention and treatment opportunities especially for those more vulnerable to the effects of crime.

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## 5.8 Assessment of bias

*Non-measurement error at unit-level*

This chapter utilised administrative data derived from the SLS which is not only a nationally representative sample based on census questions required to be collected by law, but it has an extremely low attrition rate (~12% between censuses) mainly due to Scottish residents moving out from the UK.[1] Similarly, outcome data on prescribed medication has an exceptionally high completeness with 98.7% of GP's prescriptions being linked with personal identifiers.[2]

*Non-measurement error at item-level*

No missing values for exposure and outcome were present in the dataset. Moreover, 2011 Census variables were edited and imputed by the UK Census Offices, applying the CANCEIS procedure (CANadian Census Edit and Imputation System).[3] The imputation algorithm is based on the Nearest-neighbour Imputation Method, and considered as a robust and cost-effective practice.[3] Researchers using the SLS have only access to the imputed 2011 dataset.

*Multicollinearity*

Collinearity between independent variables was explored with variance inflation factors (VIF), which did not indicate high correlation (VIF<10; 1/VIF>0.1) between variables *(Supplementary Table 5.8)*.

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# CHAPTER 6

# 6. Changing levels of crime and mental health utilising self-reported and service use data

## 6.1 Chapter overview

The previous empirical chapters focused on individuals staying in the same area, assuming longitudinal associations being mainly explained by neighbourhood features impacting mental health. However, also individuals with pre-existing mental health conditions can move to more disadvantaged areas (1.6.3.2). Chapter 5 focused on new medication regimes and provided a more descriptive analysis; using the same dataset, this last empirical chapter aims to investigate the causal relationship between neighbourhood crime and mental health, an important but neglected research question. First, it applies a natural experimental framework by taking advantage of unequally dropping small area-level crime rates across Scotland. Second, it utilises self-reported and service use data on mental health within the same study. Third, by linking continuous residential location to sample participants and repeated crime measurement across time, this study allows to separate between the effect of changing area-level crime and residential mobility.

This chapter in its current form has been published in the *Journal of Epidemiology and Community Health* and available as follows:

> *Baranyi G, Cherrie M, Curtis S, et al. Changing levels of local crime and mental health: a natural experiment using self-reported and service use data in Scotland. J Epidemiol Community Health Published Online First: 05 June 2020. doi: 10.1136/jech-2020-213837.*

At the end of the chapter, a short assessment explores the risk of bias, easing to address overall strengths and limitation at the end of the thesis. Referred supplementary material can be found in Appendix Five.

**Title**

Changing levels of local crime and mental health: A natural experiment utilising self-reported and service use data in Scotland

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*Author's contribution*: GB designed the study, conducted data analyses, interpreted the results and prepared the first draft. JP and CD participated in the study design, in the interpretation of the findings and commented on the manuscript. MC and SC contributed to the interpretation and revised the manuscript.

## 6.2 Abstract

**Background**: This study contributes robust evidence on mental health and local crime rates by showing how changing exposure to small area-level crime relates to self-reported and administrative data on mental health.

**Methods**: The study sample comprised 112251 adults aged 16-60 years, drawn from the Scottish Longitudinal Study, a 5.3% representative sample of Scottish population followed across censuses. Outcomes were individual mental health indicators: self-reported mental illness from the 2011 Census and linked administrative data on antidepressants and antipsychotics prescribed through primary care providers in the National Health Service in 2010/12. Crime rates at data zone level (populations 500-1000) were matched to the participants' main place of residence, as defined by general practitioner patient registration duration during 2004/06, 2007/09 and 2010/12. Average neighbourhood crime exposure and change in area crime were computed. Covariate adjusted logistic regressions were conducted, stratified by moving status.

**Results** In addition to average crime exposure during follow-up, recent increases in crime (2007/09-2010/12) were associated with higher risk of self-reported mental illness, among 'stayers' aged 16-30 (OR=1.11; 95% CI: 1.00-1.22), and among 'movers' aged 31-45 (OR=1.07; 95% CI: 1.01-1.13). Prescribed medications reinforced these findings; worsening crime rates were linked with antidepressant prescriptions among young stayers (OR=1.09; 95% CI: 1.04-1.14), and with antipsychotic prescriptions among younger middle-aged movers (OR=1.11; 95% CI: 1.01-1.23).

**Conclusion**: Changing neighbourhood crime exposure is related to individual mental health but associations differ by psychiatric conditions, age and moving status. Crime reduction and prevention, especially in communities with rising crime rates, may benefit public mental health.

## 6.3 Introduction

Mental health disorders are major contributors to the global disease burden and present the leading cause of disability among young adults.[1] In high-income countries the burden is even larger: one in six adults in the United Kingdom are affected by common mental disorders at any given time,[2] causing direct and indirect costs that equate to over 4% of the national Gross Domestic Product.[3] Over and above individual biopsychosocial determinants, the physical and social environment where people live influences mental health.[4-6]

Residential areas with high levels of deprivation and social disorganisation tend to have more crime and violence,[7,8] impacting mental health due to heightened risks of personal victimisation and witnessing crime,[9] and through an ecological pathway by inducing stress and fear of crime.[10] While the notion that neighbourhood-level crime is associated with self-reported symptoms and mental health service use has been confirmed in ecological,[11] cross-sectional[12,13] and longitudinal[14-16] studies, investigations examining spatial and temporal variation in exposure to crime are still lacking. Crime events are not randomly distributed; incidents in small number of micro-geographic areas are account for a large proportion of total,[8,12] which can be key to explaining the relationship with mental health.[12]

Individual exposure to residential characteristics may change as the surrounding area alters in response to political and other contextual influences (e.g. revitalisation, gentrification, post-industrial decline),[17] or through residential mobility by people moving to different areas. Increasing neighbourhood deprivation has been linked to distress among residents staying in the same area.[18] Also, moving from high to low poverty areas might be beneficial for mental health, as demonstrated in experimental[19] and observational studies.[20] Whilst there is some evidence that rising crime can be detrimental for mental health,[14,15] studies often utilise crime aggregated into large geographic units, which may lack the specificity to capture spatio-temporal variability in crime.[12] Finally, not only may neighbourhood crime cause mental

disorders, but people with disadvantaged background or with pre-existing health condition might be more likely to move into higher crime areas.[21]

Since the 1990s, the national-level reported crime rate has dropped in Scotland; however the reductions have not been uniform between communities,[8] providing an opportunity to utilise the spatio-temporal variation in crime as a natural experiment.[14] To address this research gap, we investigated how individual self-reported mental illness and prescribed psychotropic medications related to increasing neighbourhood crime levels, taking into account residential mobility. Moreover, we aimed to identify demographic groups whose mental health seemed most vulnerable to crime effects, where prevention and service development might be particularly beneficial.

## 6.4 Methods

### 6.4.1 Sample

Data were drawn from the Scottish Longitudinal Study (SLS), a 5.3% nationally representative sample of the Scottish population. The SLS includes individuals selected on the basis of 20 semi-random birthdates and present in any of the 1991, 2001 and 2011 Censuses.[22] For this study, a subsample of >126000 were extracted, including individuals present at both the 2001 and 2011 Censuses and aged between 16 and 60 in 2001. We applied age restrictions because psychopharmacological treatment among older adults may be less likely to be initiated by a mental disorder.[16,23] Individuals were excluded if living in communal establishments (e.g. nursing homes) in 2001 or 2011 (1.0%), or had missing values for the covariates (10.5%). Area-level indicators of crime were linked to SLS participants utilising residential localities and dates of their registration with a General Practitioner (GP). Healthcare administrative data were linked to participants based on unique personal identifiers (*Figure 6.1*).

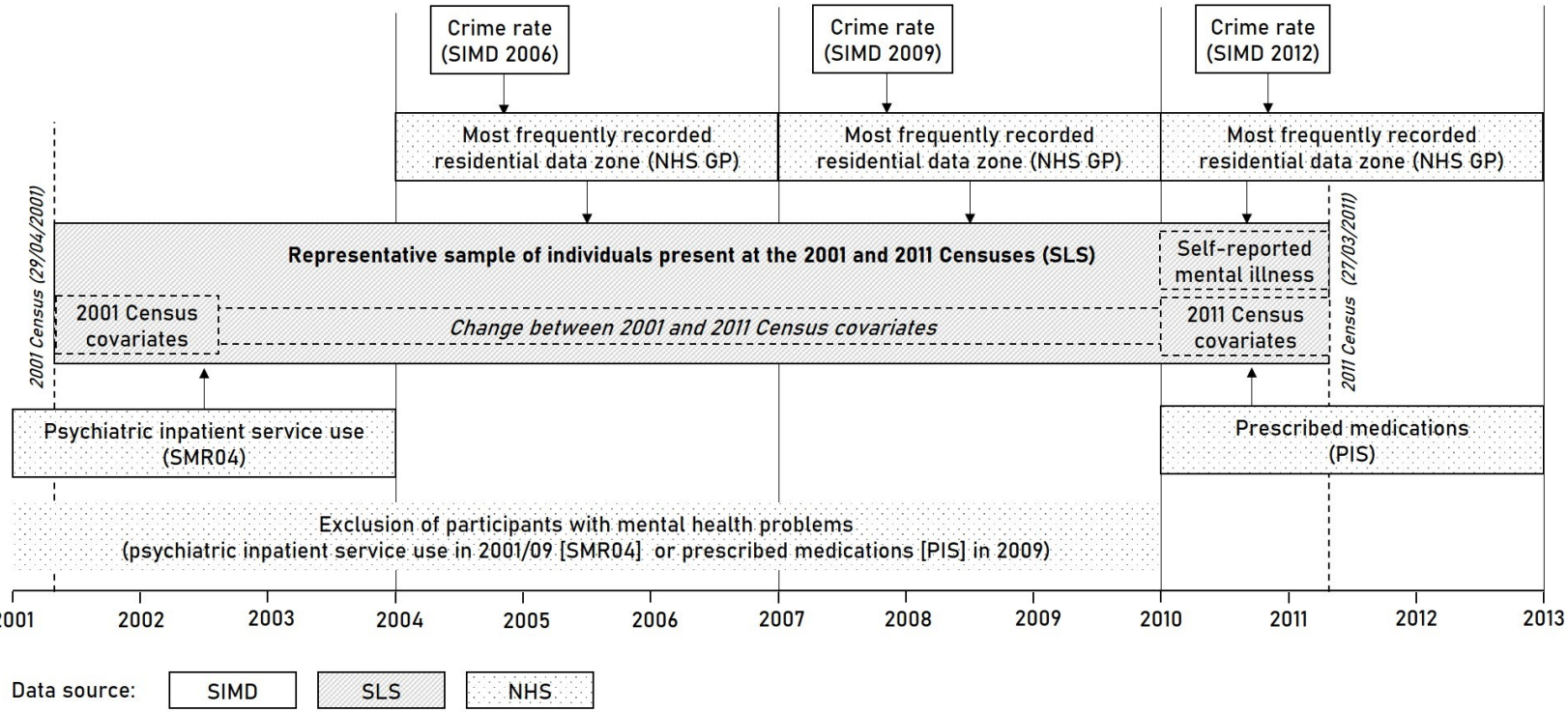


***Figure 6.1*** *Operationalising crime, covariate and mental health variables using longitudinal data linkage in Scotland (2001-2013). Crime rates reported in the 2006/2009/2012 Scottish Index of Multiple Deprivation (SIMD) were linked to the Scottish Longitudinal Study (SLS) by using the residential data zone where SLS members were registered for the longest time during 2004/06, 2007/09 and 2010/12. Residential location was derived from records of the National Health Service (NHS) general practitioner (GP) registration database. Mental health service use within the NHS system was extracted from the Scottish National Prescription Information System (PIS) and from the Scottish Morbidity Records (SMR04), and information was linked to SLS participants using unique personal identifiers. For sensitivity analysis, participants with any records of mental health service use between 2001 and 2009 (SMR04 & PIS) were excluded from the sample.*

### 6.4.2 Measures

#### *6.4.2.1 Mental health indicators*

Mental health was measured using information on self-reported mental illness, and prescribed medications. In 2011, all Census respondents were asked whether they had "*…conditions which have lasted, or are expected to last, at least 12 months?*", with a given response category of 'mental health condition', taken here to indicate self-reported mental illness. NHS administrative data on prescriptions for antidepressants (British National Formulary 4.3) and antipsychotics (British National Formulary 4.2) were derived from the Scottish National Prescription Information System, which covers all NHS Scotland prescriptions, prescribed, dispensed and reimbursed in the community setting.[24] Antidepressants are mainly used to treat moderate to severe depression, and in some cases anxiety disorders. At low dosage (≤30mg per day), amitriptyline and nortriptyline are often prescribed for neurological conditions, so these low dose prescriptions were excluded from our study.[25] Antipsychotics are principally used to treat psychotic and related disorders; however, severe anxiety can be also treated with them in the short term.[25] Individuals with at least six prescriptions for antidepressants or antipsychotics in 2010/12 were defined as cases.[16]

Self-reported mental health and prescribed medications are not available prior 2009. To control for mental illness at baseline, psychiatric inpatient service use in 2001/03 for substance use, psychotic, mood and neurotic disorders (ICD-10 codes: F10-F48) from the Mental Health Inpatient & Day Case dataset (Scottish Morbidity Records, SMR04) of NHS Scotland were linked to SLS.[26]

#### *6.4.2.2 Neighbourhood crime*

The Scottish Index of Multiple Deprivation (SIMD) includes a domain on local crime, and is available for 6505 Scottish data zones, each comprising approximately 500-1,000 residents. The crime domain aggregates police recorded and geo-referenced crimes and offences (e.g. assault, crimes of violence, domestic housebreaking, drugs offences, and vandalism) throughout the preceding financial year.[27] The Scottish

Government applies disclosure control in low crime areas by supressing exact crime counts. To approximate missing values, we first ordered data zones by their non-suppressed crime ranks, assigned 0 crime into the lowest ranked unit, and used linear interpolation to estimate suppressed numbers. Finally, crime rates per 1000 individuals were computed based on population estimates. SIMD 2006 (first release), 2009 and 2012 provided longitudinal information on crime with consistent data zone boundaries (see changes of crime levels for Glasgow City in *Figure 6.2*).

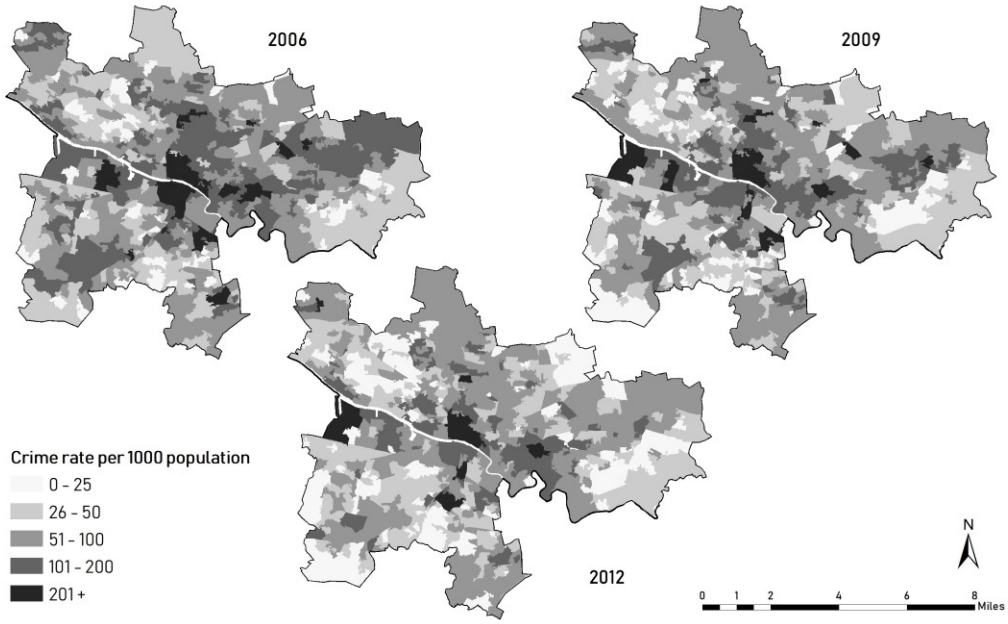


***Figure 6.2*** *Crime rates per 1000 population in Glasgow City, Scotland, as reported in the 2006, 2009 and 2012 Scottish Index of Multiple Deprivation.*

To link neighbourhood crime to SLS members, we utilised data on places of residence from the NHS GP registration database, holding records on patient registrations with GPs from 2000 onwards.[28] The SLS team derived for each participants their residential history comprising all residential data zones and dates of their changes recorded during the study. We assigned each SIMD crime release to a 3-year time interval (2004/06 for SIMD 2006, 2007/09 for SIMD 2009, and 2010/12 for SIMD 2012), extracted for each participant the main residential data zone where they were registered for the

longest time within these three intervals, and linked them to the respective crime rates. Finally, we stratified the sample into subsets, comprising individuals for whom the main residential data zone did not change during the study (stayers), changed between 2007/09 and 2010/12 (recent movers), and changed between 2004/06 and 2007/09 (past movers).

#### *6.4.2.3 Covariates*

Covariates were derived from the 2001 and 2011 Censuses. Age and sex, extracted from both censuses, were reviewed for consistency before inclusion. Baseline variables were derived from the 2001 Census and classified as follows: ethnicity (white, non-white); highest educational attainment (no qualification, levels 1-4); social class based on occupation (I/II, IIIN, IIIM, IV, V); employment status (employed, unemployed, retired, out of labour force, student); marital status (married, single, separated, divorced, widowed); living status (alone, with others); and limiting long-term illness (yes, no). For time-variant covariates, we computed binary change indicators between censuses (change, no change): gained higher level of education; separated, divorced or widowed; started to live alone; and became unemployed or left labour force. There is no consistent social class measure in 2001 and 2011 due to differences in census questions/codings; therefore, we included also the 2011 social grade variable (AB, C1, C2, D, E) in the models. Detailed description of the covariates are in *Supplementary Table 6.1*.

### 6.4.3 Statistical analysis

While repeatedly measured predictors were available, outcomes were only assessed at the end of the study. To preserve the longitudinal nature of the data, for each participant we calculated summary measures[29] of neighbourhood crime by decomposing average exposure during follow-up and change in exposure to crime. For average crime exposure ($\bar{x}$), first the arithmetic mean of the crime rates were calculated, and then log-transformed in order to minimize the effect of extreme outliers and right skewed distribution *(equation 1)*. Change in crime exposure variables ($x_{\Delta}$) were computed as the standardized difference between the person's

average of crime exposure and the crime rates of places they lived in 2004/06 or 2010/12, with positive values expressing increasing, negative decreasing rates *(equations 2, 3)*. While average crime were related to long-term differences between individuals, change in crime indicated within individual variation in exposure.

(1) $$\bar{x} = \log10(\frac{x_{t2004/06}+x_{t2007/09}+x_{t2010/12}}{3})$$

(2) $$x_{\Delta2004/06} = sdr(\frac{x_{t2004/06}+x_{t2007/09}+x_{t2010/12}}{3} - x_{t2004/06})$$

(3) $$x_{\Delta2010/12} = sdr(x_{t2010/12} - \frac{x_{t2004/06}+x_{t2007/09}+x_{t2010/12}}{3})$$

We fitted logistic regression models with clustered robust estimations, allowing standard errors varying between the 32 Scottish Local Authorities[16] as recorded at the time of outcome measurement. All models included average and change variables. In the first set of models we controlled for sex, age and age-squared. The second model additionally adjusted for all 2001 covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness) and for psychiatric inpatient care in 2001/03. Finally, in the fully adjusted model we additionally controlled for changing individual circumstances between 2001 and 2011 (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and for social grade in 2011. Models were run separately for those identified as residential 'movers' and 'stayers'. For past movers we included the 2004/06 ($x_{\Delta2004/06}$), for stayers and recent movers the 2010/12 change variable ($x_{\Delta2010/12}$). As the effect of crime might differ by age,[16] models were presented separately in young adulthood (aged 16-30 years old in 2001), younger middle adulthood (aged 31-45) and older middle adulthood (aged 46-60).

The following sensitivity analyses were carried out: (1) Using the same method as for crime, we extracted data zone income deprivation from the 2006/2009/2012 SIMDs, calculated standardized average and standardized change of deprivation, and imputed them in the final model, in order to test whether crime change had a robust effect over and above income deprivation. (2) Instead of extracting the main residential data zone in each wave, we restricted the stayer subsample to those, who

lived at the same location during the 108 months of the study. (3) In order to strengthen the causal perspective, we excluded from the sample all individuals who were likely to have long-standing mental health conditions prior to outcome measurement, indicated by those who had any psychiatric admission in 2001/09 and any psychotropic prescription in 2009 (medication data is not available prior 2009)[24] *(Figure 6.1)*. For this analysis, Poisson regression with clustered robust standard errors estimated the incidence rate ratio [IRR] of crime on mental ill health.

## 6.5 Results

Out of 112251 Scottish adults, 72% were classified as 'stayers', 14% as 'past movers', and 14% as 'recent movers' *(Table 6.1)*. At the end of the study, 5.0% of the sample reported having a long-term mental illness, 14.4% had been prescribed at least six rounds of antidepressants, and 1.2% had at least six rounds of antipsychotics prescriptions. The prevalence of mental health outcomes differed across moving status and age cohorts, with higher rates among middle-aged adults and recent movers, especially for antipsychotics *(Supplementary Table 6.2)*. For the total sample, the average neighbourhood crime rate was 44.2 per 1000 population (SD=47.1); the crime rate dropped by 5.7 (SD=30.3) between 2004/06 and 2007/09, and by 6.9 per 1000 population (SD=25.5) between 2007/09 and 2010/12. Young adults and recent movers were exposed to higher neighbourhood crime on average, but they also experienced a larger drop in exposure *(Supplementary Table 6.3)*.

***Table 6.1*** *Individual characteristics among the sample of 112 251 Scottish adults (%)*

| Variable | | Value | % |
|---|---|---|---|
| Moving status | | Stayer (2004/06 – 2010/12) | 72 |
| | | Past mover (2004/06 – 2007/09) | 14 |
| | | Recent mover (2007/09 – 2010/12) | 14 |
| 2001 covariates | Sex | Male | 47 |
| | | Female | 53 |
| | Age cohorts | 16-30 | 27 |
| | | 31-45 | 40 |
| | | 46-60 | 33 |
| | Ethnicity | White | 99 |

| | | | |
|---|---|---|---|
| | | Non-white | 1 |
| | Highest educational attainment | No | 29 |
| | | Level1 | 28 |
| | | Level2 | 16 |
| | | Level3 | 8 |
| | | Level4 | 20 |
| | Social class based on occupation | I/II - Professional, managerial and technical occupations | 33 |
| | | IIIN - Skilled non-manual occupations | 24 |
| | | IIIM - Skilled manual occupations | 19 |
| | | IV - Partly skilled occupations | 15 |
| | | V - Unskilled occupations | 6 |
| | | Other | 4 |
| | Employment status | Employed | 73 |
| | | Unemployed | 4 |
| | | Student | 6 |
| | | Retired | 2 |
| | | Out of labour force | 15 |
| | Marital status | Single | 33 |
| | | Married | 55 |
| | | Separated | 4 |
| | | Divorced | 7 |
| | | Widowed | 1 |
| | Living status | Alone | 11 |
| | | With others | 89 |
| | Long-term illness | No | 87 |
| | | Yes | 13 |
| | Psychiatric inpatient service use in 2001/03 | No | 99 |
| | | Yes | 1 |
| 2011 covariate | Social grade | AB - Higher or intermediate managerial, administrative or professional grade | 21 |
| | | C1 - Supervisory, clerical and junior managerial, administrative and professional grade | 31 |
| | | C2 - Skilled manual workers | 25 |
| | | D - Semi-skilled and unskilled manual workers | 22 |
| | | E - State pensioners, casual and lowest grade workers, unemployed with state benefits only | 3 |
| 2001 – 2011 change indicators | Education | No change | 77 |
| | | Gained education between 2001-2011 | 23 |
| | Employment | No change | 95 |
| | | Became unemployed or left labour force between 2001-2011 | 5 |
| | Marital status | No change | 93 |
| | | Separated, divorced or widowed between 2001-2011 | 7 |
| | Living status | No change | 91 |
| | | Started to live alone between 2001-2011 | 9 |

Source: Scottish Longitudinal Study.
Note: Percentages are presented in whole numbers to avoid risk of disclosure; they may not sum to 100% because of rounding errors.

### 6.5.1 Self-reported mental illness

In the fully-adjusted models, in addition to a strong association with higher average crime exposure (OR=1.51, 95% CI: 1.35-1.68), one SD increase in crime was associated with 4% higher odds of reporting mental illness (95% CI: 1.02-1.06). In the models stratified by moving status, crime increase remained significant only among recent movers (OR=1.04, 95% CI: 1.01-1.07) *(Table 6.2)*. After stratifying by age cohorts, the association with average crime exposure was stronger among younger individuals (OR=1.84; 95% CI: 1.54-2.21). Moreover, one SD increase in crime exposure elevated the odds of self-reported mental illness by 11% (95% CI: 1.00-1.22) among young stayers (due to change in local crime rates), and by 7% (95% CI: 1.01-1.13) among recently moved younger middle-aged adults *(Table 6.3)*.

***Table 6.2*** *Associations between average crime exposure, change in crime exposure and mental health outcomes*

| | **Total sample (n=112,251)** | | **Stayers (n=80,958)** | | **Past movers[a] (n=15,940)** | | **Recent movers[b] (n=15,353)** | |
|---|---|---|---|---|---|---|---|---|
| | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2004/06}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) |
| **Self-reported mental-health** | | | | | | | | |
| Model 1[c] | **3.44 (2.87-4.13)** | **1.05 (1.04-1.07)** | **3.12 (2.50-3.90)** | **1.09 (1.00-1.18)** | **3.71 (2.96-4.65)** | 1.02 (1.00-1.04) | **4.55 (3.36-6.16)** | **1.06 (1.03-1.08)** |
| Model 2[d] | **1.79 (1.60-2.00)** | **1.04 (1.02-1.06)** | **1.57 (1.38-1.77)** | 1.03 (0.95-1.11) | **2.00 (1.64-2.45)** | *1.03 (1.00-1.06)* | **2.28 (1.71-3.02)** | **1.05 (1.02-1.08)** |
| Model 3[e] | **1.51 (1.35-1.68)** | **1.04 (1.02-1.06)** | **1.40 (1.24-1.57)** | 1.02 (0.94-1.11) | **1.56 (1.27-1.91)** | 1.02 (0.99-1.05) | **1.77 (1.33-2.36)** | **1.04 (1.01-1.07)** |
| **Antidepressants medication** | | | | | | | | |
| Model 1[c] | **1.98 (1.85-2.12)** | **1.03 (1.01-1.05)** | **1.89 (1.76-2.03)** | **1.05 (1.02-1.08)** | **1.90 (1.65-2.20)** | 1.00 (0.99-1.02) | **2.44 (2.09-2.86)** | **1.03 (1.01-1.06)** |
| Model 2[d] | **1.37 (1.30-1.45)** | *1.02 (1.00-1.04)* | **1.32 (1.24-1.40)** | 1.01 (0.98-1.04) | **1.29 (1.11-1.50)** | 1.00 (0.98-1.03) | **1.55 (1.32-1.83)** | 1.02 (0.99-1.05) |
| Model 3[e] | **1.27 (1.20-1.34)** | 1.01 (0.99-1.03) | **1.25 (1.17-1.34)** | 1.01 (0.98-1.04) | *1.16 (0.99-1.36)* | 1.00 (0.98-1.03) | **1.32 (1.12-1.56)** | 1.01 (0.98-1.04) |
| **Antipsychotics medication** | | | | | | | | |
| Model 1[c] | **3.30 (2.76-3.96)** | **1.06 (1.03-1.10)** | **3.16 (2.48-4.01)** | **1.16 (1.04-1.29)** | **2.98 (1.95-4.56)** | 1.01 (0.98-1.05) | **4.70 (3.11-7.10)** | **1.06 (1.03-1.09)** |
| Model 2[d] | **1.42 (1.22-1.67)** | **1.07 (1.02-1.12)** | **1.34 (1.08-1.67)** | 1.10 (0.98-1.24) | 1.14 (0.69-1.91) | 1.04 (0.97-1.11) | **2.15 (1.34-3.44)** | **1.06 (1.01-1.11)** |
| Model 3[e] | **1.25 (1.06-1.47)** | **1.06 (1.01-1.12)** | **1.24 (1.00-1.54)** | 1.10 (0.98-1.24) | 0.94 (0.58-1.52) | 1.03 (0.97-1.10) | **1.65 (1.02-2.69)** | *1.05 (0.99-1.12)* |

Source: Scottish Longitudinal Study.

Note: Bold text indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Models were fitted with logistic regression applying cluster robust estimation at local authority level; estimates are expressed in OR with 95% CI. Average crime exposure is log10-transformed, change in crime exposure is standardized. Models included average and change variables at the same time.

[a] Main residential location changed between 2004/06 and 2007/09.

[b] Main residential location changed between 2007/09 and 2010/12.

[c] Model 1: Controlled for sex, age and age-squared.

[d] Model 2: Model 1 + 2001 baseline covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness) and psychiatric inpatient service use in 2001/03.

[e] Model 3: Model 2 + 2001 – 2011 change indicators (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and social grade in 2011.

***Table 6.3*** *Age cohort-specific associations between average crime, change in crime and mental health*

| | **Total sample (n=112,251)** | | **Stayers (n=80,958)** | | **Past movers[a] (n=15,940)** | | **Recent movers[b] (n=15,353)** | |
|---|---|---|---|---|---|---|---|---|
| | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2004/06}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) |
| **Self-reported mental-health** | | | | | | | | |
| 16-30 years old | **1.84 (1.54-2.21)** | **1.03 (1.01-1.05)** | **1.92 (1.54-2.41)** | **1.11 (1.00-1.22)** | *1.34 (0.99-1.83)* | 1.02 (0.97-1.08) | **2.18 (1.49-3.20)** | 1.02 (0.99-1.05) |
| 31-45 years old | **1.41 (1.20-1.65)** | **1.05 (1.01-1.10)** | **1.26 (1.03-1.54)** | 1.01 (0.91-1.12) | **1.89 (1.20-2.98)** | 1.04 (0.99-1.09) | **1.60 (1.09-2.34)** | **1.07 (1.01-1.13)** |
| 46-60 years old | **1.32 (1.10-1.58)** | 1.01 (0.97-1.05) | **1.27 (1.06-1.52)** | 0.97 (0.88-1.07) | 1.49 (0.87-2.54) | 1.03 (0.98-1.09) | 1.18 (0.64-2.16) | 1.04 (0.96-1.12) |
| **Antidepressants medication** | | | | | | | | |
| 16-30 years old | **1.30 (1.16-1.45)** | 1.01 (0.99-1.04) | **1.41 (1.21-1.64)** | **1.09 (1.04-1.14)** | 1.06 (0.83-1.35) | 1.01 (0.97-1.04) | *1.29 (0.99-1.67)* | 1.01 (0.97-1.04) |
| 31-45 years old | **1.24 (1.14-1.34)** | 1.01 (0.98-1.05) | **1.18 (1.05-1.33)** | 1.01 (0.94-1.07) | *1.22 (0.97-1.53)* | 1.01 (0.98-1.05) | **1.54 (1.16-2.05)** | 1.01 (0.98-1.05) |
| 46-60 years old | **1.24 (1.13-1.36)** | 1.00 (0.97-1.04) | **1.24 (1.13-1.36)** | 0.98 (0.94-1.02) | 1.20 (0.79-1.83) | 0.96 (0.91-1.02) | 0.93 (0.63-1.36) | 1.03 (0.97-1.11) |
| **Antipsychotics medication** | | | | | | | | |
| 16-30 years old | 1.19 (0.93-1.52) | 1.01 (0.92-1.10) | 1.26 (0.80-1.96) | 1.23 (0.88-1.73) | 0.98 (0.50-1.95) | 1.04 (0.97-1.12) | 1.32 (0.71-2.44) | 0.96 (0.89-1.03) |
| 31-45 years old | 1.30 (0.95-1.77) | *1.10 (1.00-1.20)* | 1.14 (0.79-1.63) | 1.04 (0.89-1.22) | 0.97 (0.45-2.08) | *1.07 (0.99-1.16)* | **2.44 (1.20-4.97)** | **1.11 (1.01-1.23)** |
| 46-60 years old | 1.22 (0.90-1.66) | 1.08 (0.97-1.20) | 1.31 (0.93-1.84) | 0.12 (0.93-1.34) | 0.71 (0.18-2.87) | 0.98 (0.86-1.12) | 0.73 (0.22-2.38) | *1.11 (1.00-1.23)* |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001. Bold text indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Average crime exposure is log10-transformed, change in crime exposure is standardized. Models were fitted with logistic regression applying cluster robust estimation at local authority level; estimates are expressed in OR with 95% CI. All models included average and change variables at the same time, and were adjusted for sex, age (and age-squared in the non-stratified total sample), 2001 baseline covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness), psychiatric inpatient service use in 2001/03, 2001 – 2011 change indicators (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and social grade in 2011.

[a] Main residential location changed between 2004/06 and 2007/09.

[b] Main residential location changed between 2007/09 and 2010/12.

### 6.5.2 Prescribed medications

Higher average crime exposure increased the risk of having been prescribed at least six rounds of antidepressants (OR=1.27, 95% CI: 1.20-1.34), or antipsychotics (OR=1.25; 95% CI 1.06-1.47), with associations being stronger among recent movers. Change in crime exposure, however, only remained significant for antipsychotics in the fully adjusted models (OR=1.06; 95% CI: 1.01-1.12) *(Table 6. 2)*. When exploring association by age cohorts, models of prescribed medications reinforced the findings for self-reported mental illness *(Table 6.3)*: one SD increase in crime exposure among young stayers increased the odds of antidepressant prescriptions by 9% (95% CI: 1.04-1.14); among younger middle-aged movers it increased the odds of antipsychotic prescriptions by 11% (95% CI: 1.01-1.23).

### 6.5.3 Sensitivity analyses

After further adjustment for income deprivation, associations with average crime exposure only remained significant among older middle-aged stayers for antipsychotics and among young stayers for self-reported mental illness. Associations with change in exposure to crime were substantially attenuated for self-reported mental illness; however, they did not materially change for antidepressants and antipsychotics prescriptions *(Supplementary Table 6.4)*. Findings on individuals staying all 108 months of the study at the same location, reinforced that young adults were more vulnerable to increasing crime rates, with elevated risk of self-reported mental illness and antidepressant prescriptions *(Supplementary Table 6.5)*. Finally, after excluding participants with mental health service use between 2001 and 2009, the prevalence of self-reported mental illness, antidepressant and antipsychotic prescriptions during 2010/12 dropped with 80, 74 and 92%, respectively; drops in cases were particularly pronounced among middle-aged adults. The findings in this reduced sample confirmed previous associations for antidepressant medications among young stayers (IRR=1.12; 95% CI: 1.04-1.21). For antipsychotics, increasing crime exposure among young stayers significantly predicted prescriptions (IRR=1.59;

95% CI: 1.07-2.37), while the substantial drop in cases precluded analyses among movers *(Supplementary Table 6.6)*.

## 6.6 Discussion

This study provides longitudinal perspective on the association between long-term average neighbourhood crime exposure, recent changes in crime and mental health in Scotland, utilizing a natural experimental framework. Associations between average crime exposure and self-reported mental illness were twice as strong as for prescriptions, and were mainly driven by relationships for the youngest age group. Recent increases in crime rates were related to mental health in two population subgroups: for self-reported mental illness and antidepressants among young adults staying in the same neighbourhood; for self-reported mental illness and antipsychotics among recently moved younger middle-aged adults. Sensitivity analyses reinforced the findings on antidepressants, but they challenged the causal perspective for antipsychotics.

This study extends the literature on the longitudinal relationships between neighbourhood crime and mental health,[14-16] by estimating the link for self-reported versus service use outcomes, and different age cohorts. Stronger association between average crime exposure and self-reported mental illness, in comparison to prescribed medications, may reflect the way how the former variable was measured. Self-reported mental illness might capture more serious and long-standing problems, and thus, has a lower prevalence than antidepressants prescriptions. It is also plausible that using psychotropic medications underestimated the association with crime by not fully capturing affected individuals from lower socioeconomic groups[2] and including prescriptions not related to mental illness.[25] Moreover, while the treatment gap between mental health need and service use is disproportionately large among young adults with very low utilisation of medications,[2] they are more often victims of crime and violence.[30] This may explain the stronger links between crime exposure and self-reported mental illness in this cohort.

In comparison to average neighbourhood crime exposure, changes in individual exposure are less likely to be affected by residual confounding, and may strengthen the causal evidence between exposure and outcome. Associations with increasing crime were evident in younger age, confirmed by both self-reported and medication data. Because of higher frequency of victimisation,[30] young adults remaining in the same neighbourhood may be more vulnerable to increasing crime in their locality, linked to mental health conditions treated with antidepressants. Sensitivity analyses confirmed this link by supporting that the causation hypothesis[31] may provide a suitable explanation for the neighbourhood-level crime and depression association.

Associations with changing crime exposure for antipsychotic prescriptions were more complex. After excluding individuals with pre-existing psychiatric conditions, the previously robust association among movers could not be estimated because of the large drop in cases. It is plausible that findings among younger middle-aged individuals (for whom the highest incidence rate of first episode psychosis in young adulthood has already passed)[32] reflect health selected migration into higher crime areas related to pre-existing severe mental disorders.[21] Moreover, the increased risk of antipsychotics medication among young adults staying in the same area may require further exploration, as there is evidence suggesting that growing up in high crime neighbourhoods may increase the risk of presenting psychotic symptoms through increased social stress and crime victimisation.[33,34]

This longitudinal data-linkage study benefited from a large and representative sample, covering the entire country and presenting very low attrition rates.[22] The NHS is (effectively) universally used in Scotland and prescribed medications were routinely collected with an exceptional completeness (95% of reimbursed prescriptions within NHS Scotland are captured with unique personal identifiers).[24] However, several limitations have to be considered. First, while the NHS GP registration database contains residential localities with high accuracy, the reliability of the data might differ across age and clinical groups. Second, in Scotland only 40% of crimes are reported to the police,[30] which may introduce bias to our findings. Third,

outcomes were not available prior to 2009, precluding more robust statistical analyses (e.g. fixed-effects models).[14] Finally, self-reported mental illness and prescription data cannot be directly linked to psychiatric conditions; further studies with specific diagnoses are required to break down the neighbourhood crime-mental health relationship.

In conclusion, neighbourhood-level crime is a significant determinant of mental health and requires systems-based actions. Crime reduction through neighbourhood interventions[35] and spatially targeted policing[36] may be beneficial for population mental health, particularly for young adults. Delivering mental health promotion for young people in high crime areas, such as school-based preventions,[37] and indicative prevention for high risk individuals,[38] as well as allocating services (e.g. early psychosis programs)[39] to the vicinity of high crime areas may improve mental health outcomes and reduce the associated societal and economic burden.

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**Data availability statement** The data used in this research is publicly not available, but may be accessible for scientific and statistical purposes after a successful application process (https://sls.lscs.ac.uk/). Researcher has access to anonymized data in secure settings controlled by SLS. Results released for publication are carefully monitored to avoid any risk of disclosure about individuals.

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## 6.8 Assessment of bias

*Non-measurement error at unit-level*

This chapter is based on the same dataset as Chapter 5. As reported earlier, the linked SLS sample is likely free of any selection bias at unit-level because of very small non-response and attrition rates (please refer for further information to 5.8).

*Non-measurement error at item-level*

No missing values for exposure and outcome were present in the dataset. Although covariates from the 2011 Census have been imputed (see 5.8), they were not for the 2001 Census, resulting in 10.5% missing values, mainly attributable to missingness in socioeconomic variables (educational attainment in 2001, social grade in 2001). Similarly to Chapter 3 & 4, post-hoc logistic regression analyses were conducted to test whether being a complete case was determined by the outcome, after taking into consideration baseline covariates.[1] Analyses did not find evidence for biased estimates in the complete cases analyses; self-reported mental illness (p=0.697), antidepressant (p=0.276) or antipsychotic medications (p=0.413) did not determine missingness, as a result, multiple imputation was not required.

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# CHAPTER 7

# 7. Conclusions

## 7.1 Chapter overview

This final chapter brings together the five research papers, comparing the findings of the empirical papers with those found in the systematic review and meta-analysis, and integrating the results into the existing literature. First, a short summary on the main results is given by highlighting novel contributions to the literature. Second, findings are synthetized around the three main research questions: (1) which contextual features, (2) for whom, and (3) how they affect anxiety, depression and psychotic disorders. Third, strengths and limitations of the overall work are discussed. Finally, the chapter ends with a consideration of the implications for policy, service development and suggest directions for future research.

## 7.2 Main findings

### 7.2.1 Living in a high crime area is associated with mental disorders

Chapter 2 presented a systematic review and meta-analysis of the associations between area-level crime and different mental disorders. Available evidence was more convincing for depression and psychological distress; for anxiety and psychosis only a few studies could be identified. For depression and psychological distress, associations were relatively stronger in studies utilising cross-sectional design and measuring crime through individual participants' perception, in comparison to longitudinal studies and objectively measured area-level crime. Pooled effect sizes were larger in magnitude among young and older adults, and weaker among children; however, age-related findings were based on very few estimates per group. More importantly, even after taking into account the differences in design, type of crime measurement and sample characteristics, associations remained significant for depression and close to significant for psychological distress.

**Contribution to the literature**: This systematic review and meta-analysis is not only the first on this subject, filling an important research gap, but also one of the first meta-analyses statistically estimating the relationship between a particular place-based condition and mental health, providing evidence for an existing association. This robust and important finding has wider clinical and policy implications, and has the potential to guide future research.

### 7.2.2 Neighbourhood effects vary across countries, which can be partly explained by macro-level social, political, economic and environmental factors

One of the main limitations of the existing literature is the low cross-national generalizability of findings, as an overwhelming majority of studies originates from Anglophone countries (e.g. United States, United Kingdom, Australia). Chapter 3 pooled three comparable datasets (English Longitudinal Study of Ageing [ELSA], Health and Retirement Study [HRS], and the Survey of Health, Ageing and Retirement in Europe [SHARE]) capturing adults aged 50 and over in 15 European countries and in the United States. Individual participant meta-analyses indicated 25% higher odds of developing clinically relevant levels of depression if older adults were residing in areas with perceived neighbourhood disorder (including crime), and 76% higher odds when reporting lack of social cohesion. Associations were stronger among those already in retirement. Although between-country heterogeneity was generally low, meta-regression identified cross-level interactions by income inequality, population density and levels of air pollution for social cohesion and forest coverage for neighbourhood disorder. An invited commentary on this paper recommended exploring specific welfare regime policies in future research, rather than utilising crude welfare regime categories. Responding to this commentary, further analysis on country-level social expenditure indicated that social policies aiming to support elderly have the potential to buffer the detrimental effects of neighbourhood disorder on depression.

**Contribution to the literature**: This chapter examined neighbourhood effects on depression in countries where often no previous longitudinal studies in this subject were available (i.e. Eastern and Southern European countries). Furthermore, investigating neighbourhood effects between countries and linking effect heterogeneity to macro-level indicators is a novel contribution to the literature.

### 7.2.3 Childhood experiences modify neighbourhood effects

Despite growing evidence on neighbourhood effects and mental health, there is limited understanding on differential vulnerability among individuals. Although childhood is a crucial developmental stage, we do not know whether exposure to stressors in this sensitive period can have long-lasting effects on neighbourhood effects. Utilizing prospective data on neighbourhood and depression, and retrospective information on exposure to childhood experiences (SHARE), Chapter 4 reported 36% higher odds of developing depression when individuals lived in areas with neighbourhood nuisances (including crime), and 22% lower odds when sufficient neighbourhood services were available. More importantly, childhood socioeconomic conditions modified these associations: older adults who grew up in more advantaged circumstances benefited more from living in an area with good access to services. However, they had higher risk of depression when residing in a neighbourhood with significant nuisances. Childhood experiences have long-lasting effects on health and coping mechanism, by determining who is more likely to benefit from positive neighbourhood resources but also affecting adaptation to area-based stressors.

**Contribution to the literature**: This chapter with a long-term follow-up (6-10 years) provided a rare prospective evidence on associations between access to neighbourhood services, neighbourhood nuisances and depression. Furthermore, exploring effect modifications by childhood stressors sets an example of how to implement the life course approach in the neighbourhood literature.

### 7.2.4 Area-level crime effects are modified by age, sex and socioeconomic status, and differ across psychiatric conditions

Chapter 5 further explored differential vulnerability to neighbourhood stressors, but instead of utilizing perceived neighbourhood measurements and self-reported depressive symptoms, it made use of police recorded crime and mental health service use data. Objective exposure measure can provide a more conservative and robust assessment of neighbourhood effects (due to free from potential implications of same sources bias), and using service use data gives information on another aspect of mental health. A large longitudinal data-linkage study (Scottish Longitudinal Study [SLS]) was carried out on Scottish adults (aged 16+) utilising census information linked to prescribed psychotropic medications and area-level crime. Over and above area-level income deprivation, population density and individual covariates, findings showed 5% higher odds of antidepressant and 20% higher odds of antipsychotic prescriptions when living in high crime areas, in comparison to low; anxiolytics were not linked to area-level crime. Stronger positive association with antidepressants was found among younger/middle-aged individuals (especially women), and with antipsychotics among middle-aged men. Skilled workers and people from lower non-manual occupations had an increased risk of medications in high crime areas. Unexpectedly, among older adults antidepressant or anxiolytic prescriptions were linked to lower area crime rates.

**Contribution to the literature**: This chapter presented one of the first longitudinal investigations on neighbourhood crime and mental health service use, utilising detailed individual-level data. It is particularly important for the psychosis-related outcome (antipsychotic prescriptions), for which limited evidence is available due to low population prevalence precluding the utilisation of non-ecological investigations.

### 7.2.5 Changing crime rates impact mental health, but underlying mechanisms might differ across psychiatric conditions and over the life course

Area-level crime exposure may change due to rising or falling crime rates in the community or due to individuals' residential mobility. Although investigating the

effect of changing environment could help to better understand causal inference between exposure and outcome, applying a natural experiment framework is rare in the literature. In Chapter 6, the SLS sample was further linked with exposure to neighbourhood crime at three time points, and analysed whether changes in exposure among residential stayers and movers could be associated to self-reported mental illness, and antidepressants or antipsychotics medication. Recent changes in crime rates were linked to individual-level self-reported mental illness and antidepressants prescription among young adults staying in the same area during the study; and to self-reported mental illness and antipsychotics prescription among younger middle-aged movers. After excluding pre-existing mental disorders, findings indicated that the relationship in the former group was likely causal. However, among middle-aged individuals pre-existing severe mental health conditions could have led residential mobility towards higher crime areas.

**Contribution to the literature**: This natural experiment made use of the changing neighbourhood-level crime rates in Scotland. Thanks to the novel design, it was able to identify age- and condition-specific causal mechanism behind the neighbourhood crime and mental health association, reported at several points in this thesis.

## 7.3 Synthesis of the findings

Overall, this thesis highlighted and confirmed in various settings, utilising perceived and objective neighbourhood measurements, self-reported and service use indicated outcomes, that neighbourhood-level stressors are important risk factors for mental ill health. This section brings together findings across all chapters and integrates them into the literature by answering where and which neighbourhood factors, for whom and how these factors impact mental health.

### 7.3.1 Context matters for mental health

*7.3.1.1 Neighbourhood characteristics*

*7.3.1.1.1 Neighbourhood crime and related stressors*

Crime in the residential area is a serious public health, economic, social and legal concern, which was consistently associated with mental ill health throughout this thesis. However, effect sizes were relatively small, especially in comparison to relevant individual-level factors, such as socioeconomic status,[1] or direct exposure to violence.[2] First, neighbourhood effects are generally small at the population level, which is often a result of averaging out the differences between subgroups. Second, although average neighbourhood crime effect sizes in this thesis were relatively small, they were comparable in magnitude with associations usually found in genetics research[3] or in studies assessing the effect of second-hand smoking on cancer rate; a major public health concern.[4] Third, even tiny effects can have clinical and public health relevance, if they affect a large share of the population.[3] Neighbourhood stressors, such as crime are not only common, but in several low- and middle-income country the level of violence is dramatically rising,[5] presenting a serious public health concern. Also, the lifetime prevalence of (common) mental disorders is very high,[6] so that even small effects may have clinical significance.

In line with the main findings of the meta-analysis, the empirical chapters identified stronger effects on mental health when neighbourhood stressors (including crime) were assessed as the focal perception of study participants, rather than objectively recorded crime. Possible reasons have already been highlighted (2.6), including the hypothesis that the perception of neighbourhood stressors, as a more proximal risk factor of mental disorders, may at least partly mediate the effects of objective crime exposure.[7] However, also measurement-specific errors and biases linked to perceived and objective neighbourhood assessments can explain the difference in effect magnitude (see 7.5.2.2).

Neighbourhood crime associations vary across mental health conditions. Although the meta-analysis identified anxiety with the largest and psychosis with the smallest effect size, Chapter 5 found the exact opposite when utilising psychotropic medications. However, few studies were available on anxiety and psychosis for the meta-analysis, with study design, variable operationalisations, and covariates

adjustment largely varying across investigations. When only considering those studies exploring more than one condition within the same study setting, results were similar to the findings of this thesis, indicating stronger area crime effects on depression than on anxiety;[8-10] unless anxiety disorders only captured post-traumatic stress disorder,[11] likely indicating personal exposure to violence rather than ecological effects. Moreover, Chapter 5 found psychosis-related outcomes to be strongest associated with neighbourhood crime. Although no previous studies compared area-level crime effects on psychotic disorders with other conditions, they still seem to play an important role in the aetiology of psychosis, by being one of its most powerful neighbourhood-level predictor.[12,13]

*7.3.1.1.2 Social cohesion*

The detrimental effect of perceived lack of neighbourhood social cohesion on later life mental health has been confirmed in this thesis, utilising data from 16 high-income countries. This finding is in line with evidence from systematic reviews,[14,15] showing that especially individual-level cognitive social capital (also measured in this thesis) can be protective against mental health problems. The quality and quantity of social relationships may impact mental health on both individual and ecological level,[14] by providing social support,[16] tackling loneliness,[17] and ultimately promoting healthy ageing in a more resilient and less hostile enviroment.[14,18]

*7.3.1.1.3 Access to neighbourhood services*

Having access to, mainly health-related, neighbourhood services and to public transportation was beneficial for older adults' mental health. Access to neighbourhood services can help to maintain physical and mental health, by supporting social participation, residential independence, and it is considered as a sign of social inclusion.[19-21] Ease of access is crucial for older adults. Accessible neighbourhoods can mitigate the detrimental effects of limited mobility on daily life, arising from physical morbidities and functional decline,[19] and support mental[21] and physical health,[22] and overall healthy ageing. Furthermore, accessibility might be

even more important among less advantaged individuals living in deprived and unsafe areas, without access to car.[23]

#### *7.3.1.2 Macro-level determinants*

The larger social, economic, political and environmental context does not only directly matter for health,[24] but also moderates the association between neighbourhoods and depression. Linking macro-level determinants to the neighbourhood-depression association provided novel findings on how the '*causes of the causes of the causes*'[24] may interact with the context of daily living by affecting mental health. Although welfare regimes were not directly linked to neighbourhood effects, which is plausible because of the crude country classification (as Rostila pointed out in his invited commentary on Chapter 3),[25] specific social policies, operationalised as types of social spending, could provide further insights into the neighbourhood-depression relationship. For example, higher pension spending was identified as a buffer for the effect of neighbourhood disorder on depression among retired individuals, linking context directly to policy.

Another interesting result pointed out that among older adults in retirement, lack of social cohesion had stronger detrimental effects on mental health, if participants were from countries where people live in closer proximity to each other. Once again, it is not only a plausible finding, indicating that less mobile older adults[19,26] rely more on neighbours in more densely populated countries, but also points towards how important it is to consider the macro-level context when developing local policies.

Finally, in more equal countries, lack of social cohesion had stronger effects on depression, which could be explained by low social cohesion/ social capital violating the expected norm of egalitarian societies; so that the discrepancy between expectations and perception may lead to significant distress. However, it is important to note that the post-transition Eastern European countries belonged to the more equal societies in this study, implying that the historical context and evolution of macro-determinants should also be considered when interpreting findings; as pointed out in the response to Rostila's commentary.[25] Still, as these findings are

rather novel, applying methods (e.g. IPD meta-analysis, meta-regression) new to the field of contextual determinants, more research is needed to understand the complex interplay between macro-, local- and individual-level factors impacting mental health.

### 7.3.2 Individual characteristics and neighbourhood effects

As highlighted in the systematic review, less is known about effect heterogeneity in relation to neighbourhood crime and mental health. This thesis was able to identify several vulnerable population subgroups, providing opportunities for prevention and intervention.

#### *7.3.2.1 Age*

The meta-regression in Chapter 2 identified young adults and older adults as being more vulnerable to the effects of area-level crime. Chapter 5 & 6 confirmed that young adults had elevated risk of having antidepressant medications when living in high crime areas and/or areas with increasing crime rates. This age group has not only one of the highest prevalence of depression in the population[27] but young adults are also at higher risk of becoming victim of (violent or property) crime in Scotland.[28] This finding is not without precedent, a recent large-scale longitudinal household survey from Mexico showed decreasing risk of depression by age in areas with high homicide rates.[5] Moreover, young adulthood might be a vulnerable period not only for depression, but also for psychosis-related outcomes, as suggested in Chapter 6.

Among older adults the relationship seems to be less straightforward to interpret. When neighbourhood crime was objectively recorded, higher rates were associated with lower risk of antidepressant prescriptions, whereas perceived neighbourhood problems, including crime, were more strongly linked to depression in later life, and even more strongly among those already in retirement. Although this discrepancy may be best resolved in datasets, where both types of measurements are available, it was not feasible in this thesis. Still, a possible interpretation recognises functional decline and limited mobility as an accelerator for the perceived crime-depression

relationship, but also a barrier of mental health service use utilisation. Older adults are more often concerned about crime[29] because of their limited mobility[19] or lower sense of control,[5] which may increase the risk of depressive symptoms, despite their lower risk of crime victimisation.[28] Living in an unsafe area, however, can also be a barrier to any kind of mobility within the neighbourhood,[30] possibly restricting older individuals from consulting their health practitioners. Still, it should be recognised that psychotropic medication use among older adults is less likely initiated by mental disorders, in comparison to earlier ages,[31,32] warranting very careful interpretation of these results.

#### *7.3.2.2 Sex*

Although the meta-analysis did not identify significant sex differences, there were studies pointing towards stronger neighbourhood crime-psychological distress association among women compared to men;[33,34] likely caused by higher perceived risk of victimisation among women.[29] Analyses in this thesis could not fully confirm this hypothesis. First, Chapter 3 did not find interaction between sex and perceived neighbourhood disorder (including crime). Second, when crime was expressed with objectively recorded events across Scotland (Chapter 5), higher risk of antidepressant prescription rates among women were only identified in young adulthood, but the difference was small. Third, unequivocal proof for sex differences could only be detected for antipsychotics medication with much stronger risk among younger middle-aged men in comparison to women. Elevated risk of antipsychotics medication among men living in high crime areas is a clear and novel finding. Although more men than women suffer from schizophrenia,[35] and there is also a slightly, but not significantly, higher risk of violent victimisation among men in Scotland,[28] it still does not provide enough explanation for such marked sex difference. Further possible explanations may include increased alcohol and drug use among men in high crime areas,[7,36] which is linked to psychosis incidence.[37] Still, the causal pathway with psychosis-related outcomes is rather complex with possible health selective migration dominating the reported associations in middle adulthood (see 7.3.3).

#### *7.3.2.3 Socioeconomic status*

Effect heterogeneity has been found across childhood (Chapter 4) and adult (Chapter 5) socioeconomic conditions. Childhood socioeconomic conditions (CSCs) interacted differently with neighbourhood resources and stressors by impacting mental health in later life. Living in accessible neighbourhoods increased the effects of CSCs, with the most advantaged benefiting the most. To put it differently, in less accessible areas childhood background played a smaller role in depression aetiology. On the other hand, when exposed to neighbourhood stressors older adults coming from the most disadvantaged CSCs were less affected. These findings stress the importance of life course approach in the investigation of neighbourhood effects, with childhood being a crucial period in human development and depression aetiology.[38] Socioeconomic position in the early years may channel individuals into different life course trajectories with accumulating advantages and disadvantages,[39] and a widening of inequalities over time;[40] thus health effects being more apparent in a resourceful physical environment. However, early life disadvantage may also posit moderate stressors to children, which can help to build up resilience and coping mechanism useful when exposed to adverse neighbourhoods in later life (i.e. stress inoculation hypothesis).[41]

Also, adult social grade interacted with neighbourhood stressors: individuals from middle social grades were found to be more vulnerable to crime effects. Because of the low social mobility in Scotland,[42] disadvantaged individuals have been likely raised in poor CSCs, so they might have been already adapted to stressful environments or equipped with coping mechanism used to deal with stress arising from high crime residential areas. On the other hand, individuals with higher adult social grade may have better material and social resources help to cope with neighbourhood stressors,[43] independent from their childhood background.

### 7.3.3 Neighbourhood crime and mental health: causal perspectives

The empirical chapters have mainly focused on individuals staying in the same residential area during the study follow up, assuming that long-term exposure to

neighbourhood affects residents' mental health. While it is a plausible explanation, individuals with pre-existing mental health conditions or those being vulnerable to develop mental disorders could have been already preselected into disadvantaged areas. The neighbourhood-mental health associations, therefore, might also occur because of health selective migration or social drift (1.6.3.2).

The findings from this thesis suggest that both causal neighbourhood crime effects as well as residential selection into less safe areas can contribute to the relationship between neighbourhood crime and mental health. Not only average crime exposure, but also increasing crime rates in the residential area were linked to young adults' mental health, providing a stronger case for a causal relationship, mainly for depression-related outcomes. Although young adults are at higher risk of victimisation, the majority of them do not experience crime,[28] highlighting the possibility of neighbourhood-level or ecological processes affecting health through crime-induced social stress, fear of crime or through mediating pathways, such as unhealthy behaviours.

In addition to depression-related outcomes, where the causation hypothesis is an appropriate explanation for the effects of social and contextual determinants,[44] there is also some evidence linking childhood or early adolescence exposure to neighbourhood crime to first episode psychosis.[45] Exposure to place-based stressors in earlier ages, or during the prodromal/ subsyndromal stage of psychosis, can hit at a critical period in psychosis aetiology, with little effect of exposure after this time window has passed.[46] Therefore, it is plausible that living in a high crime area in young adulthood is causally linked to antipsychotic medications (especially if individuals are still living at their parent's place). However, the genetic heritability of psychotic disorders is very high (80%),[47] making intergenerational selection processes also a valid explanation.

In older ages, however, health selective migration towards more disadvantaged and higher crime areas provides a possible explanation, especially for psychosis (as shown in Chapter 6). This finding might appear to contradict the results presented in

Chapter 5, showing middle-aged men are more likely to have antipsychotic medication when living in high crime areas (also confirmed by sensitivity analyses focusing only on stayers). However, the exclusion criteria and study focus were very different in these chapters: Chapter 5 excluded medications in the first 6 months of the study and only explored new medication regimes, while Chapter 6 excluded all medications and inpatient service use in the first 8 years of the study, focusing on possible underlying disorders rather than treatments. Moreover, antipsychotics are only a proxy of psychosis-related mental disorders (see more in 7.5.2.3) and cannot indicate the course of the underlying disorder. It is likely that higher risk of antipsychotics medication among middle-aged men is related to a recurrent episode of psychosis, but not to the first episode psychosis. Moreover, patients with psychotic disorders have very low adherence to medication;[48] therefore, a 'new' episode of antipsychotic treatment can likely be caused by higher non-adherence to previous prescriptions in higher crime areas.

## 7.4 Strengths

This thesis builds on a systematic review and meta-analysis providing an up-to-date knowledge base for the four empirical chapters. Research questions were derived from the findings of this review ensuring that each chapter had an original contribution to the literature. Chapters 3-6 not only built on each other's findings, they also further strengthened and reinforced the evidence presented in the systematic review.

### 7.4.1 Strengths of evidence

Evidence in clinical research can be classified into a hierarchical model with increasing internal validity from case reports to meta-analysis.[49] Findings from Chapter 2 (systematic review and meta-analysis), and Chapter 3 (IPD meta-analysis) provide some of the strongest evidence of neighbourhood associations, achievable with observational data. Very few experimental studies with random assignment into

'treatment' and 'control' groups are available in the neighbourhood literature (e.g. Moving to Opportunity study[50]) as they are often deemed unethical.[51] Therefore, natural and quasi-experiments are advocated, for which this thesis included an example in Chapter 6, utilising the recent crime drop in Scotland. Regarding the hierarchy of evidence, cohort studies follow, on which the remaining chapters were based (Chapter 4 & 5). The majority of studies in neighbourhood research are cross-sectional investigations presenting on average a lower quality of evidence than any of these chapters.

### 7.4.2 Strengths related to data sources

Empirical data for Chapter 3-6 were based on 4 different datasets with a follow-up time ranging between 2 (Chapter 3) and 12 years (Chapter 6). Included surveys and administrative datasets had different but complementary strengths. ELSA, HRS and SHARE are large and representative cohort studies providing information on older adults. Data collection in these surveys is highly systematic, designed for specific scientific purposes with capturing a target population, and including valid and reliable measurements.[52] There is a wide range of prospectively collected individual-level information available for researchers after rigorous data cleaning and data management has been completed by the data owners. Moreover, retrospective information on childhood stressors is a unique data source when studying the life course development of health inequalities.

Using the SLS enabled me to conduct analyses on a representative administrative dataset capturing individuals across the entire Scotland including remote areas and islands,[53] while not being affected by well-established declining survey responses.[54] SLS is a rich source of individual-level information based on administrative records and census questions that require collection by law; therefore, it is free of non-response bias and has an extremely low attrition rate (12% over 10 years) mainly driven by residents moving out of the country.[53] Because of the very large sample size, it enabled an exploration of rare events (e.g. antipsychotics medication) across different geographies and population groups, which would have rarely been possible

in non-ecological studies. Furthermore, linked prescriptions issued in the primary care within National Health Service (NHS) Scotland have an exceptional high coverage and quality. NHS is publicly-funded and universally used in Scotland; therefore the prescription data is, also, free from any selection bias.[55] As prescriptions have to be submitted to NHS Scotland by dispensers for reimbursement, it has a high level of completeness: GPs account for over 95% of total prescribing in the primary care, and 98.7% of their prescriptions had a unique personal identifier in 2014, enabling longitudinal data linkage.[55] Moreover, the Scottish Parliament abolished prescription charges in 2011,[56] minimising the risk of prescription data being affected by patients' financial difficulties.

### 7.4.3 Methodological strengths

The systematic review in Chapter 2 followed the PRISMA criteria[57] and the Cochrane guideline,[58] searched a large number of data bases, applied rigorous inclusion and exclusion criteria and included a state-of-the-art three-level random- and mixed-effects meta-analysis.[59] Chapter 3 not only applied a novel IPD meta-analysis, but reported findings estimated with all major methods of analysing multicentre data (one- and two-stage IPD meta-analysis, both with random and fixed-effects).[60] A wide range of sensitivity analyses assessed the robustness of findings in Chapter 4 and Chapter 5 applying multilevel models. Finally, by separating change effects from average neighbourhood crime exposure, Chapter 6 was able to take into account the dynamic interplay between neighbourhood and mental health.

## 7.5 Limitations

Despite these strengths, the thesis has several limitations warranting caution in interpreting the findings. Errors arising in quantitative studies can be broadly grouped into random and systematic errors.[61] While random errors are taken into account in data analyses and expressed with p-values or confidence intervals, indicating the role of chance in the estimation, systematic errors (or biases) can

seriously affect findings and conclusions.[61] First, the three main types of systematic errors (non-measurement, measurement error, and confounding) are presented arising from survey and administrative data. Second, limitations related to the causal perspective of the findings are discussed.

### 7.5.1 Systematic non-measurement error

Systematic non-measurement error is linked to selection bias, compromising the representativeness of findings for target population.[62] Non-measurement error may occur in any stages of the research process; non-measurement error at unit- and item-level are presented in more detail (refer also the "Assessment of selection bias" sections at the end of each empirical chapter [3.9, 4.8, 5.8, and 6.8]).

#### *7.5.1.1 Non-measurement error at unit-level*

Selection bias can be introduced when eligible units (e.g. households, individuals) do not participate in the data collection, compromising the reliability and generalisability of findings.[63] Different response behaviour have been found across sex, age, socioeconomic and health status.[61] Baseline response rates were higher than 70% in ELSA and HRS, with the lowest values in the SHARE (>60%); introducing the risk of non-response bias. Attrition rates were under 20% for ELSA and HRS, but over 20% for SHARE in Chapter 3 and over 40% for SHARE in Chapter 4. As sample non-response is strongly predicted by pre-existing depression,[64] the main outcome of these analyses, attrition bias was likely present when utilising SHARE data, especially in Chapter 4. To somewhat try to mitigate this bias, a variable indicating sample attrition (no attrition, dropped out, deceased) was included in the models. Although applying sample weights is often used in epidemiology to correct for response bias, especially for descriptive studies (e.g. to determine the prevalence of depression), it is not advised and can be potentially harmful for precision when causal effects are to be explored.[65,66] Moreover, if the sampling probabilities vary based on the explanatory variables controlled in the statistical models (e.g. income, age), the error term is likely not linked to the sampling.[65] In contrary to Chapter 3 & 4, Chapter 5 & 6 utilised

administrative data extracted from the SLS, where findings were free of selection or attrition bias caused by systematic non-measurement error on unit-level.

#### *7.5.1.2 Non-measurement error at item-level*

Once respondents are willing to participate in the data collection, they can still decline to answer particular questions, so systematic non-measurement error at item-level could lead to loss of precision.[63,67] Missing data at item-level may affect findings, when there are systematic differences between observed and unobserved data, as opposed to Missing Completely At Random.[67] There are several methods to account for missingness when data is Missing At Random (i.e. systematic differences between observed and missing data can be explained by associations with the observed data)[67] or Missing Not At Random (i.e. systematic differences between observed and missing data cannot be explained by associations with the observed data).[67] Although multiple imputation is often seen as an appropriate method dealing with missing data, complete case analysis, overwhelmingly conducted in this thesis, can be unbiased is certain cases.[67] Following the recent recommendation of Hughes et al,[67] post-hoc analyses at the end of relevant empirical chapters (3.9, 4.8, and 6.8) did not find indication for missingness being determined by mental health (outcome variable) after explanatory variables were taken into account; therefore, complete case analyses were likely unbiased and multiple imputation was not required.

#### *7.5.1.3 Publication bias*

Finally, a specific type of selection bias may have affected the conclusions drawn upon the finding of the systematic review and meta-analysis. Systematic reviews seek to identify all eligible publications; however, this attempt can be compromised if published literature do not represent all studies carried out in the topic of interest.[58] Studies with significant results, reporting associations in the expected direction are more likely to be published.[58,62] Therefore, it is expected from systematic reviewers to search for unpublished studies and assess publication bias. Grey literature was systematically searched which yielded the inclusion of several dissertations and studies where neighbourhood crime was only considered as a covariate and not the

main exposure. Furthermore, publication bias was assessed with rank correlation test indicated funnel plot asymmetry, which was only detectable for depression linked to two outlier estimates. However, it is very likely that, despite the systematic approach, a few relevant studies were not found and included in the review.

### 7.5.2 Systematic measurement error

During the data collection stage, there are further sources of potential errors or information biases, which may systematically distort findings. This section introduces information biases, followed by specific misspecifications linked to exposure and outcome measurement.

#### *7.5.2.1 Information bias*

Covariates and depression symptomatology were collected with computer-assisted personal interviewing for ELSA and SHARE,[68,69] and either in-person or per telephone for HRS.[70] Perceived neighbourhood assessment was mainly derived from self-competition questionnaires (see Chapter 3 for more detail). For SLS, individual-level covariates were collected through census questionnaires,[53] delivered by post and sent back by respondents.[71] Depending on the strategy for data collection, the following sources of biases should be noted:[62,63]

*Reporting bias*. Systematic underreporting may occur when respondents do not disclose sensitive or socially undesirable personal information. Inaccurate reporting of financial situation (e.g. earnings, wealth) or health behaviour (e.g. alcohol consumption, smoking) in Chapter 3 & 4 may have led to biased estimates in the analyses, especially if reporting behaviour was different between individuals with and without depression.

*Recall Bias*. Studies collecting information retrospectively may be prone to recall bias.[62] The overwhelming majority of variables in this thesis assessed current social, economic and health status; the only exemption was Chapter 4, which derived retrospectively collected information on childhood stressors. As indicated in the limitation section of Chapter 4 (4.6.1), subjective assessments of childhood

socioeconomic circumstances and childhood health problems can be considered as fairly well reported in the SHARE study;[72] however, retrospectively reported childhood adverse events might have led to an overestimation of their real effects on depression.[73]

#### *7.5.2.2 Measuring context*

Neighbourhood was measured in two distinct ways, utilising perceived and objective assessments (1.6.1). Each *perceived neighbourhood* variable in Chapter 3 (neighbourhood disorder, lack of social cohesion) & 4 (neighbourhood nuisances, access to services) was based on two items; item loadings on the same dimension were statistically assessed with principal component analysis and multiple correspondence analysis. Although by utilising longitudinal data with clear baseline or adjusting for baseline symptoms, this thesis aimed to mitigate the risk of reverse causation, same source bias could have led to biased estimates.

*Objective neighbourhood* measurements in Chapter 5 & 6 were extracted from the 2006, 2009 and 2012 Scottish Index of Multiple Deprivation; four potential sources of measurement errors should be considered. First, although the smallest available spatial unit (data zone) was utilised for crime, as suggested by the law of crime concentration,[11] it is likely that the data zones in rural areas were still too large to capture the true effect of neighbourhood crime. Choosing the most appropriate scale and shape of spatial units is crucial, as indicated by the modifiable area unit problem.[74] Second, even if the right geographic scale and shape is identified, it may still differ from the true causally relevant context of exposure, as individuals have highly different activity spaces where neighbourhood can affect them.[74] The bias arising from this dynamic space-time uncertainty of exposure is described by the uncertain geographic context problem.[74]

Third, although it is plausible that violent and property crime have different effects on health,[11,34] there was no information available on types of crime on data zone level. Last, crime incidents are notoriously underreported: in Scotland fewer than 4 out of 10 crimes or offences are recorded by the police.[28] Reporting crimes and offences is

not random, and can be strongly affected by procedural justice, whether or not the victim assumes that the police can be trusted in dealing appropriately with the their complaint.[75] Younger people, ethnic minorities, individuals living in disadvantaged and high crime areas have generally lower trust in the police,[28,75,76] leading to lower intention to report crime events.[75] Chapter 5 utilised relative crime levels (i.e. low, moderate and high), which was less likely affected by bias in crime reporting, given the large and distinct differences between groups. However, using absolute crime rates (Chapter 6) might have led to underestimating crime effects due to disproportionate reporting behaviour in high crime communities.

#### *7.5.2.3 Measuring mental health*

Mental health was assessed in two distinct ways (1.6.2): utilising screening scales in Chapter 3 & 4, and mental health service use data in Chapter 5 & 6. Two reliable and valid *screening scales* (CES-D[77] and EURO-D[78]) assessed depression. Before analyses, total symptom scores were dichotomised using conventional cut-off points indicating clinically relevant levels of depression. Although both scales have high sensitivity (i.e. identifying a true case) and specificity (i.e. not identifying a non-case),[77-80] by definition they cannot provide exact depression diagnosis.

Analysing *service use data* on mental health implies several limitations. First, there is a large treatment gap between mental health service use utilisation and mental health needs in the general population,[81] likely to be affected by mental health stigma present at the service user and service provider side.[82] Self-stigma (i.e. affected individuals endorse the public stereotypes and agree with the prejudices)[83] and own stigmatising attitudes (i.e. attitudes of an individual towards people with mental health conditions)[83] decrease the likelihood of active help-seeking behaviour in the general population,[83] with treatment gap varying across socio-demographic groups.[81] Also, health providers with higher endorsement of mental health stigma have been found to refer patients less likely to specialists or prescribe psychotropic medications.[84]

Second, prescribed anxiolytics, antidepressants and antipsychotics in the primary care are a proxy of mental disorders; specific diagnoses are not available in the

Scottish National Prescription Information System.[55] Although lower dosage of amitriptyline and nortriptyline, used to treat headaches and neuropathic pain,[85] were excluded from the analyses, antidepressants and antipsychotics are often prescribed for neurological conditions among older adults without the presents of mental disorders.[31,32] To mitigate this problem, Chapter 6 concentrated on individuals younger than 60 years old at baseline. Still, antidepressants among young and middle-aged individuals can be also prescribed for e.g. improve motoric recovery from ischemic stroke.[86] Moreover, treatment gaps vary across mental disorders. Whereas there is a smaller gap by severe mental illnesses, such as psychosis (approximately 30%),[87] only half of the people with severe depression and anxiety symptoms are receiving prescribed psychotropic medication and/or psychotherapy in England.[81]

Finally, because of the prescription data was not available prior to 2009,[55] Chapter 6 utilised information on psychiatric inpatient and day case service use to identify ongoing or previous episodes of mental disorders. Patients receiving care in psychiatric facilities present more severe and acute clinical symtoms,[88] in comparison to those being on psychotropic medications in primary care. For a comparison, the number of patients in Scotland with antidepressants (>800,000)[85] and antipsychotics (>90,000)[85] were substantially higher in 2015/16, than those in psychiatric care (>19,000).[88] Therefore, by excluding patients in mental health specialities did not capture all individuals with pre-existing mental disorders.

### 7.5.3 Confounding

Confounding occurs when a variable *"is a risk factor for an effect among non-exposed persons and is associated with the exposure of interest in the population from which the effect derives, without being affected by the exposure or the disease"*(p.640).[62] If confounding is present in the analyses, it can lead to spurious associations between exposure and outcomes. Each empirical chapter took into consideration potential sociodemographic and health-related confounders selected based on the literature (1.5.1); still, there might be further sources of residual confounding. First, as indicated

in 7.5.2.1, misclassification in the measurement of potential confounders, especially those related to socioeconomic and health status, might have reduced the ability to control for their effects. Second, analyses in Chapter 5 & 6 based on the SLS sample were restricted to information measured in the census or linked to the dataset from administrative records. An important confounder in the neighbourhood-mental health relationship is income or household wealth, which was not directly measured in SLS. Although models included proxy measures (social class in 2001, social grade in 2011), it is plausible that further socioeconomic confounding was present in the analyses.

### 7.5.4 Causal inference

To mitigate reverse causation, each analysis (1) controlled for baseline level of mental health problems, or excluded individuals with existing mental health conditions; and (2) either focused on those participants staying at the same residential location during follow-up or took into consideration moving to different neighbourhoods. Nonetheless, there are major limitations regarding the causal perspective of the findings.

First, survey (ELSA, HRS, and SHARE) data collection took place every second year, and depressive symptoms were captured by screening scales covering symptoms from one month before assessment. It is plausible that depressive episodes occurring between waves or before the first wave of data collection affected neighbourhood perception or led to selection into certain neighbourhoods. (Note that the average onset of depression is in the mid 20-ies while the samples included individuals aged 50 and over).[89]

Second, for psychotic disorders a mix of causation and health selection acting over the life course might explain the link to neighbourhood crime (7.3.3). Still, longitudinal data in this thesis could not provide 'long enough' time coverage to appropriately test this hypothesis.

Third, as pointed out several times, the causal relationships between neighbourhood crime, individual victimisation and mental health are very complex and interrelated. While at the neighbourhood-level, causation and health selection may interact over time and affect mental health as pointed out earlier (7.3.3), at individual-level, people with mental health conditions do not only have a higher risk of victimisation,[90] but they commit violent crimes more often (1.6.3).[91] Available data in this thesis could not further elaborate on these complex mechanisms.

## 7.6 Implications

The following section present policy and research implications arising from the conclusions of this thesis. Although the association between neighbourhood and mental health likely exist globally; recommendations for interventions and mental health service development in this section are solely focusing on high-income countries, especially on the UK and Scotland.

### 7.6.1 Implications for neighbourhood-based interventions

Supporting communities to become more inclusive, resilient, cohesive and safe is not only included in the United Nation's Sustainable Developmental Goals,[92] but also constitutes one of Scotland's most important public health priorities outlined in June 2018.[93] Moreover, it is aligned with the Scottish Government's National Performance Framework, bringing together national and local governments, businesses, voluntary organisations and the population of Scotland, in order to achieve the 11 national outcomes (including safer communities), monitored across 81 indicators (e.g. crime, crime victimisation, social capital).[94] This section aims to contribute to this holistic and systems-based approach by specifying potential interventions and policy actions.

#### *7.6.1.1 Reducing crime and violence*

Despite the substantial decline in total crime rates over the last decades across England[95] and Scotland,[28] some serious violent offences (e.g. homicide, gun crime, knife crime) have been reported to increase since 2014 in major cities, raising not only

public but also policy attention (e.g. 'Serious Violence Strategy' policy brief of HM Government[95]). As shown throughout this thesis, area-level crime is linked to mental health of residents; therefore, strategies for reducing crime and violence are needed, which can contribute to safer and healthier communities:

(a) Crime is spatially patterned, with violent crime events being particularly concentrated around few hot spots.[11] While it is important not to increase fear of crime among residents[7] or produce place-based stigma by e.g. constant police present, focused and data-driven police interventions at crime hot spots have the potential to reduce crime.[96]

- *Hot spot policing may be effective to reduce crime events.*

(b) Interventions aiming to change the built environment can contribute to crime reduction by providing fewer opportunities for offending, as suggested by the 'crime prevention through environmental design' approach.[97] A recent review found decreased levels of violence after interventions focusing on area rehabilitation, mitigation of dilapidated housing, blight remediation and cleaning of vacant parcels.[97] Restricting alcohol availability,[97] providing access to urban green space can reduce violence[98] and promote mental health.[99]

- *Interventions in the built environment might reduce crime and violence.*

(c) It is plausible that hot spot policing and changing the built environment only displace crime to other areas;[97] interventions aiming to achieve sustainable changes should consider also the social determinants of crime (e.g. social disorganisation, lack of collective efficacy). Evidence from the 'Communities First' project in Wales provides an example on how a complex urban regeneration programme involving installing street lights to reduce crime, redeveloping wasteland, but also building community facilities improves population mental health.[100] Moreover, further analyses highlighted that the beneficial mental health effects were mainly linked to increased neighbourhood quality and reduced neighbourhood disorder.[101] Therefore, holistic place-based interventions aiming to change the social and physical

determinants of crime, would have larger population health benefits in comparison to 'pure' crime reduction programmes, as they have also direct links to mental health (e.g. green space,[99] social capital[14]) over and above crime effects.

- *Complex area-based interventions targeting social and physical determinants of crime should be prioritised to achieve sustainable changes and promote population mental health.*

#### *7.6.1.2 Promoting community social cohesion*

Lack of neighbourhood social cohesion was strongly linked to depression in older adults, especially among those in retirement. A community-based intervention in Spain among older adults found long-lasting effects of social capital intervention on depression, by integrating project components such as raising awareness of loneliness, training community volunteers, and providing a group-based programme on social participation.[102]

- *Promoting social cohesion and social capital among older adults may help to reduce depression in later life.*

#### *7.6.1.3 Providing access to neighbourhood services*

Better access to neighbourhood amenities (e.g. medical care, pharmacies, and groceries) and to public transportation was linked to good mental health among older adults. Mobility can be increased among the elderly by providing barrier-free public transportation, smart ticketing and technologies to compensate deteriorated perceptive faculties.[103] Also, visiting nurses and social workers may support daily life for those living with limited mobility.

- *Providing access to services and removing barriers, especially in disadvantaged and remote communities should be improved.*

### 7.6.2 Implications for mental health prevention and service development

Although neglected for a long time in favour of physical conditions, mental health problems are being increasingly recognised by national governments as a key element

for the long-term social and economic prosperity of the society.[104] Signalising this current change in mind-set, the Scottish Government included mental wellbeing in the six public health priorioty areas (alongside with healthy places and communities),[93] and Scotland (with Iceland and New Zealand) created a global collaboration on wellbeing economy, which prioritise the human and ecological wellbeing to the country's economy.[105]

While the wellbeing economy approach present a broader vision, the Scottish Government has more precisely outlined in its Mental Health Strategy 2017-2027 the following working areas: (1) prevention and early intervention; (2) access to treatment and joined-up, accessible services; (3) physical wellbeing of people with mental health problems; and (4) rights, information use and planning.[106] The findings of this thesis aim to contribute to plan in two of the highlighted areas: prevention and early intervention, and by providing better access to treatments.

#### *7.6.2.1 Prevention and early intervention in high crime areas*

One way to reduce the global burden of mental disorders is to reduce the incidence of new cases. Prevention can focus on the general population (i.e. universal prevention), or target higher risk groups (i.e. selective prevention) or individuals with prodromal symptoms (i.e. indicated prevention).[107] Although successful programmes are available to prevent common mental disorders and promote mental health,[107,108] their implementation in public health context is still rare.[92]

(a) Allocating prevention programmes in high crime areas may be beneficial for residents. More precisely, providing selective prevention for individuals from vulnerable social and age groups (e.g. young adults) in these neighbourhoods, or indicative prevention for those already victimised or witnessed crime might reduce the mental health burden.

- *Allocating targeted prevention programmes in the vicinity of high crime areas may reduce the incidence of common mental disorders.*

(b) The average age of first onset of depression and anxiety is in the mid 20-ies.[89,109] Early onset is not only associated with worse life course mental health outcomes but also with physical health problems and poor academic trajectories.[108] Therefore, prevention programmes before the first onset should be prioritised. There is systematic evidence of a small but conclusive effect of school-based universal and targeted (selective or indicative) preventions on common mental disorders, with stronger effect size among children than adolescents. Furthermore, school context can also help to include people in prevention who are harder to reach but vulnerable.

- *School-based prevention programmes conducted in high crime areas, especially in early ages, may have long-term population health benefits.*

(c) Psychotic disorders have a strong genetic background with very high heritability.[47] As shown in this thesis, they are strongly associated with neighbourhood crime, irrespective from the potential causal mechanism. Identifying individuals with high risk of psychosis and providing them indicative prevention may delay the onset and ameliorate the severity of first episode psychosis.[110] Therefore, supporting GPs in high crime areas to identify individuals at high risk of psychosis, and providing indicative prevention may reduce the burden linked to psychosis.[110]

- *Allocating indicative prevention of psychosis into high crime areas may improve the outcomes of first episode psychosis.*

#### *7.6.2.2 Access to treatment*

Another way of decreasing the burden of mental disorders is to reduce their prevalence by providing adequate treatment as early as possible.

(a) In the Mental Health Strategy 2017-2027, the Scottish Government aims to allocate additional funding for 800 new mental health workers in Emergency Departments, GP practices, police stations and prisons.[106] Mental health workers allocated in high crime areas should receive specialist training, including crisis intervention, with a strong focus on how to work with vulnerable populations, and engage with individuals involved in crime and violence at both victim and offender side. It is

important to also consider previous offenders, as evidence points towards very high prevalence of mental disorders, especially post-traumatic stress disorders among prisoners as a result of own victimisation in earlier life.[111]

- *Providing specialist training for mental health professionals in high crime areas should be prioritized in order to tackle the circle of violence.*

(b) Early detection of mental disorders is crucial. The early phase of first episode psychosis is a critical time for secondary intervention[112] and affects the long-term outcomes such as hospitalisation, violence, suicide and onset of comorbid mental disorders.[113] There is evidence showing that multielement programs (e.g. coordinated specialty care, with including pharmacological treatment, cognitive and behavioural psychotherapy, family support, education, and case management)[113] have the potential to improve not only health outcomes, but future employment status.[114] It is crucial because of the very high unemployment rates (80-90%)[47,113] and downwards social mobility in schizophrenia.[44]

- *Early detection and provision of multielement treatments for severe mental disorders (especially for psychosis) in high crime areas can not only improve quality of life, but also the social and economic situation of affected individuals.*

(c) Finally, mental health professionals should work closely together with the police when aiming to reduce the effect of neighbourhood crime on population mental health. Police are often the first contact in situations where people with mental health problems are involved.[115] However, as a recent evaluation on policing and mental health in England and Wales pointed out, police forces are often left alone with mental health crises in 24/7 service.[116] Despite promising international (e.g. pairing together mental health clinicians with police officers when working in crime hot spots),[115] and national pilot projects (e.g. Crisis Care Concordat, Street Triage),[116,117] further cooperation is needed with clear strategic and tactical guidelines to better respond to the needs of people with mental health problems.[116]

- *Stronger partnership between police and mental health professionals should be prioritised with clear guidelines of action.*

### 7.6.3 Recommendations for future research

While replication studies from other countries, especially in low- and middle-income economies with increasing crime rates, would be very welcome in order to reinforce findings in different contexts, further theoretical and methodological work is needed.

#### *7.6.3.1 Theoretical directions*

(a) This thesis explained the neighbourhood crime and mental health relationship with underlying direct and indirect pathways, without testing them empirically. While there is some evidence linking neighbourhood crime to physiological stress response,[118] robust investigations on mediating pathways, such as lower engagement in physical activity and social participation in higher crime area, are largely missing in the literature. The systematic review was only able to identify one cross-sectional analysis testing physical activity as a mediating pathway between neighbourhood crime and mental health using appropriate statistical methods.[119]

- *High quality longitudinal investigations are needed to explore direct and indirect causal pathways between neighbourhood crime and mental health.*

(b) Despite the theoretical and empirical evidence on the crime concentration in micro-geographic units,[11] studies with very large area of crime aggregation (e.g. local authorities, states) were also able to identify connections between neighbourhood crime and mental health.[5,33,34] Moreover, while violent crime seemed to be more strongly related to mental health when utilising small area measurements,[11] in large geographies property crime had stronger associations with population mental health.[34] It is plausible that different crime-related processes operate at different geographic scales (e.g. direct victimisation at micro-scale, lower engagement in health promoting behaviour at local level, incoherent crime prevention policies at macro-level); still, it is largely unexplored.

- *Systematic crime type- and geographic scale-specific investigations are needed to better understand crime effects and underlying processes.*

(c) The relationship between committing crime, becoming a victim of crime and mental health is very complex and intertwined with the local- and macro-level influences where crime takes place (7.5.4). While these associations have enormous public health potential, complex investigations are missing in the literature. Interdisciplinary and longitudinal studies would be welcomed which are able to explore how growing up in high crime areas affects human development, offending behaviour and mental health, and how they are interrelated with each other within the constantly evolving and endogenous contextual framework. To support empirical research, analytical and conceptual reviews (such as Lorenc et al[7]) could usefully propose plausible connections. Also, analysing complex feedback loops in time and space can benefit from the life course framework.

- *To disentangle complex relationships between neighbourhood, offending, victimisation and mental health, researchers should work interdisciplinary and apply the life course framework.*

(d) Finally, while neighbourhood crime research should 'scale down', to adjust to the spatial specificity of crime, there is a need to 'scale up' in order to better understand policies and other macro-level determinants impacting neighbourhood effects.[120] While it requires a complex systems-level approach with inputs from life course approaches applied to human, local- and macro-level context (see in the Response to Commentary [3.8]), this thinking has direct and valuable benefits for research, policy and prevention. For example, the recent global economic recession, might have led to a loosening of community ties and increasing crime in small areas, which affected individuals at different points in their life course development, impacting also mental health trajectories.

- *Applying system-based thinking and exploring the larger political, economic, social and environmental context can contribute not only to neighbourhood research but also to policy development.*

*7.6.3.2 Methodological and data innovations*

(a) By utilizing longitudinal linked administrative data, this thesis sets an example of how this data source can benefit public mental health research. Low risk of selection bias and large sample size can enable researchers to explore rare outcomes or effect heterogeneity across many subgroups, a particular challenge for traditional surveys. Innovations enabling data-linkage could further extend the variety of research questions; still, administrative data is underutilised.

- *Using linked administrative data should be considered more often in public health and epidemiological research.*

(b) To facilitate the application of life course approaches to the contextual determinants of health, historical data on area-based social and physical features are required.[121] This thesis utilised small area-level crime, which was first published in the 2006 Scottish index of Multiple Deprivation. Although collecting historical data on total crime might be challenging because of changing crime definitions and different data recording practices across police forces, focusing on specific types of crime which are more likely to be collected constantly by the police (e.g. homicide), and also reported in other sources, such as in newspapers, might ease historical data collection. While researchers utilising longitudinal contextual data should be aware of limitations linked to e.g. inconsistent data availability and coverage, and the larger historical context, historical data offers a great potential for research on life course health and space.

- *Historical data on contextual exposures are needed to facilitate life course research.*

(c) Finally, to overcome main biases inherent in observational data, natural and quasi-experiments should be priorities in health geography. Although this thesis provided an example of how to utilise changing neighbourhood crime rates, there are several further opportunities to explore how police actions can reduce crime and improve population mental health, or investigate the effect of the recent surge of violence related to gun and knife in big cities.[122] For example, findings in Chapter 6 could be

usefully extended by narrowing down the focus to the effects of crime reduction, linked to the intervention of the Violence Reduction Unit at Police Scotland.[123]

- *Utilising natural and quasi-experiments can further reinforce the causal inference between neighbourhood and mental health.*

## 7.7 Concluding remarks

Despite the growing number of studies on the contextual determinants of health, research gaps and methodological constrains limit our understanding on how, where and for whom neighbourhood is linked to mental ill health. This thesis contributed to the literature by describing neighbourhood stressors and resources, identifying vulnerable population subgroups, and suggesting causal pathways between exposure and outcome. It had a particular focus on the effects of area-level crime on three major mental health conditions: anxiety, depressive and psychotic disorders. Empirical data were based on cross-national cohort studies, and on a linked administrative dataset from Scotland. More importantly, all analyses utilised longitudinal information providing more robust evidence on the neighbourhood and mental health relationship, in comparison to cross-sectional investigations representing the majority of existing literature.

This thesis addressed two out of the six public health priorities of Scotland: healthy places and communities, and mental wellbeing. Neighbourhood features are modifiable and provide opportunities for policy and practice to reduce disease burden on population level. Hot spot policing, targeting the physical and social determinants of crime can not only reduce crime rates but might benefit residents' mental health and wellbeing. Providing access to local services and supporting neighbourhood social cohesion can contribute to social inclusion and better mental health among physically restricted older adults. Identifying vulnerable communities and providing them with universal and targeted prevention programmes, especially in earlier ages, would likely reduce the incidence of common mental disorders and contribute to better outcomes of severe mental illnesses; while allocating mental

health services in the vicinity of high crime areas may further narrow mental health inequalities across neighbourhoods. Finally, as the burden associated with both crime and mental health problems affects various aspects of policy from public health to social, economic and judicial sectors, holistic and systems-based approaches would be welcomed with practitioners across disciplines working closely together.

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# APPENDICES

# 8. Appendices

## 8.1 Appendix One: Supplementary Material for Chapter 2

**Contents**

**Supplementary Material 2.1**: General search terms

1. Mental health:

depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR psychotropic OR antidepressant* OR antipsychotic*

2. Neighbourhood crime:

((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*))

OR

"social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows"

Limit: no Animals

**Supplementary Table 2.1**: Database searches

| Mental health | Neighbourhood crime | |
|---|---|---|
| Applied Social Sciences Index and Abstracts (ASSIA) (28/03/2019) (1351)* | | |
| depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR Exact("mental disorders") OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR Exact("psychotropic drugs") OR psychotropic OR antidepressant* OR antipsychotic* (287,037) | noft(((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*))) (4,467) (5,011) | noft("social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows") (752) |
| CAB Abstracts (28/03/2019) (235)* | | |
| (depress* or anx* or schizophrenia or psychos* or psychot*).mp. or mental disorders.sh. or "mental health".mp. or "mental disorder".mp. or distress.mp. or wellbeing.mp. or well-being.mp. or internalising.mp. or internalizing.mp. or psychopharmacotherapy.mp. or psychotropic.mp. or antidepressant*.mp. or antipsychotic*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (125,336) | ((neighbourhood* or neighborhood* or area* or residen* or communit* or local or urban or geographic* or spot or contextual or ecological) adj2 (violen* or crim* or homicide or vandalism or safety or deprivation or nuisance or stressor*)).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (1,945) (2,074) | ("social disorganisation" or "exposure to violence" or "exposure to crime" or "neighbourhood disorder" or "neighborhood disorder" or "broken windows").mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (149) |
| Embase (28/03/2019) (2,825)* | | |
| (depress* or anx* or schizophrenia or psychos* or psychot*).mp. or mental disease/ or "mental health".mp. or "mental disorder".mp. or distress.mp. or wellbeing.mp. or well-being.mp. or internalising.mp. or internalizing.mp. or psychopharmacotherapy/ or psychotropic.mp. or antidepressant*.mp. or antipsychotic*.mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, | ((neighbourhood* or neighborhood* or area* or residen* or communit* or local or urban or geographic* or spot or contextual or ecological) adj2 (violen* or crim* or homicide or vandalism or safety or deprivation or nuisance or stressor*)).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word] (8,513) | ("social disorganisation" or "exposure to violence" or "exposure to crime" or "neighbourhood disorder" or "neighborhood disorder" or "broken windows").mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, |

| | | |
|---|---|---|
| floating subheading word, candidate term word] (1,720,113) | (10,464) | floating subheading word, candidate term word] (2,321) |
| Global Health (28/03/2019) (645)* | | |
| (depress* or anx* or schizophrenia or psychos* or psychot*).mp. or mental disorders/ or "mental health".mp. or "mental disorder".mp. or distress.mp. or wellbeing.mp. or well-being.mp. or internalising.mp. or internalizing.mp. or psychotropic drugs/ or psychotropic.mp. or antidepressant*.mp. or antipsychotic*.mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (117,858) | ((neighbourhood* or neighborhood* or area* or residen* or communit* or local or urban or geographic* or spot or contextual or ecological) adj2 (violen* or crim* or homicide or vandalism or safety or deprivation or nuisance or stressor*)).mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (2,488) | ("social disorganisation" or "exposure to violence" or "exposure to crime" or "neighbourhood disorder" or "neighborhood disorder" or "broken windows").mp. [mp=abstract, title, original title, broad terms, heading words, identifiers, cabicodes] (437) |
| | (2,847) | |
| International Bibliography of the Social Sciences (IBSS) (28/03/2019) (976)* | | |
| depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR Exact("mental disorders") OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR Exact("psychotropic drugs") OR psychotropic OR antidepressant* OR antipsychotic* (247,037) | noft(((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*))) (6,730) | noft("social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows") (722) |
| | (7,273) | |
| MEDLINE(R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE(R) Daily and Ovid MEDLINE(R) 1946 to Present (28/03/2019) (1,938)* | | |
| (depress* or anx* or schizophrenia or psychos* or psychot*).mp. or Mental Disorders/ or "mental health".mp. or "mental disorder".mp. or distress.mp. or wellbeing.mp. or well-being.mp. or internalising.mp. or internalizing.mp. or Psychotropic Drugs/ or psychotropic.mp. or antidepressant*.mp. or antipsychotic*.mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, | ((neighbourhood* or neighborhood* or area* or residen* or communit* or local or urban or geographic* or spot or contextual or ecological) adj2 (violen* or crim* or homicide or vandalism or safety or deprivation or nuisance or stressor*)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary | ("social disorganisation" or "exposure to violence" or "exposure to crime" or "neighbourhood disorder" or "neighborhood disorder" or "broken windows").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, |

| | | |
|---|---|---|
| protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1,311,131) | concept word, unique identifier, synonyms] (6,888) | organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] (1,893) |
| | (8,463) | |
| PsycINFO (28/03/2019) (3,439)* | | |
| (depress* or anx* or schizophrenia or psychos* or psychot*).mp. or exp Mental Disorders/ or "mental health".mp. or "mental disorder".mp. or distress.mp. or wellbeing.mp. or well-being.mp. or internalising.mp. or internalizing.mp. or psychotropic.mp. or antidepressant*.mp. or antipsychotic*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures] (1,271,135) | ((neighbourhood* or neighborhood* or area* or residen* or communit* or local or urban or geographic* or spot or contextual or ecological) adj2 (violen* or crim* or homicide or vandalism or safety or deprivation or nuisance or stressor*)).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures] (7,080) | ("social disorganisation" or "exposure to violence" or "exposure to crime" or "neighbourhood disorder" or "neighborhood disorder" or "broken windows").mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures] (2,864) |
| | (9,259) | |
| Scopus (28/03/2019) (4,080)* | | |
| TITLE-ABS-KEY ( depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR psychotropic OR antidepressant* OR antipsychotic* ) (2,100,395) | TITLE-ABS-KEY ( ( ( neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological ) W/2 ( violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor* ) ) ) (28,778) | TITLE-ABS-KEY ( "social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows" ) (3,463) |
| | (31,527) | |
| Social Services Abstracts (28/03/2019) (893)* | | |
| depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR Exact("mental disorders") OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR Exact("psychotropic drugs") OR psychotropic OR antidepressant* OR antipsychotic* (92,065) | noft(((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*))) (2,778) | noft("social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows") (643) |
| | (3,216) | |

| | | |
|---|---|---|
| Sociological Abstracts (28/03/2019) (1,297)* | | |
| depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR Exact("mental disorders") OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR Exact("psychotropic drugs") OR psychotropic OR antidepressant* OR antipsychotic* (165,365) | noft(((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*))) (8,347) | noft("social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows") (1,177) |
| Web of Science (28/03/2019) (4,047)* | | |
| TS=(depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR psychotropic OR antidepressant* OR antipsychotic*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years (1,414,806) | TS=((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*)) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years (21,967) (23,639) | TS=("social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows") Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC Timespan=All years (1,672) |
| **Grey literature** | | |
| OpenGrey (28/03/2019) (17)† | | |
| depress* OR anx* OR schizophrenia OR psychos* OR psychot* OR "mental health" OR "mental disorder" OR distress OR wellbeing OR well-being OR internalising OR internalizing OR psychotropic OR antidepressant* OR antipsychotic* (11,528) | ((neighbourhood* OR neighborhood* OR area* OR residen* OR communit* OR local OR urban OR geographic* OR spot OR contextual OR ecological) NEAR/2 (violen* OR crim* OR homicide OR vandalism OR safety OR deprivation OR nuisance OR stressor*)) (311) (319) | "social disorganisation" OR "exposure to violence" OR "exposure to crime" OR "neighbourhood disorder" OR "neighborhood disorder" OR "broken windows" (8) |

*Numbers after discharging duplicates

†Hits were not exported in reference manager

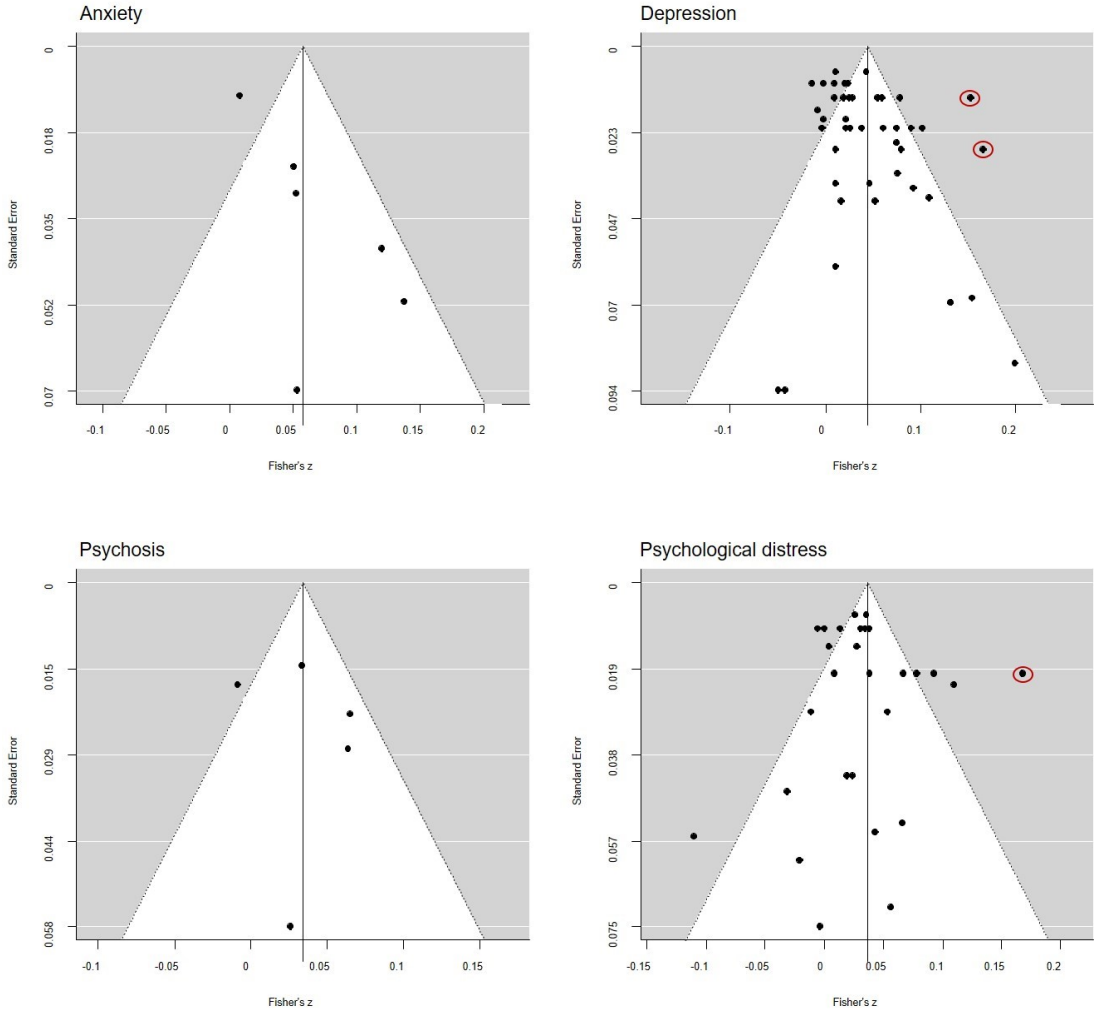
**Supplementary Material 2.2:** Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies*

| Criteria | Rating[a] |
|---|---|
| 1. Was the research question or objective clearly stated?<br>(1) The authors described their goal in conducting this research, which is explicitly stated, comprehensive and easy to follow.<br>(0) Research question is not clearly stated. | |
| 2. Was the study population clearly specified and defined?<br>(1) Description of recruitment was appropriate and replicable, using demographics (age, gender), location and time period; reader can follow the steps of selection.<br>(0) Study population was not described specific enough. | |
| 3. Was the participation rate of eligible individuals at least 50% at baseline?<br>(1) Baseline participation rate was ≥ 50%.<br>(0) Baseline participation rate was < 50%. | |
| 4. Were the individuals selected to participate in the study likely to be representative of the target population?<br>(1) Sample was drawn from the general population or from particular age groups; site selection was representative.<br>(0) Selected groups were taken (e.g. low income adults, ethnic minority). | |
| 5. Was a sample size justification, power description, or variance and effect estimates provided?<br>(1) Analytic sample size was ≥ 500, or authors provided sample size justification, power description.<br>(0) Sample size was < 500 and no power calculation or sample justification were reported. | |
| 6. Was the exposure of interest measured prior to the outcome being measured?<br>(1) Exposure of interest was measured prior the outcome of interest.<br>(0) Exposure and outcome was measured concurrently, or outcome was measured earlier. | |
| 7. Did the study examine different levels of the exposure as related to the outcome?<br>(1) At least three categories of exposure were assessed or exposure was measured as continuous variable in order to present dose-response relationship.<br>(0) Exposure was measured with dichotomous variable. | |
| 8. Was the exposure clearly defined, valid, reliable and implemented consistently across all study participants?<br>(1) Exposure was clearly defined and consistently implemented. By studies with objective crime measure: study used participant-centred/ participant-defined or small administrative units (average population <5000). By studies with self-reported crime measure: all items in the composite index assessed crime in the neighbourhood.<br>(0) Exposure was not clearly defined, neighbourhood units were too large or composite index were not solely crime-related. | |
| 9. Was the exposure assessed more than once over time?<br>(1) Exposure was measured at least twice during the course of the study period.<br>(0) Exposure was measured only once during the course of the study period. | |
| 10. Was the outcome clearly defined, valid, reliable and implemented consistently across all study participant?<br>(1) Outcome was clearly defined, consistently measured with valid and reliable screening or diagnostic scales; information on diagnosis of mental disorders came from service use data (e.g. outpatient care).<br>(0) Outcome was not clearly defined, consistently measured and/or medication or self-reported diagnosis were taken as proxy. | |
| 11. Was the outcome assessed more than once over time? | |

| |
|---|
| (1) Outcome for each person was measured at least twice (during baseline and follow-up) during the course of the study period; outcome indicates incidence cases following a clear baseline.<br>(0) Outcome for each person was measured only once during the course of the study period. |
| 12. Was loss to follow-up after baseline 20% or less?<br>(1) Loss to follow up was < 20% among studies shorter than 5 years. By studies with longer duration (e.g. 10-15 years), higher attrition rates can be also acceptable (30-40%).<br>(0) Attrition rate was ≥ 20% in studies with shorter follow up. |
| 13. Were statistical methods used in the study appropriate?<br>(1) Geographic clustering of individual-level data was taken into account (e.g. fitting multilevel models, calculating cluster robust standards error estimations).<br>(0) No data clustering was taken into account; study made use of ecological-level data. |
| [a] Further options: NA - Not applicable; NR – Not reported TOTAL SCORE: |

*Based on the NIH's Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies checklist (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools).

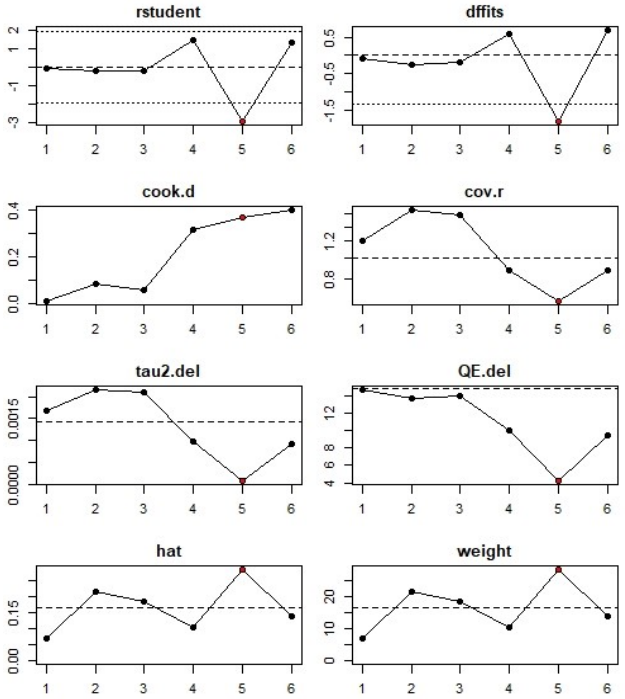
**Supplementary Figure 2.1:** Funnel plots indicating publication bias

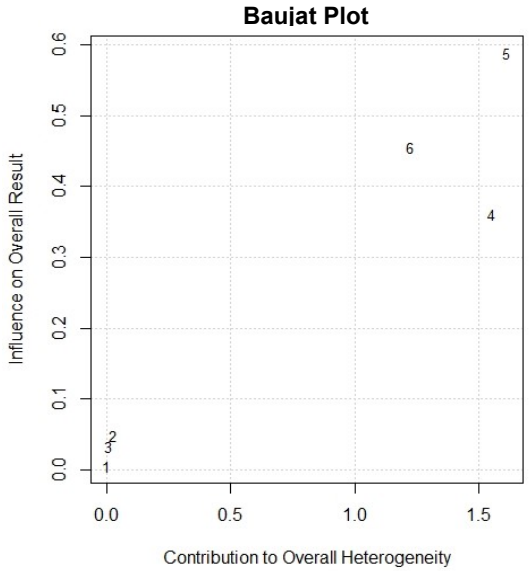



Note: Publication bias was present for depression (Kendall's tau=0.215; p=0.047), but not for anxiety (Kendall's tau=0.200; p=0.719), psychosis (Kendall's tau=0.000; p=1.00), or psychological distress (Kendall's tau=-0.017; p=0.905). Excluded outliers in the sensitivity analysis are indicated with the red circle.

**Supplementary Figure 2.2:** Outlier and influence diagnostics for studies with (a) anxiety, (b) depression, (c) psychosis and (d) psychological distress outcomes.

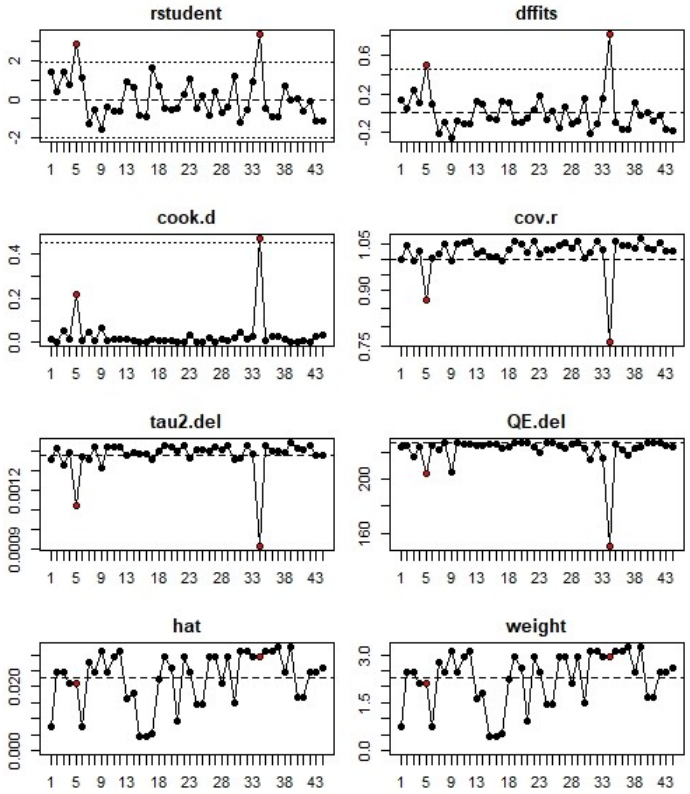
(a) Anxiety

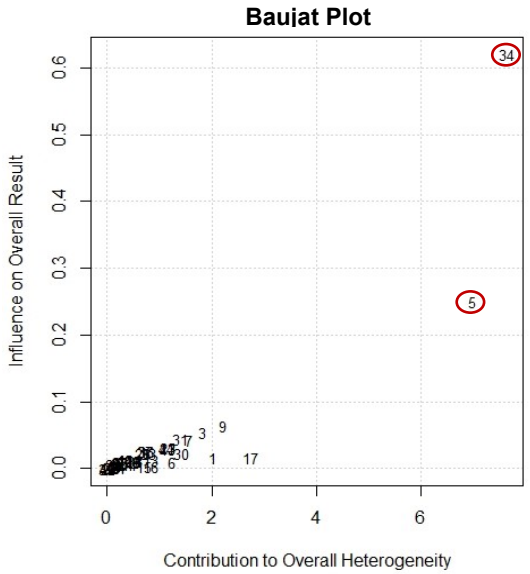



Note: *Rstudent* present the externally standardized residuals, *dffits* the dffits values, *cook.d* the Cook's distance measure, *cov.r* the covariance ratios, *tau2del* the leave-out-estimates of the amount of heterogeneity, *QE.del* the leave-out-value of the test statistics for heterogeneity, *hat* the hat-values and *weight* the study weights.[1] The *Baujat plot* indicates the estimate specific contribution to the overall heterogeneity versus the influence of the estimate on the overall results.[2] See http://www.metafor-project.org/ for more details.

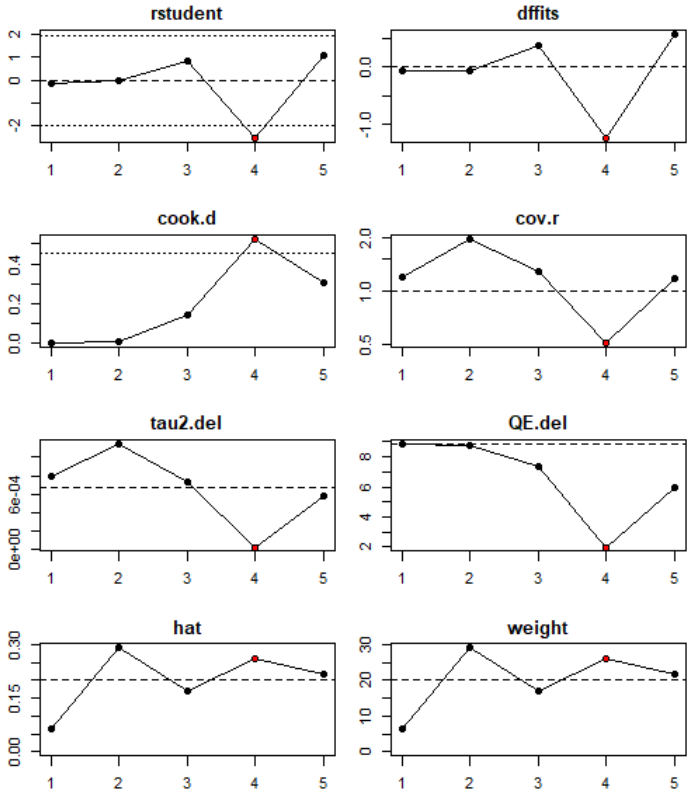
(b) Depression

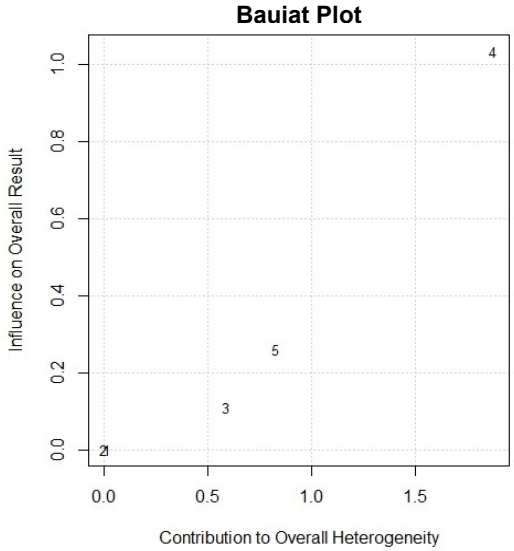



Note: *Rstudent* present the externally standardized residuals, *dffits* the dffits values, *cook.d* the Cook's distance measure, *cov.r* the covariance ratios, *tau2del* the leave-out-estimates of the amount of heterogeneity, *QE.del* the leave-out-value of the test statistics for heterogeneity, *hat* the hat-values and *weight* the study weights.[1] The *Baujat plot* indicates the estimate specific contribution to the overall heterogeneity versus the influence of the estimate on the overall results.[2] See http://www.metafor-project.org/ for more details. Outliers are indicated with red circles, and were excluded in the sensitivity analysis.

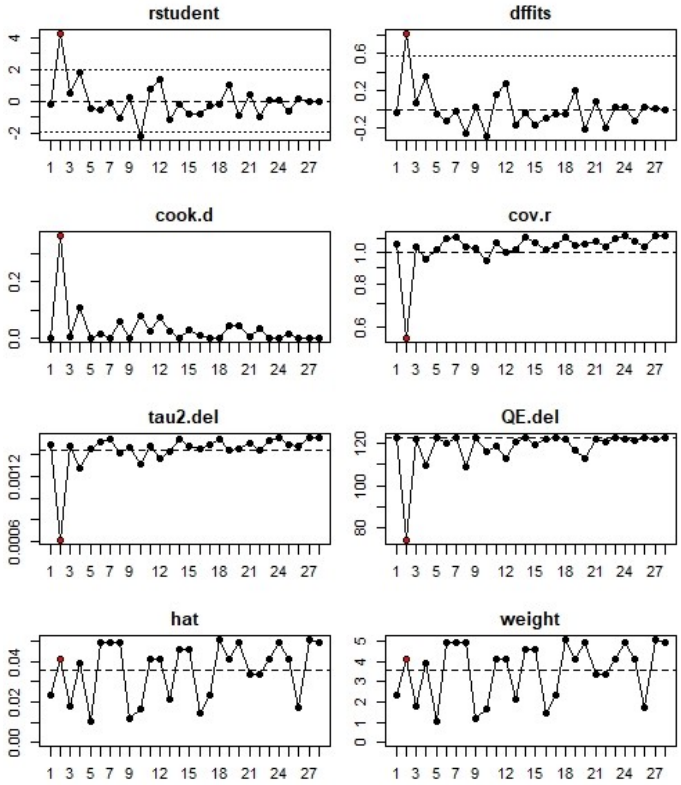
(c) Psychosis

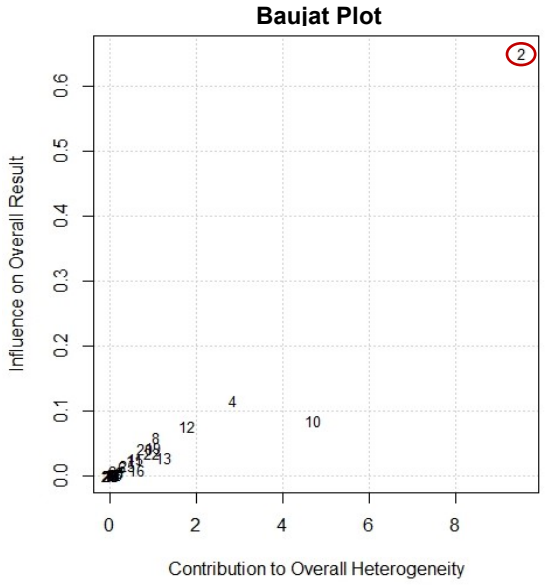



Note: *Rstudent* present the externally standardized residuals, *dffits* the dffits values, *cook.d* the Cook's distance measure, *cov.r* the covariance ratios, *tau2del* the leave-out-estimates of the amount of heterogeneity, *QE.del* the leave-out-value of the test statistics for heterogeneity, *hat* the hat-values and *weight* the study weights.[1] The *Baujat plot* indicates the estimate specific contribution to the overall heterogeneity versus the influence of the estimate on the overall results.[2] See http://www.metafor-project.org/ for more details.

(d) Psychological distress




Note: *Rstudent* present the externally standardized residuals, *dffits* the dffits values, *cook.d* the Cook's distance measure, *cov.r* the covariance ratios, *tau2del* the leave-out-estimates of the amount of heterogeneity, *QE.del* the leave-out-value of the test statistics for heterogeneity, *hat* the hat-values and *weight* the study weights.[1] The *Baujat plot* indicates the estimate specific contribution to the overall heterogeneity versus the influence of the estimate on the overall results.[2] See http://www.metafor-project.org/ for more details. Outliers are indicated with red circles, and were excluded in the sensitivity analysis.

**Supplementary Table 2.2:** Sensitivity analysis after excluding outliers

| | r | 95% CI lower | 95% CI upper | P-value | Heterogeneity Cochran's Q | Heterogeneity P-value |
|---|---|---|---|---|---|---|
| Depression (k=42) | 0.036 | 0.024 | 0.048 | <0.001 | 125.808 | <0.001 |
| Publication bias: | Kendall's tau=0.117; | | | 0.113 | | |
| Psychological distress (k=27) | 0.032 | 0.016 | 0.048 | <0.001 | 74.040 | <0.001 |
| Publication bias: | Kendall's tau=-0.036; | | | 0.800 | | |

**Supplementary Table 2.3:** Sensitivity analysis with cluster robust variance estimations

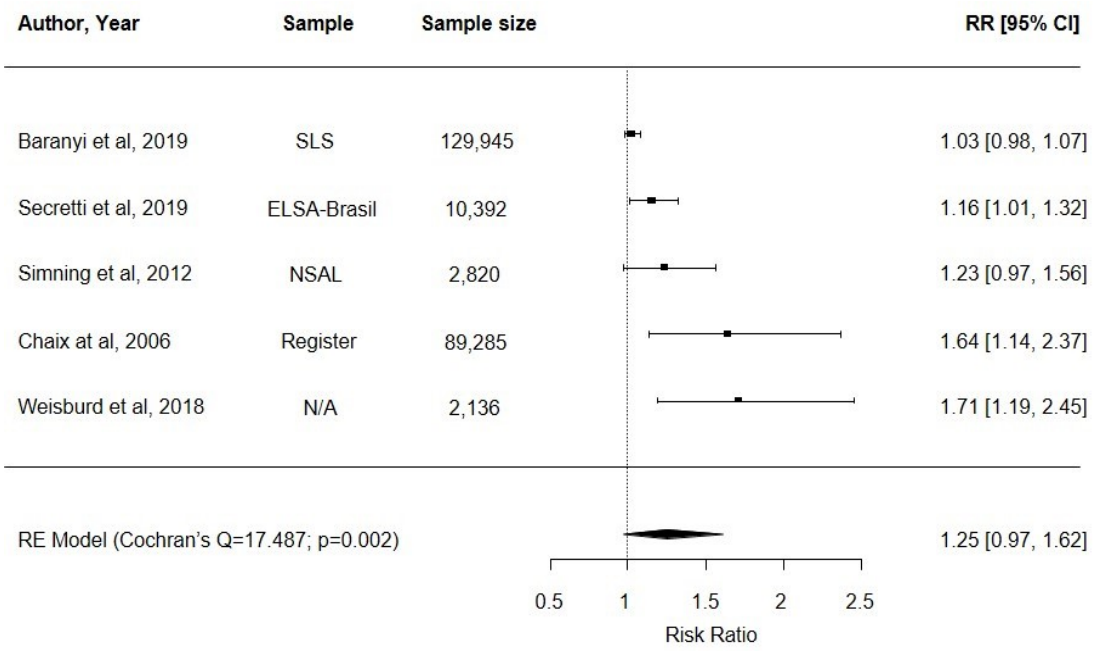
| | r | 95% CI lower | 95% CI upper | P-value |
|---|---|---|---|---|
| Anxiety (k=7) | 0.058 | 0.005 | 0.110 | 0.037 |
| Depression (k=44) | 0.044 | 0.029 | 0.060 | <0.001 |
| Psychosis (k=5) | 0.034 | -0.009 | 0.077 | 0.093 |
| Psychological distress (k=28) | 0.036 | 0.017 | 0.056 | <0.001 |

**Supplementary Table 2.4:** Sensitivity analysis with excluding studies that controlled for 5 or more neighbourhood covariates

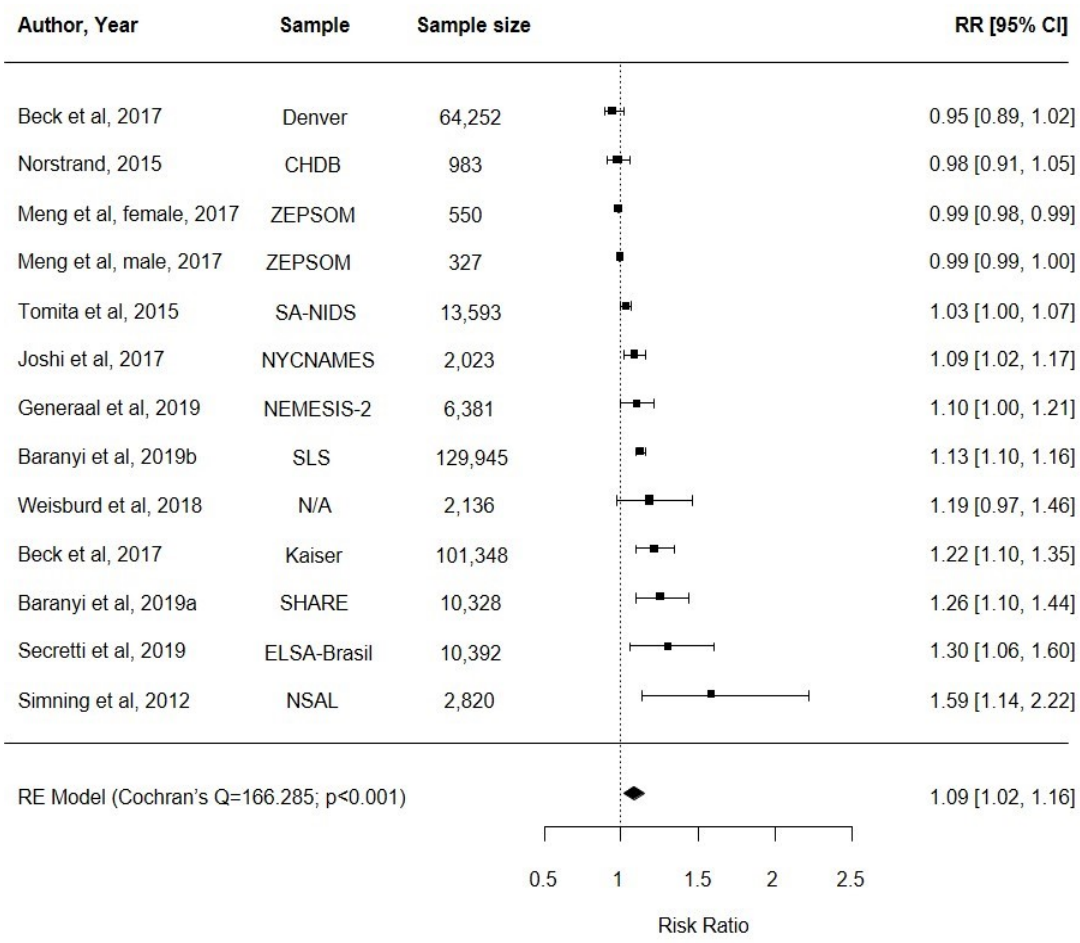
| | r | 95% CI lower | 95% CI upper | P-value | Heterogeneity Cochran's Q | Heterogeneity P-value |
|---|---|---|---|---|---|---|
| Anxiety (k=6) | 0.058 | 0.004 | 0.111 | 0.040 | 14.843 | 0.011 |
| Depression (k=32) | 0.056 | 0.036 | 0.076 | <0.001 | 168.585 | <0.001 |
| Psychosis (k=3) | 0.029 | -0.059 | 0.116 | 0.295 | 7.329 | 0.026 |
| Psychological distress (k=23) | 0.042 | 0.021 | 0.063 | <0.001 | 102.400 | <0.001 |

**Supplementary Figure 2.3:** Three-level random-effects meta-analyses pooling study estimates on neighbourhood crime and binary outcomes of (a) anxiety, (b) depression, (c) psychosis and (d) psychological distress (RR with 95% CI).

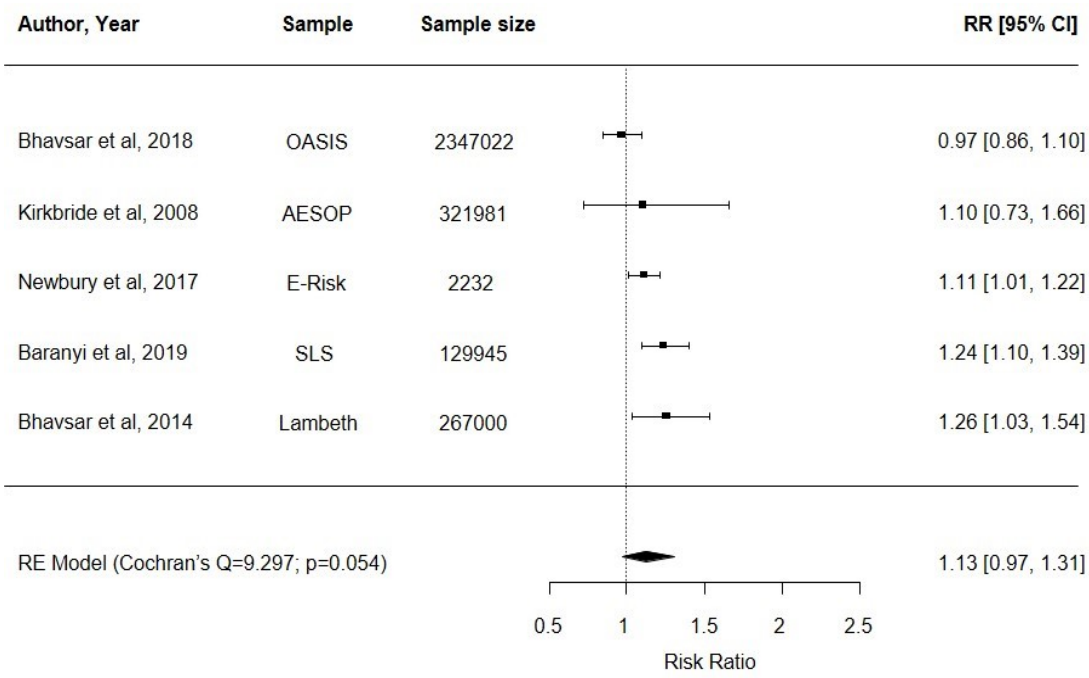
(a) Anxiety



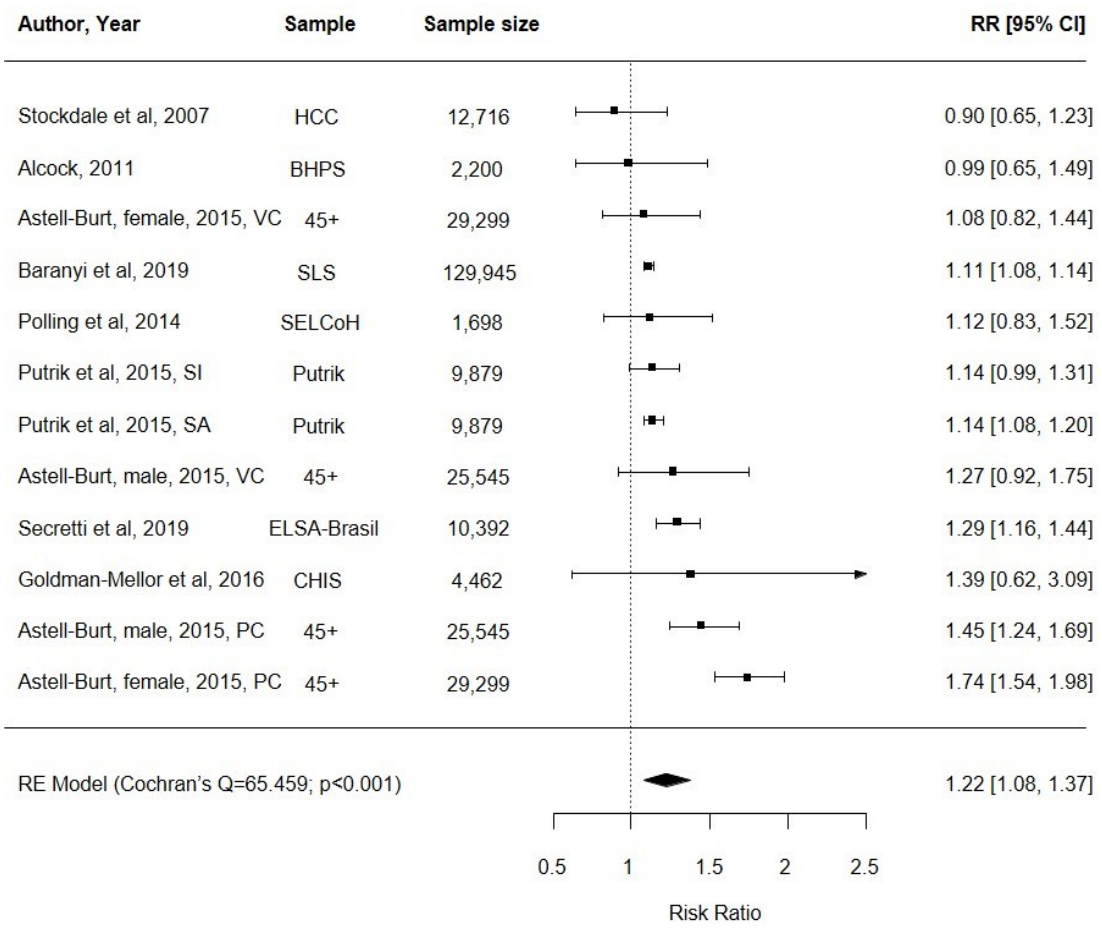
(b) Depression



(c) Psychosis


Author, Year
Sample
Sample size
RR [95% CI]
Bhavsar et al, 2018
OASIS
2347022
0.97 [0.86, 1.10]
Kirkbride et al, 2008
AESOP
321981
1.10 [0.73, 1.66]
Newbury et al, 2017
E-Risk
2232
1.11 [1.01, 1.22]
Baranyi et al, 2019
SLS
129945
1.24 [1.10, 1.39]
Bhavsar et al, 2014
Lambeth
267000
1.26 [1.03, 1.54]
RE Model (Cochran's Q=9.297; p=0.054)
1.13 [0.97, 1.31]
0.5
1
1.5
2
2.5
Risk Ratio

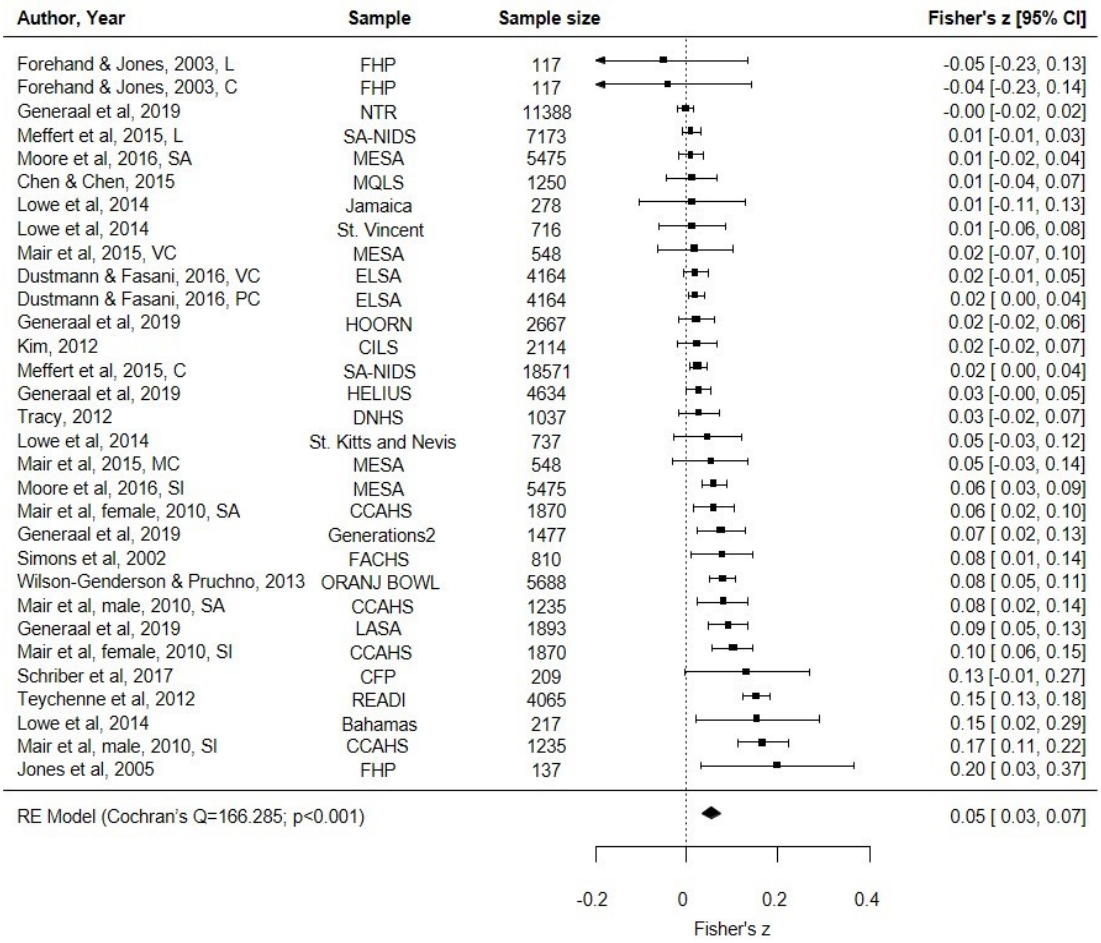
(d) Psychological distress




Abbreviations: PC, property crime; SI, self-reported (individual-level); SA, self-reported (aggregated); VC, violent crime.

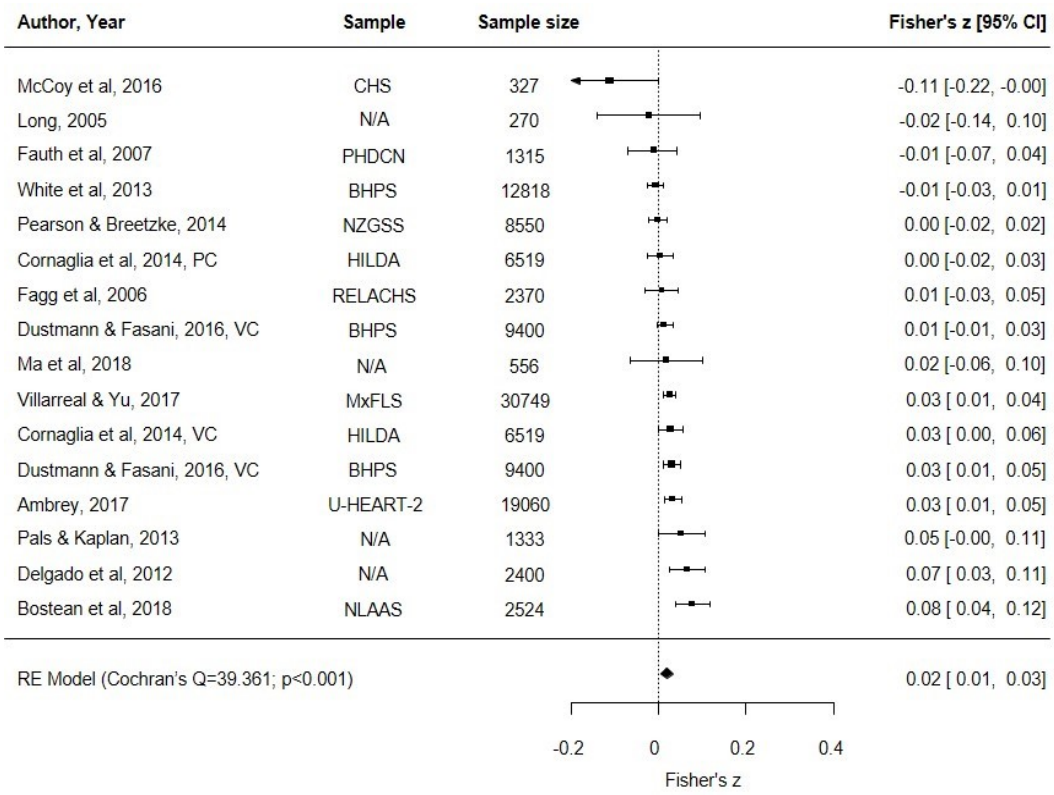
**Supplementary Figure 2.4:** Three-level random-effects meta-analyses pooling study estimates on neighbourhood crime and continuous outcomes of (a) depression and (b) psychological distress (Fisher's *z*-s with 95% CI).

(a) Depression




Abbreviations: C, cross-sectional; L, longitudinal; MC, mixed crime; PC, property crime; SI, self-reported (individual-level); SA, self-reported (aggregated); VC, violent crime.

(b) Psychological distress




Abbreviations: PC, property crime; VC, violent crime.

## REFERENCES

1 Viechtbauer W, Cheung MW. Outlier and influence diagnostics for meta-analysis. *Res Synth Methods* 2010;**1**:112-25.

2 Baujat B, Mahe C, Pignon JP, et al. A graphical method for exploring heterogeneity in meta-analyses: application to a meta-analysis of 65 trials. *Stat Med* 2002;**21**:2641-52.

## 8.2 Appendix Two: Supplementary Material for Chapter 3

**Contents**

**Supplementary Table 3.1:** Country-Level Indicators[a] Extracted From the World Bank Database

| Country | Year | GDP PPP per Capita ($) | Gini Index | Population Density (per km²) | Urban Population (%) | Forest Coverage (%) | Air Pollution, $PM_{2.5}$ ($\mu g/m^3$) |
|---|---|---|---|---|---|---|---|
| Austria | 2013 | 47,922 | 30.8 | 102.7 | 57.3 | 46.8 | 15.9 |
| Belgium | 2013 | 43,520 | 27.7 | 369.3 | 97.8 | 22.5 | 15.9 |
| Czech Republic | 2013 | 30,486 | 26.5 | 136.1 | 73.3 | 34.5 | 19.8 |
| Denmark | 2013 | 46,727 | 28.5 | 133.7 | 87.3 | 14.3 | 10.3 |
| England[b] | 2014 | 40,707 | 34.0 | 267.1 | 82.4 | 13.0 | 12.1 |
| Estonia | 2013 | 27,496 | 35.1 | 31.1 | 68.1 | 52.7 | 8.2 |
| France | 2013 | 39,524 | 32.5 | 120.5 | 79.1 | 30.6 | 12.3 |
| Germany | 2013 | 45,232 | 31.1 | 231.2 | 77.2 | 32.7 | 13.7 |
| Israel | 2013 | 34,129 | 41.4 | 372.4 | 92.0 | 7.4 | 18.7 |
| Italy | 2013 | 36,131 | 34.9 | 204.8 | 69.0 | 31.2 | 16.6 |
| Luxembourg | 2013 | 95,591 | 32.0 | 209.8 | 89.6 | 33.5 | 16.3 |
| Slovenia | 2013 | 29,797 | 26.2 | 102.3 | 53.3 | 61.9 | 17.2 |
| Spain | 2013 | 32,604 | 36.2 | 93.2 | 79.1 | 36.7 | 9.7 |
| Sweden | 2013 | 45,673 | 28.8 | 23.6 | 85.9 | 68.9 | 5.6 |
| Switzerland | 2013 | 60,109 | 32.5 | 204.7 | 73.7 | 31.5 | 12.0 |
| United States | 2013 | 50,782 | 41.0 | 34.6 | 81.3 | 33.8 | 8.5 |

Abbreviations: GDP PPP, gross domestic product in purchasing power parity; $PM_{2.5}$, particulate matter ≤2.5 μm in diameter.

[a] Date of data extraction: 31.01.2019.

[b] As England is not reported separately in the database, indicators for the United Kingdom were extracted.

**Supplementary Table 3.2:** Correlation Between Country-Level Indicators[a]

| | GDP PPP per Capita | Gini Index | Population Density | % of urban Population | % of forest Coverage | Air Pollution |
|---|---|---|---|---|---|---|
| GDP PPP per capita | 1.000 | | | | | |
| Gini index | -0.0003 | 1.000 | | | | |
| Population density | 0.114 | 0.081 | 1.000 | | | |
| % of urban population | 0.334 | 0.205 | 0.494 | 1.000 | | |
| % of forest coverage | -0.093 | -0.358 | -0.724* | -0.566* | 1.000 | |
| Air pollution | -0.007 | -0.194 | 0.591* | -0.147 | -0.311 | 1.000 |

Abbreviations: GDP PPP, Gross Domestic Product in Purchasing Power Parity (in current international $).

* $P < 0.05$.

[a] Values were standardized before inclusion in the analyses.

**Supplementary Table 3.3:** Stage 1 Results of the IPD Meta-Analysis, Covariate Adjusted Logistic Model Estimates of Depression Among Adults Aged 50 and Over Between 2012 and 2017 (Results are Presented by Country)

| Variable | | Austria (*n* = 1,448) | | Belgium (*n* = 1,875) | | Czech Republic (*n* = 1,645) | | Denmark (*n* = 1,491) | |
|---|---|---|---|---|---|---|---|---|---|
| | | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Sex | | | | | | | | | |
| | Male | Referent | | Referent | | Referent | | Referent | |
| | Female | 1.84 | 1.31, 2.59 | 1.79 | 1.36, 2.35 | 1.39 | 0.99, 1.95 | 1.67 | 1.11, 2.51 |
| Age | | | | | | | | | |
| | 50-59 | Referent | | Referent | | Referent | | Referent | |
| | 60-69 | 0.76 | 0.45, 1.29 | 0.76 | 0.51, 1.13 | 0.87 | 0.48, 1.56 | 0.58 | 0.31, 1.10 |
| | 70-79 | 1.07 | 0.62, 1.86 | 0.59 | 0.36, 0.96 | 1.17 | 0.61, 2.24 | 0.59 | 0.26, 1.38 |
| | ≥80 | 2.19 | 1.15, 4.17 | 0.91 | 0.53, 1.56 | 1.52 | 0.72, 3.22 | 1.29 | 0.51, 3.28 |
| Country of birth | | | | | | | | | |
| | Country of interview | Referent | | Referent | | Referent | | Referent | |
| | Outside country | 1.24 | 0.71, 2.17 | 1.39 | 0.91, 2.13 | 0.93 | 0.46, 1.89 | 1.39 | 0.53, 3.68 |
| Educational attainment | | | | | | | | | |
| | Primary | 1.29 | 0.75, 2.21 | 1.14 | 0.74, 1.73 | 1.30 | 0.74, 2.29 | 0.38 | 0.16, 0.89 |
| | Secondary | 1.05 | 0.72, 1.52 | 1.08 | 0.81, 1.44 | 1.08 | 0.69, 1.69 | 0.83 | 0.55, 1.26 |
| | Tertiary | Referent | | Referent | | Referent | | Referent | |
| Equalized household wealth | | | | | | | | | |
| | Low | 1.34 | 0.91, 1.97 | 1.53 | 1.11, 2.13 | 0.98 | 0.67, 1.43 | 1.79 | 1.07, 2.98 |
| | Medium | 1.15 | 0.78, 1.71 | 1.20 | 0.87, 1.65 | 1.13 | 0.79, 1.61 | 1.04 | 0.62, 1.75 |
| | High | Referent | | Referent | | Referent | | Referent | |
| Economic activity | | | | | | | | | |
| | Employed | Referent | | Referent | | Referent | | Referent | |
| | Retired | 1.31 | 0.73, 2.36 | 1.39 | 0.90, 2.15 | 0.92 | 0.49, 1.72 | 1.24 | 0.62, 2.50 |
| | Out of labor force | 1.25 | 0.63, 2.47 | 1.54 | 1.02, 2.35 | 1.49 | 0.70, 3.13 | 2.42 | 1.26, 4.65 |
| Partnership status | | | | | | | | | |
| | In a couple | Referent | | Referent | | Referent | | Referent | |
| | Alone | 1.00 | 0.72, 1.39 | 1.05 | 0.80, 1.37 | 1.31 | 0.97, 1.79 | 0.65 | 0.42, 1.00 |
| Current smoking | | | | | | | | | |
| | No | Referent | | Referent | | Referent | | ref | |
| | Yes | 1.18 | 0.79, 1.74 | 1.14 | 0.81-1.61 | 1.04 | 0.72, 1.49 | 1.74 | 1.12, 2.70 |
| Chronic diseases or conditions | | | | | | | | | |
| | <2 | Referent | | Referent | | Referent | | Referent | |
| | ≥2 | 1.65 | 1.17, 2.32 | 1.48 | 1.10, 1.99 | 1.37 | 1.01, 1.87 | 2.05 | 1.33, 3.15 |
| Functional limitations | | | | | | | | | |
| | 0 | Referent | | Referent | | Referent | | Referent | |
| | ≥1 | 1.36 | 0.86, 2.14 | 1.55 | 1.08, 2.22 | 2.38 | 1.60, 3.50 | 1.10 | 0.58, 2.07 |
| Composite neighborhood problems score | | 1.13 | 0.48, 2.68 | 2.60 | 1.44, 4.69 | 2.58 | 1.39, 4.78 | 3.63 | 1.36, 9.73 |
| | | **England (*n* = 4,634)** | | **Estonia (*n* = 1,713)** | | **France (*n* = 1,250)** | | **Germany (*n* = 1,819)** | |
| | | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Sex | | | | | | | | | |
| | Male | Referent | | Referent | | Referent | | Referent | |
| | Female | 1.56 | 1.27, 1.91 | 1.68 | 1.28, 2.20 | 1.80 | 1.33, 2.43 | 1.67 | 1.24, 2.25 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Age | | | | | | | | |
| 50-59 | Referent | | Referent | | Referent | | Referent | |
| 60-69 | 0.72 | 0.52, 0.98 | 0.95 | 0.65, 1.38 | 0.95 | 0.56, 1.60 | 0.92 | 0.58, 1.45 |
| 70-79 | 0.77 | 0.53, 1.11 | 0.71 | 0.45, 1.13 | 0.91 | 0.49, 1.66 | 1.12 | 0.62, 2.01 |
| ≥80 | 0.93 | 0.61, 1.44 | 1.43 | 0.83, 2.45 | 1.34 | 0.69, 2.59 | 1.83 | 0.92, 3.65 |
| Country of birth | | | | | | | | |
| Country of interview | Referent | | Referent | | Referent | | Referent | |
| Outside country | 1.13 | 0.75, 1.69 | 1.21 | 0.91, 1.60 | 0.75 | 0.43, 1.32 | 0.89 | 0.57, 1.38 |
| Educational attainment | | | | | | | | |
| Primary | 1.34 | 1.01, 1.79 | 1.64 | 0.84, 3.19 | 1.18 | 0.78, 1.79 | 4.32 | 1.10, 16.9 |
| Secondary | 1.17 | 0.92, 1.49 | 1.12 | 0.84, 1.49 | 0.90 | 0.62, 1.30 | 1.03 | 0.75, 1.41 |
| Tertiary | Referent | | Referent | | Referent | | Referent | |
| Equalized household wealth | | | | | | | | |
| Low | 1.52 | 1.16, 1.98 | 1.17 | 0.87, 1.57 | 1.05 | 0.72, 1.52 | 1.32 | 0.91, 1.90 |
| Medium | 1.33 | 1.05, 1.70 | 0.98 | 0.73, 1.31 | 1.09 | 0.76, 1.55 | 1.07 | 0.75, 1.53 |
| High | Referent | | Referent | | Referent | | Referent | |
| Economic activity | | | | | | | | |
| Employed | Referent | | Referent | | Referent | | Referent | |
| Retired | 1.52 | 1.13, 2.06 | 1.26 | 0.87, 1.82 | 1.09 | 0.64, 1.88 | 0.92 | 0.55, 1.53 |
| Out of labor force | 1.72 | 1.18, 2.53 | 1.35 | 0.84, 2.19 | 1.74 | 0.98, 3.10 | 1.18 | 0.73, 1.89 |
| Partnership status | | | | | | | | |
| In a couple | Referent | | Referent | | Referent | | Referent | |
| Alone | 1.09 | 0.87, 1.37 | 0.90 | 0.70, 1.15 | 0.89 | 0.66, 1.20 | 0.71 | 0.51, 0.99 |
| Current smoking | | | | | | | | |
| No | Referent | | Referent | | Referent | | Referent | |
| Yes | 1.15 | 0.82, 1.60 | 1.11 | 0.80, 1.56 | 1.39 | 0.94, 2.05 | 0.70 | 0.46, 1.07 |
| Chronic diseases or conditions | | | | | | | | |
| <2 | Referent | | Referent | | Referent | | Referent | |
| ≥2 | 1.33 | 1.07, 1.67 | 1.28 | 0.98, 1.66 | 1.67 | 1.20, 2.32 | 1.26 | 0.92, 1.74 |
| Functional limitations | | | | | | | | |
| 0 | Referent | | Referent | | Referent | | Referent | |
| ≥1 | 2.01 | 1.60, 2.52 | 1.38 | 1.00, 1.91 | 1.63 | 1.02, 2.61 | 2.38 | 1.55, 3.65 |
| Composite neighborhood problems score | 1.85 | 1.18, 2.90 | 1.88 | 1.09, 3.25 | 1.86 | 0.92, 3.77 | 1.59 | 0.69, 3.67 |

| | **Israel (*n* = 561)** | | **Italy (*n* = 1,157)** | | **Luxembourg (*n* = 456)** | | **Slovenia (*n* = 1,144)** | |
|---|---|---|---|---|---|---|---|---|
| | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Sex | | | | | | | | |
| Male | Referent | | Referent | | Referent | | Referent | |
| Female | 1.39 | 0.80, 2.41 | 1.95 | 1.39, 2.73 | 2.81 | 1.54, 5.12 | 1.49 | 1.05, 2.10 |
| Age | | | | | | | | |
| 50-59 | Referent | | Referent | | Referent | | Referent | |
| 60-69 | 0.65 | 0.30, 1.41 | 1.27 | 0.75, 2.13 | 0.57 | 0.25, 1.29 | 1.81 | 1.07, 3.08 |
| 70-79 | 0.54 | 0.22, 1.33 | 1.22 | 0.67, 2.21 | 1.94 | 0.80, 4.70 | 1.78 | 0.98, 3.21 |
| ≥80 | 1.39 | 0.48, 4.06 | 2.10 | 1.01, 4.38 | 0.70 | 0.22, 2.23 | 2.48 | 1.27, 4.86 |
| Country of birth | | | | | | | | |
| Country of interview | Referent | | Referent | | Referent | | Referent | |
| Outside country | 0.84 | 0.49, 1.43 | 0.61 | 0.13, 2.88 | 1.12 | 0.63, 2.01 | 0.75 | 0.42, 1.32 |
| Educational attainment | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Primary | 1.87 | 0.94, 3.74 | 1.35 | 0.72, 2.52 | 1.72 | 0.74, 4.00 | 1.83 | 0.91, 3.69 |
| Secondary | 0.81 | 0.45, 1.46 | 1.28 | 0.70, 2.34 | 1.25 | 0.58, 2.70 | 1.54 | 0.95, 2.51 |
| Tertiary | Referent | | Referent | | Referent | | Referent | |
| Equalized household wealth | | | | | | | | |
| Low | 0.88 | 0.48, 1.63 | 1.45 | 0.98, 2.12 | 1.70 | 0.83, 3.48 | 1.38 | 0.90, 2.11 |
| Medium | 0.76 | 0.41, 1.41 | 1.22 | 0.84, 1.76 | 1.02 | 0.54, 1.94 | 1.39 | 0.91, 2.10 |
| High | Referent | | | | | | | |
| Economic activity | | | | | | | | |
| Employed | Referent | | Referent | | Referent | | Referent | |
| Retired | 3.07 | 1.42, 6.66 | 1.42 | 0.80, 2.54 | 1.04 | 0.43, 2.54 | 0.89 | 0.47, 1.70 |
| Out of labor force | 3.14 | 1.35, 7.32 | 1.21 | 0.69, 2.10 | 0.76 | 0.32, 1.80 | 1.46 | 0.73, 2.91 |
| Partnership status | | | | | | | | |
| In a couple | Referent | | Referent | | Referent | | Referent | |
| Alone | 1.76 | 1.03, 3.03 | 1.37 | 0.97, 1.93 | 0.89 | 0.48, 1.63 | 1.11 | 0.76, 1.61 |
| Current smoking | | | | | | | | |
| No | Referent | | Referent | | Referent | | Referent | |
| Yes | 1.24 | 0.59, 2.64 | 1.15 | 0.75, 1.77 | 1.29 | 0.63, 2.65 | 1.21 | 0.76, 1.94 |
| Chronic diseases or conditions | | | | | | | | |
| <2 | Referent | | Referent | | Referent | | Referent | |
| ≥2 | 3.50 | 2.03, 6.00 | 1.01 | 0.69, 1.48 | 1.47 | 0.82, 2.63 | 1.51 | 1.04, 2.18 |
| Functional limitations | | | | | | | | |
| 0 | Referent | | Referent | | Referent | | Referent | |
| ≥1 | 0.79 | 0.40, 1.56 | 1.60 | 0.85, 3.00 | 1.24 | 0.52, 2.99 | 1.50 | 0.91, 2.47 |
| Composite neighborhood problems score | 1.23 | 0.43, 3.49 | 1.36 | 0.68, 2.71 | 1.69 | 0.37, 7.68 | 6.26 | 2.24, 17.51 |

| | **Spain (*n* = 1,742)** | | **Sweden (*n* = 1,640)** | | **Switzerland (*n* = 1,310)** | | **United States (*n* = 8,646)** | |
|---|---|---|---|---|---|---|---|---|
| | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** | **OR** | **95% CI** |
| Sex | | | | | | | | |
| Male | Referent | | Referent | | Referent | | Referent | |
| Female | 1.72 | 1.27, 2.32 | 1.40 | 0.99, 1.98 | 2.69 | 1.80, 4.01 | 1.44 | 1.24, 1.68 |
| Age | | | | | | | | |
| 50-59 | Referent | | Referent | | Referent | | Referent | |
| 60-69 | 1.02 | 0.67, 1.53 | 0.72 | 0.41, 1.28 | 0.53 | 0.29, 0.96 | 0.87 | 0.71, 1.07 |
| 70-79 | 1.29 | 0.81, 2.06 | 0.89 | 0.43, 1.83 | 0.54 | 0.26, 1.11 | 0.87 | 0.68, 1.10 |
| ≥80 | 2.22 | 1.31, 3.76 | 1.63 | 0.74, 3.57 | 0.81 | 0.37, 1.81 | 1.05 | 0.79, 1.40 |
| Country of birth | | | | | | | | |
| Country of interview | Referent | | Referent | | Referent | | Referent | |
| Outside country | 0.25 | 0.08, 0.83 | 1.37 | 0.77, 2.41 | 1.98 | 1.28, 3.04 | 1.13 | 0.90, 1.42 |
| Educational attainment | | | | | | | | |
| Primary | 1.93 | 1.16, 3.20 | 0.78 | 0.45, 1.32 | 1.09 | 0.49, 2.39 | 1.17 | 0.91, 1.52 |
| Secondary | 1.22 | 0.72, 2.08 | 1.12 | 0.76, 1.66 | 1.06 | 0.63, 1.78 | 1.10 | 0.91, 1.32 |
| Tertiary | Referent | | Referent | | Referent | | Referent | |
| Equalized household wealth | | | | | | | | |
| Low | 1.41 | 1.01, 1.95 | 1.28 | 0.83, 1.99 | 1.29 | 0.80, 2.07 | 1.42 | 1.15, 1.74 |
| Medium | 1.21 | 0.88, 1.67 | 1.09 | 0.71, 1.67 | 1.28 | 0.82, 2.01 | 1.19 | 1.00, 1.42 |
| High | Referent | | Referent | | Referent | | Referent | |
| Economic activity | | | | | | | | |
| Employed | Referent | | Referent | | Referent | | Referent | |
| Retired | 1.73 | 1.06, 2.81 | 1.00 | 0.58, 1.72 | 1.83 | 0.99, 3.40 | 1.26 | 1.02, 1.54 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Out of labor force | 1.87 | 1.19, 2.93 | 0.68 | 0.23, 2.06 | 1.08 | 0.56, 2.09 | 1.77 | 1.43, 2.19 |
| Partnership status | | | | | | | | |
| In a couple | Referent | | Referent | | Referent | | Referent | |
| Alone | 1.15 | 0.86, 1.55 | 1.23 | 0.86, 1.76 | 0.91 | 0.61, 1.34 | 1.10 | 0.94, 1.29 |
| Current smoking | | | | | | | | |
| No | Referent | | Referent | | Referent | | Referent | |
| Yes | 0.97 | 0.62, 1.52 | 0.80 | 0.45, 1.42 | 0.90 | 0.57, 1.41 | 1.42 | 1.15, 1.75 |
| Chronic diseases or conditions | | | | | | | | |
| <2 | Referent | | Referent | | Referent | | Referent | |
| ≥2 | 1.34 | 1.00, 1.80 | 1.47 | 1.02, 2.13 | 1.35 | 0.84, 2.17 | 1.45 | 1.23, 1.71 |
| Functional limitations | | | | | | | | |
| 0 | Referent | | Referent | | Referent | | Referent | |
| ≥1 | 1.41 | 0.96, 2.08 | 1.72 | 1.02, 2.90 | 2.48 | 1.34, 4.59 | 2.13 | 1.76, 2.59 |
| Composite neighborhood problems score | 0.87 | 0.38, 1.96 | 0.44 | 0.09, 2.23 | 1.42 | 0.50, 4.10 | 1.57 | 1.21, 2.02 |

Abbreviations: CI, confidence interval; OR, odds ratio.

**Supplementary Table 3.4:** Meta-Regression Analysis on the Effect Estimates of Perceived Neighborhood Problems on Depression in 16 High-Income Countries Between 2012 and 2017

| Country-Level Indicator[a] | Neighborhood Problems | | |
|---|---|---|---|
| | β | SE | *P* |
| *Aged 50 Years or Older* | | | |
| Sample size | -0.043 | 0.055 | 0.45 |
| % of female participants | 0.044 | 0.106 | 0.69 |
| GDP PPP per capita | -0.130 | 0.141 | 0.37 |
| Gini index | -0.160 | 0.071 | 0.04 |
| Population density | 0.079 | 0.089 | 0.39 |
| % of urban population | -0.014 | 0.126 | 0.91 |
| % of forest coverage | -0.034 | 0.131 | 0.80 |
| Air pollution ($PM_{2.5}$) | 0.142 | 0.095 | 0.16 |
| Welfare regime | [b] | | |
| *In Retirement* | | | |
| Sample size | -0.059 | 0.069 | 0.41 |
| % of female participants | -0.042 | 0.126 | 0.74 |
| GDP PPP per capita | -0.006 | 0.159 | 0.97 |
| Gini index | -0.137 | 0.092 | 0.16 |
| Population density | 0.202 | 0.103 | 0.07 |
| % of urban population | 0.207 | 0.134 | 0.15 |
| % of forest coverage | -0.248 | 0.138 | 0.095 |
| Air pollution ($PM_{2.5}$) | 0.170 | 0.110 | 0.14 |
| Welfare regime | [c] | | |

Abbreviations: GDP PPP, Gross Domestic Product in Purchasing Power Parity (in current international $); $PM_{2.5}$, particulate matter ≤2.5 μm in diameter; SE, standard error.

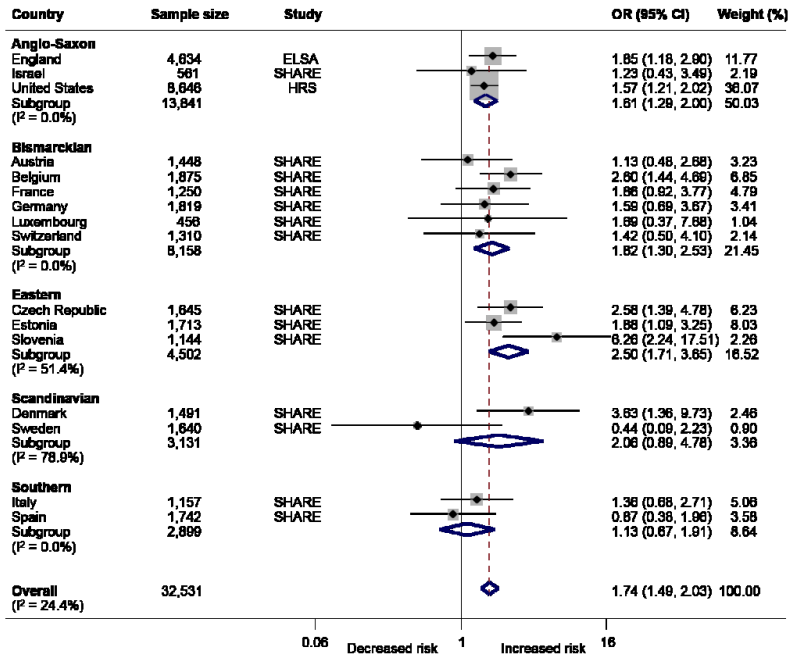
[a] Raw data was standardized before meta-regression, with the exception of welfare regime.

[b] $F(4,11) = 1.42$; $P = 0.29$.

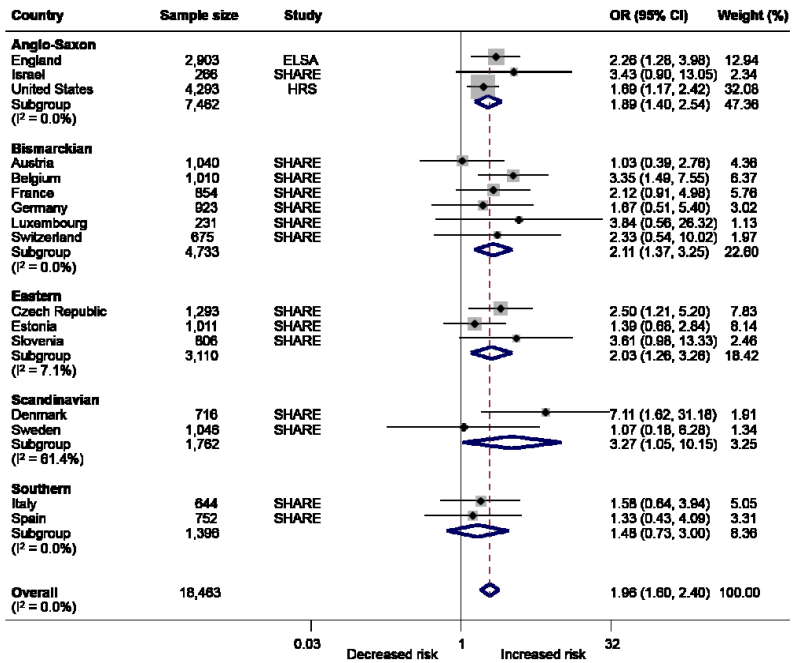
[c] $F(4,11) = 0.40$; $P = 0.81$.

**Supplementary Figure 3.1:** Country-specific and pooled associations of perceived neighborhood problems (composite score) with depression A) among adults aged 50 and over and B) among individuals in retirement in 16 high-income countries between 2012 and 2017. Models are adjusted for age, sex, country of birth, education, wealth, economic activity, partnership status, current smoking, chronic diseases or conditions, and functional limitations; countries are grouped by welfare regime. CI, confidence interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; OR, odds ratio; SHARE, Survey of Health, Ageing and Retirement in Europe.

**A)**

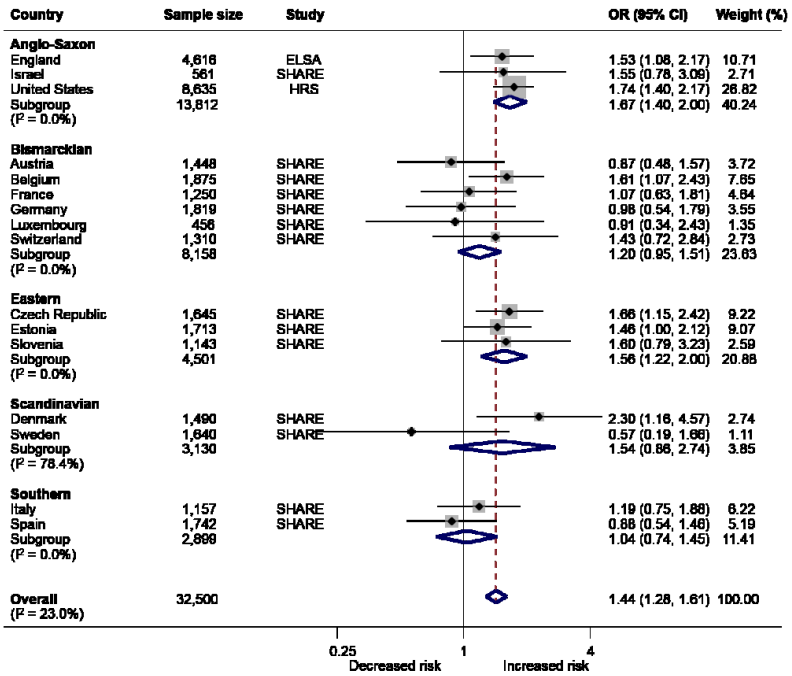



**B)**

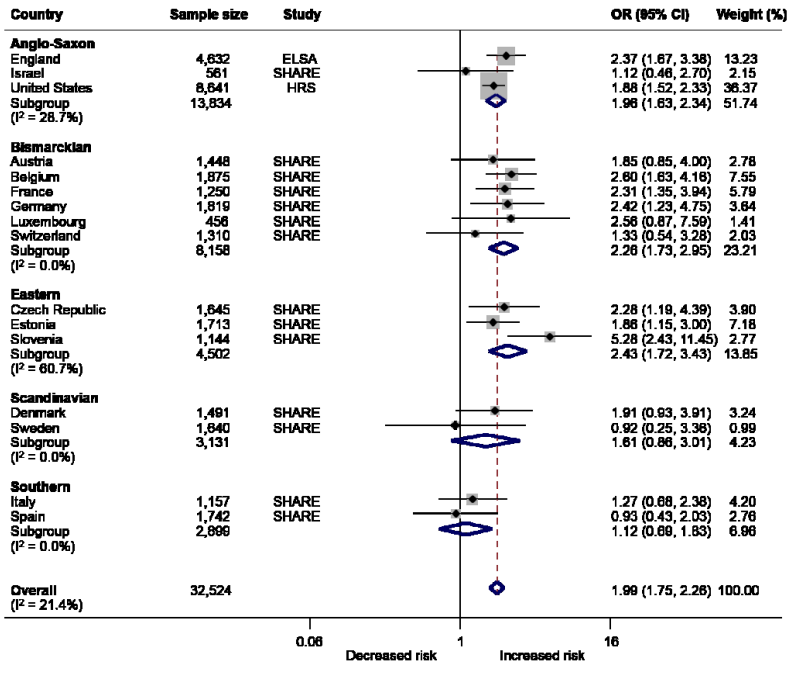


**Supplementary Figure 3.2:** Country-specific and pooled associations of A) perceived neighborhood disorder and B) perceived lack of social cohesion with depression among adults aged 50 and over in 16 high-income countries between 2012 and 2017. Models are adjusted for sex and age; countries are grouped by welfare regime. CI, confidence interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; OR, odds ratio; SHARE, Survey of Health, Ageing and Retirement in Europe.

**A)**

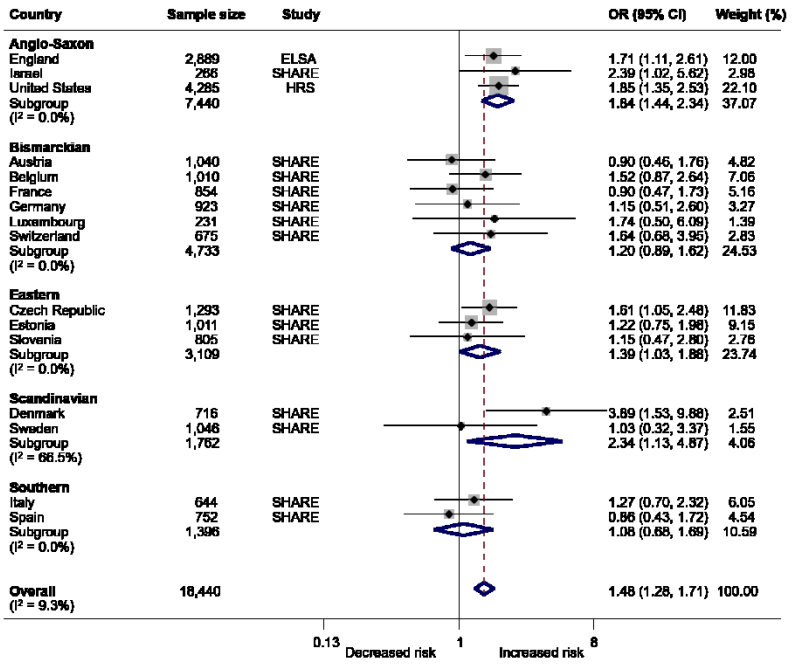



**B)**

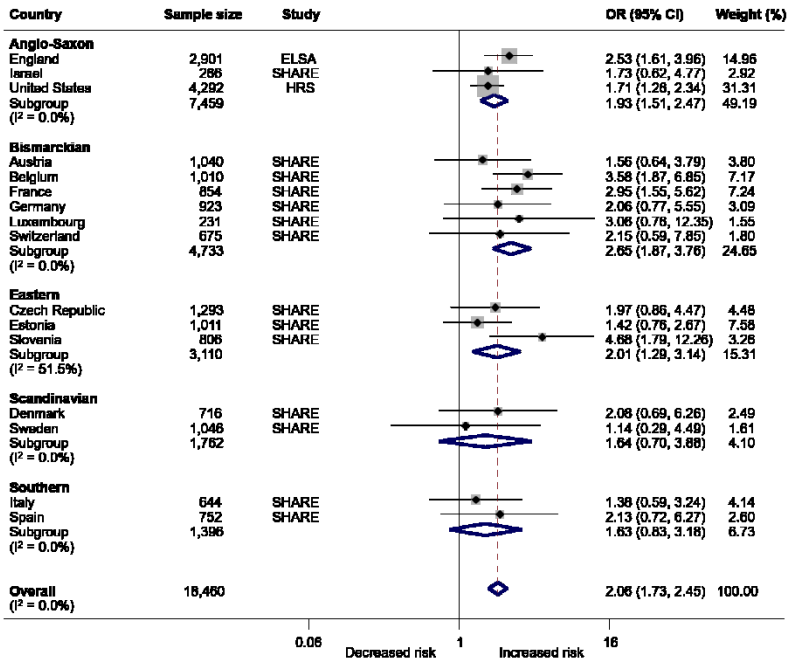


**Supplementary Figure 3.3:** Country-specific and pooled associations of A) perceived neighborhood disorder and B) perceived lack of social cohesion with depression among individuals in retirement in 16 high-income countries between 2012 and 2017. Models are adjusted for sex and age; countries are grouped by welfare regime. CI, confidence interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; OR, odds ratio; SHARE, Survey of Health, Ageing and Retirement in Europe.

**A)**

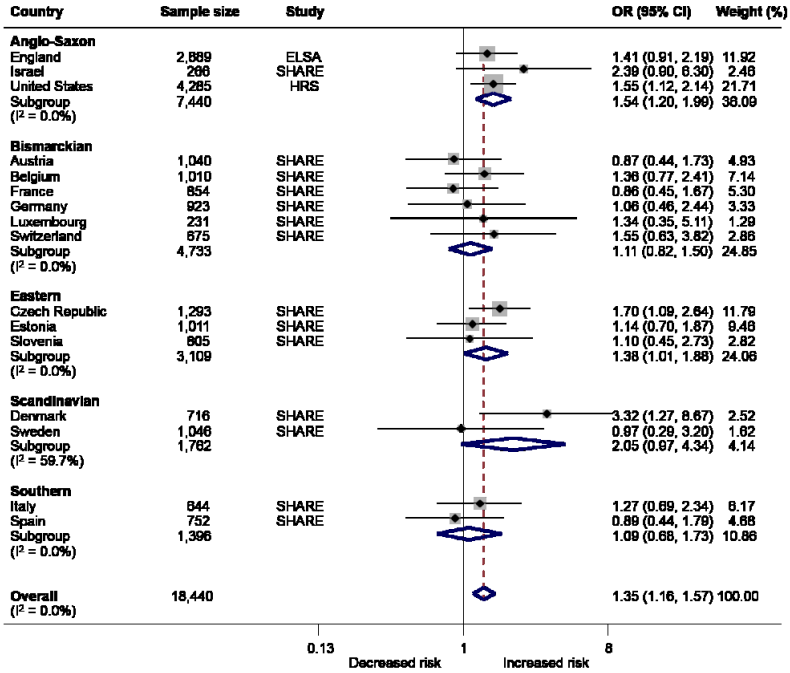



**B)**

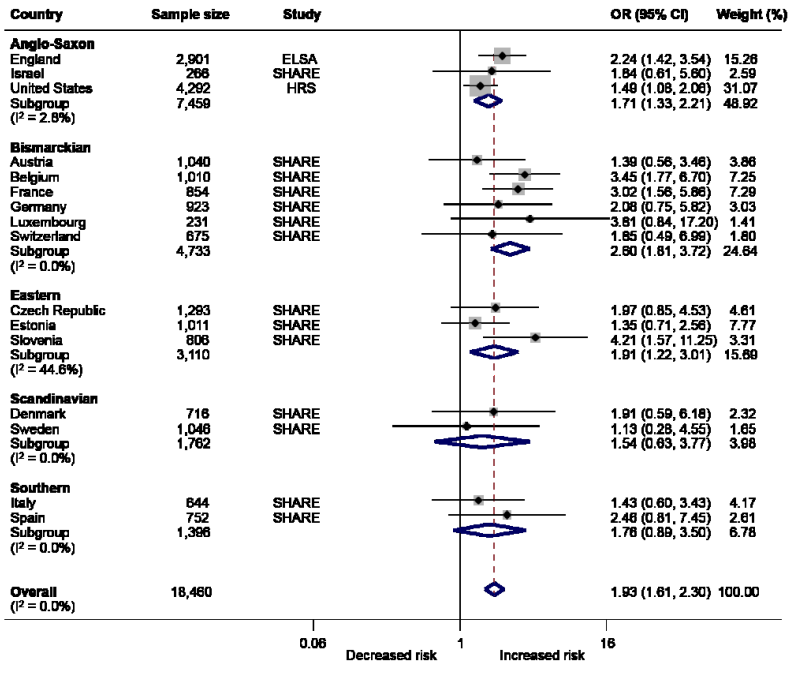


**Supplementary Figure 3.4:** Country-specific and pooled associations of A) perceived neighborhood disorder and B) perceived lack of social cohesion with depression among individuals in retirement in 16 high-income countries between 2012 and 2017. Models are adjusted for age, sex, country of birth, education, wealth, economic activity, partnership status, current smoking, chronic diseases or conditions, and functional limitations; countries are grouped by welfare regime. CI, confidence interval; ELSA, English Longitudinal Study of Ageing; HRS, Health and Retirement Study; OR, odds ratio; SHARE, Survey of Health, Ageing and Retirement in Europe.

**A)**




**B)**



**Supplementary Table 3.5:** Sensitivity Analysis Providing Pooled Estimates of Neighborhood Effects on Depression With Different Statistical Approaches

| Exposure | One-Stage IPD Meta-Analysis | | Two-Stage IPD Meta-Analysis | |
|---|---|---|---|---|
| | Fixed Effects | Random Effects | Fixed Effects | Random Effects |
| | OR (95% CI) | OR (95% CI) | OR (95% CI) | OR (95% CI) |
| *Aged 50 Years or Older* | | | | |
| Neighborhood disorder | 1.25 (1.11, 1.40) | 1.25 (1.12, 1.40) | 1.25 (1.11, 1.41) | 1.25 (1.11, 1.41) |
| Lack of social cohesion | 1.73 (1.51, 1.97) | 1.72 (1.51, 1.97) | 1.76 (1.54, 2.01) | 1.81 (1.53, 2.15) |
| Composite neighborhood problems score | 1.72 (1.48, 2.00) | 1.72 (1.48, 2.00) | 1.74 (1.49, 2.03) | 1.77 (1.45, 2.16) |
| *In Retirement* | | | | |
| Neighborhood disorder | 1.34 (1.16, 1.56) | 1.35 (1.16, 1.56) | 1.35 (1.16, 1.57) | 1.35 (1.16, 1.57) |
| Lack of social cohesion | 1.88 (1.58, 2.24) | 1.88 (1.58, 2.24) | 1.93 (1.61, 2.30) | 1.93 (1.61, 2.30) |
| Composite neighborhood problems score | 1.93 (1.58, 2.35) | 1.93 (1.58, 2.36) | 1.96 (1.60, 2.40) | 1.96 (1.60, 2.40) |

Abbreviations: CI, confidence interval; IPD, individual participant data; OR, odds ratio.

**Supplementary Table 3.6:** Sample description in the original and analytical samples

| Characteristics[c] | ELSA | | HRS waves 11 & 12 | | HRS waves 12 & 13 | | SHARE[b] | |
|---|---|---|---|---|---|---|---|---|
| | **Original** (n=8,087) | **Analytical** (n=4,634) | **Original**[a] (n=18,075) | **Analytical** (n=4,432) | **Original**[a] (n=15,751) | **Analytical** (n=4,214) | **Original** (n=47,523) | **Analytical** (n=19,251) |
| Gender | | | | | | | | |
| Male | 44.4 | 46.3 | 40.8 | 42.0 | 40.6 | 42.0 | 43.3 | 45.5 |
| Female | 55.6 | 53.7 | 59.2 | 58.0 | 59.4 | 58.0 | 56.7 | 54.5 |
| Missing* | 0.0 | NA | 0.0 | NA | 0.0 | NA | 0.0 | NA |
| Age | | | | | | | | |
| 50-59 | 23.1 | 18.2 | 32.4 | 25.7 | 34.3 | 26.7 | 29.0 | 28.4 |
| 60-69 | 39.6 | 43.3 | 27.1 | 28.3 | 28.4 | 32.1 | 35.2 | 37.1 |
| 70-79 | 26.5 | 29.1 | 26.2 | 31.5 | 25.9 | 30.6 | 24.8 | 24.8 |
| 80< | 10.8 | 9.3 | 14.3 | 14.5 | 11.4 | 10.5 | 11.0 | 9.7 |
| Missing* | 0.0 | NA | 0.0 | NA | 0.0 | NA | 0.0 | NA |
| Country of birth | | | | | | | | |
| Born in the country | 88.0 | 94.1 | 85.3 | 88.7 | 84.7 | 88.4 | 87.5 | 89.5 |
| Born outside | 7.0 | 5.9 | 14.7 | 11.3 | 15.2 | 11.6 | 11.4 | 10.5 |
| Missing* | 5.0 | NA | 0.0 | NA | 0.1 | NA | 1.1 | NA |
| Educational attainment | | | | | | | | |
| Primary | 21.7 | 19.2 | 18.5 | 13.0 | 17.9 | 12.6 | 20.7 | 17.3 |
| Secondary | 44.5 | 46.2 | 58.7 | 60.9 | 58.7 | 59.3 | 54.8 | 55.9 |
| Tertiary | 30.8 | 34.6 | 22.8 | 26.1 | 23.4 | 28.1 | 23.0 | 26.8 |
| Missing* | 3.1 | NA | 0.0 | NA | 0.0 | NA | 1.5 | NA |
| Equalized household wealth | | | | | | | | |
| Low | 32.7 | 26.1 | 33.0 | 22.7 | 33.3 | 22.2 | 33.4 | 30.8 |
| Medium | 32.7 | 35.7 | 33.3 | 35.5 | 33.3 | 36.9 | 33.3 | 33.4 |
| High | 32.7 | 38.2 | 33.7 | 41.8 | 33.3 | 41.0 | 33.3 | 35.8 |
| Missing* | 1.9 | NA | 0.0 | NA | 0.0 | NA | 0.0 | NA |
| Economic activity | | | | | | | | |
| Employed | 32.9 | 30.4 | 35.9 | 36.2 | 34.2 | 34.7 | 27.7 | 29.6 |
| Retired | 58.4 | 62.6 | 41.3 | 48.4 | 43.7 | 51.0 | 56.4 | 58.7 |
| Out of labor force | 9.7 | 7.0 | 22.6 | 15.4 | 21.9 | 14.4 | 15.0 | 11.7 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Missing* | 0.0 | NA | 0.2 | NA | 0.2 | NA | 0.9 | NA |
| Partnership status | | | | | | | | |
| In a couple | 73.2 | 77.1 | 63.7 | 68.9 | 62.7 | 68.2 | 69.5 | 63.9 |
| Alone | 26.8 | 22.9 | 36.3 | 31.1 | 37.3 | 31.8 | 29.4 | 36.1 |
| Missing* | 0.0 | NA | 0.0 | NA | 0.0 | NA | 1.1 | NA |
| Current smoking | | | | | | | | |
| No | 89.3 | 91.6 | 85.1 | 88.9 | 86.6 | 90.2 | 82.4 | 82.8 |
| Yes | 10.7 | 8.4 | 14.3 | 11.1 | 12.8 | 9.8 | 17.5 | 17.2 |
| Missing* | 0.0 | NA | 0.6 | NA | 0.5 | NA | 0.1 | NA |
| Chronic diseases or conditions | | | | | | | | |
| Less than two | 71.4 | 76.9 | 40.6 | 41.9 | 38.6 | 41.1 | 71.7 | 76.3 |
| Two or more | 22.1 | 23.1 | 58.9 | 58.1 | 60.9 | 58.9 | 28.1 | 23.7 |
| Missing* | 6.5 | NA | 0.5 | NA | 0.5 | NA | 0.2 | NA |
| Functional limitations | | | | | | | | |
| No | 77.2 | 83.4 | 82.6 | 90.6 | 81.5 | 90.5 | 84.1 | 90.7 |
| At least one | 22.8 | 16.6 | 17.3 | 9.4 | 18.4 | 9.5 | 15.8 | 9.3 |
| Missing* | 0.0 | NA | 0.1 | NA | 0.1 | NA | 0.1 | NA |
| Neighbourhood variables* | | | | | | | | |
| One or more | 86.7 | 100.0 | 36.6 | 100.0 | 41.3 | 100.0 | 64.5 | 100.0 |
| Missing | 13.3 | NA | 63.4 | NA | 58.7 | NA | 35.5 | NA |
| Depression at baseline* | | | | | | | | |
| Yes | 17.5 | 0.0 | 21.3 | 0.0 | 20.8 | 0.0 | 25.0 | 0.0 |
| No | 78.2 | 100.0 | 74.7 | 100.0 | 75.7 | 100.0 | 72.4 | 100.0 |
| Missing | 4.4 | NA | 4.1 | NA | 3.5 | NA | 2.6 | NA |
| Depression at follow up | | | | | | | | |
| Yes | 18.2 | 10.4 | 21.2 | 11.0 | 19.7 | 9.7 | 24.4 | 15.2 |
| No | 76.2 | 89.6 | 73.6 | 89.0 | 74.1 | 90.3 | 70.9 | 84.8 |
| Missing | 5.7 | NA | 5.2 | NA | 6.2 | NA | 4.7 | NA |

Note: Numbers may not sum up to 100 because of rounding errors.

[a] Only half of the sample participated in the in-person assessment.

[b] Subsample dropped with 53.4% in Austria, 56.8% in Belgium, 62.7% in the Czech Republic, 55.5% in Denmark, 62.6% in Estonia, 60.6% in France, 57.9% in Germany, 68.7% in Israel, 68.4% in Italy, 58.6% in Luxemburg, 53.4% in Slovenia, 66.2% in Spain, 53.6% in Sweden, and 49.5% in Switzerland.

* Inclusion criteria

**Supplementary Table 3.7:** Variance inflation factors exploring multicollinearity between independent variables

| Variables | | VIF | 1/VIF |
|---|---|---|---|
| Sex | | | |
| | Male | Ref | |
| | Female | 1.07 | 0.935088 |
| Age | | | |
| | 50-59 | Ref | |
| | 60-69 | 2.05 | 0.488920 |
| | 70-79 | 2.52 | 0.396980 |
| | ≥80 | 1.89 | 0.529649 |
| Country of birth | | | |
| | Country of interview | Ref | |
| | Outside country | 1.01 | 0.986437 |
| Educational attainment | | | |
| | Primary | 1.41 | 0.710411 |
| | Secondary | 1.51 | 0.663424 |
| | Tertiary | Ref | |
| Equalized household wealth | | | |
| | Low | 1.42 | 0.703635 |
| | Medium | 1.30 | 0.770150 |
| | High | Ref | |
| Economic activity | | | |
| | Employed | Ref | |
| | Retired | 2.09 | 0.479128 |
| | Out of labor force | 1.36 | 0.736370 |
| Partnership status | | | |
| | In a couple | Ref | |
| | Alone | 1.11 | 0.897326 |
| Current smoking | | | |
| | No | Ref | |
| | Yes | 1.06 | 0.944611 |
| Chronic diseases or conditions | | | |
| | Less than two | Ref | |
| | Two or more | 1.10 | 0.908847 |
| Functional limitations | | | |
| | No | Ref | |
| | At least one | 1.08 | 0.929834 |
| Composite neighborhood problems score | | 1.03 | 0.974291 |
| **Mean** | | 1.44 | |

Abbreviations: VIF, variance inflation factor

## 8.3 Appendix Three: Supplementary Material for Chapter 4

**Contents**

**Supplementary Table 4.1**: Interaction effects of adverse childhood experiences and neighbourhood conditions on depression among 10328 older European adults (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | 0.79 (0.69-0.91) | 0.83 (0.71-0.98) | | 0.80 (0.68-0.94) |
| Neighbourhood nuisances (ref: No) | 1.35 (1.17-1.55) | | 1.35 (1.15-1.59) | 1.38 (1.17-1.62) |
| ACEs (ref: No) | | | | |
| 1 ACE | 1.37 (1.17-1.61) | 1.61 (1.21-2.15) | 1.42 (1.17-1.72) | 1.55 (1.15-2.09) |
| 2 or more ACEs | 1.54 (1.14-2.08) | 1.26 (0.73-2.19) | 1.45 (1.00-2.09) | 1.33 (0.74-2.37) |
| Access to services x ACEs | | | | |
| Access x 1 ACE | | 0.80 (0.56-1.12) | | 0.88 (0.62-1.24) |
| Access x 2 or more ACEs | | 1.30 (0.68-2.51) | | 1.22 (0.63-2.34) |
| Neighbourhood nuisances x ACEs | | | | |
| Nuisances x 1 ACE | | | 0.88 (0.62-1.24) | 0.90 (0.63-1.27) |
| Nuisances x 2 or more ACEs | | | 1.23 (0.64-2.35) | 1.11 (0.58-2.12) |

All models were adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression.
Abbreviations: ACEs, adverse childhood experiences; CI, confidence intervals; OR, odds ratios.

**Supplementary Table 4.2**: Interaction effects of childhood health problems and neighbourhood conditions on depression among 10328 older European adults (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | 0.79 (0.69-0.91) | 0.82 (0.70-0.96) | | 0.82 (0.70-0.97) |
| Neighbourhood nuisances (ref: No) | 1.34 (1.17-1.55) | | 1.31 (1.11-1.55) | 1.33 (1.13-1.57) |
| CHPs (ref: No) | | | | |
| 1 or more CHPs | 1.40 (1.22-1.62) | 1.49 (1.15-1.94) | 1.40 (1.18-1.67) | 1.54 (1.17-2.02) |
| Access to services x 1 or more CHPs | | 0.94 (0.69-1.28) | | 0.87 (0.64-1.18) |
| Neighbourhood nuisances x 1 or more CHPs | | | 1.01 (0.74-1.37) | 1.03 (0.76-1.40) |

All models were adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression.

Abbreviations: CI, confidence intervals; CHPs, childhood health problems; OR, odds ratios

**Supplementary Table 4.3**: Depression by neighbourhood conditions among 10328 older European adults, using continuous depression scores at baseline and follow-up (β with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | Access to services | | Neighbourhood nuisances | | M3: Access and nuisances | M4: Control for baseline depression |
|---|---|---|---|---|---|---|
| | M1a: Initial | M2a: Fully-adjusted | M1b: Initial | M2b: Fully-adjusted | | |
| Age (centred, in 10 years) | 0.33 (0.23-0.44) | 0.26 (0.15-0.37) | 0.34 (0.23-0.45) | 0.27 (0.16-0.38) | 0.27 (0.16-0.38) | 0.29 (0.19-0.40) |
| Age² (centred, in 10 years) | 0.22 (0.16-0.27) | 0.19 (0.14-0.25) | 0.22 (0.17-0.28) | 0.20 (0.14-0.25) | 0.20 (0.14-0.25) | 0.19 (0.14-0.24) |
| Gender (ref: Female) | -0.87 (-0.94--0.79) | -0.74 (-0.82--0.66) | -0.86 (-0.94--0.79) | -0.74 (-0.82--0.66) | -0.74 (-0.82--0.66) | -0.47 (-0.54--0.40) |
| Birth cohort (ref: After 1945) | | | | | | |
| 1919 and 1928 | -0.08 (-0.40-0.24) | -0.25 (-0.57-0.07) | -0.09 (-0.41-0.23) | -0.25 (-0.57-0.07) | -0.25 (-0.57-0.07) | -0.31 (-0.61--0.00) |
| 1929 and 1938 | 0.24 (0.05-0.43) | 0.14 (-0.05-0.34) | 0.24 (0.05-0.43) | 0.14 (-0.05-0.33) | 0.14 (-0.05-0.33) | 0.12 (-0.06-0.30) |
| 1939 and 1945 | 0.20 (0.07-0.33) | 0.13 (-0.00-0.26) | 0.20 (0.07-0.33) | 0.13 (-0.00-0.26) | 0.13 (-0.00-0.26) | 0.14 (0.02-0.26) |
| Attrition during follow-up (ref: No attrition) | | | | | | |
| Dropped out | 0.10 (-0.05-0.25) | 0.04 (-0.11-0.19) | 0.09 (-0.07-0.24) | 0.03 (-0.12-0.18) | 0.03 (-0.12-0.18) | 0.05 (-0.09-0.19) |
| Deceased | 0.60 (0.41-0.80) | 0.41 (0.22-0.59) | 0.60 (0.41-0.79) | 0.41 (0.22-0.59) | 0.41 (0.22-0.60) | 0.40 (0.23-0.58) |
| Born in the country (ref: No) | | -0.23 (-0.38--0.07) | | -0.22 (-0.38--0.06) | -0.22 (-0.38--0.06) | -0.11 (-0.25-0.04) |
| Education (ref: Tertiary) | | | | | | |
| Primary | | -0.21 (-0.30--0.11) | | -0.22 (-0.32--0.13) | -0.22 (-0.31--0.12) | -0.13 (-0.21--0.04) |
| Secondary | | -0.24 (-0.36--0.12) | | -0.26 (-0.38--0.14) | -0.25 (-0.37--0.13) | -0.15 (-0.26--0.04) |
| Equalized household net wealth (ref: Low) | | | | | | |
| Medium | | -0.17 (-0.26--0.08) | | -0.16 (-0.25--0.07) | -0.16 (-0.25--0.07) | -0.11 (-0.20--0.03) |
| High | | -0.25 (-0.35--0.16) | | -0.24 (-0.33--0.15) | -0.25 (-0.34--0.15) | -0.16 (-0.24--0.07) |
| Health Behaviours index | | 1.08 (0.93-1.22) | | 1.08 (0.93-1.22) | 1.08 (0.93-1.22) | 0.88 (0.74-1.01) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Living status (ref: Living alone) | | 0.03 (-0.05-0.11) | | 0.04 (-0.04-0.12) | 0.04 (-0.05-0.12) | 0.15 (0.07-0.22) |
| Labour market status (ref: Employed) | | | | | | |
| Out of the labour force | | 0.46 (0.33-0.58) | | 0.45 (0.33-0.57) | 0.45 (0.33-0.58) | 0.35 (0.23-0.47) |
| Unemployed | | 0.46 (0.25-0.66) | | 0.44 (0.24-0.65) | 0.44 (0.24-0.65) | 0.24 (0.05-0.42) |
| Retired | | 0.20 (0.09-0.32) | | 0.19 (0.08-0.31) | 0.19 (0.08-0.31) | 0.17 (0.07-0.28) |
| ADL (ref: No restrictions) | | 0.54 (0.39-0.69) | | 0.54 (0.38-0.69) | 0.53 (0.38-0.68) | 0.21 (0.07-0.36) |
| IADL (ref: No restrictions) | | 0.69 (0.56-0.82) | | 0.69 (0.57-0.82) | 0.69 (0.56-0.81) | 0.28 (0.16-0.40) |
| Access to services (ref: No) | -0.13 (-0.21--0.04) | -0.08 (-0.15-0.00) | | | -0.09 (-0.17--0.02) | -0.07 (-0.14-0.00) |
| Neighbourhood nuisances (ref: No) | | | 0.27 (0.19-0.35) | 0.24 (0.16-0.32) | 0.25 (0.17-0.33) | 0.13 (0.06-0.21) |
| Baseline depression (wave 1 or 2) | | | | | | 0.36 (0.34-0.37) |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; CI, confidence intervals; OR, odds ratios. Note: Models were estimated with multilevel linear regression.

**Supplementary Table 4.4**: Interaction effects of childhood socioeconomic conditions and neighbourhood conditions on depression among 10328 older European adults, using continuous depression scores at baseline and follow-up (β with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | -0.06 (-0.14-0.01) | 0.08 (-0.09-0.24) | | 0.08 (-0.08-0.25) |
| Neighbourhood nuisances (ref: No) | 0.14 (0.06-0.21) | | -0.05 (-0.23-0.12) | -0.07 (-0.25-0.11) |
| CSCs (ref: Most disadvantaged) | | | | |
| Disadvantaged | -0.07 (-0.18-0.04) | -0.03 (-0.21-0.15) | -0.17 (-0.30--0.04) | -0.11 (-0.30-0.08) |
| Middle | -0.17 (-0.28--0.05) | -0.04 (-0.22-0.13) | -0.21 (-0.34--0.08) | -0.09 (-0.27-0.10) |
| Advantaged | -0.14 (-0.27--0.02) | 0.01 (-0.20-0.21) | -0.23 (-0.37--0.08) | -0.07 (-0.28-0.14) |
| Most advantaged | -0.21 (-0.39--0.04) | -0.01 (-0.32-0.30) | -0.29 (-0.49--0.10) | -0.09 (-0.41-0.23) |
| Access to services x CSCs | | | | |
| Access x Disadvantaged | | -0.07 (-0.29-0.15) | | -0.10 (-0.32-0.12) |
| Access x Middle | | -0.18 (-0.38-0.03) | | -0.19 (-0.40-0.02) |
| Access x Advantaged | | -0.22 (-0.45-0.02) | | -0.24 (-0.47--0.00) |
| Access x Most advantaged | | -0.28 (-0.63-0.08) | | -0.29 (-0.64-0.06) |
| Neighbourhood nuisances x CSCs | | | | |
| Nuisances x Disadvantaged | | | 0.30 (0.07-0.53) | 0.31 (0.08-0.54) |
| Nuisances x Middle | | | 0.13 (-0.08-0.35) | 0.15 (-0.07-0.37) |
| Nuisances x Advantaged | | | 0.28 (0.03-0.52) | 0.30 (0.05-0.54) |
| Nuisances x Most advantaged | | | 0.26 (-0.09-0.62) | 0.28 (-0.08-0.64) |

All models were adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression.
Abbreviations: CI, confidence intervals; CSC, childhood socioeconomic conditions; OR, odds ratios.
Note: Models were estimated with multilevel linear regression.

**Supplementary Table 4.5**: Depression by neighbourhood conditions among 10328 older European adults, with adjustment for type of residence (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | Access to services | | Neighbourhood nuisances | | M3: Access and nuisances | M4: Control for baseline depression |
|---|---|---|---|---|---|---|
| | M1a: Initial | M2a: Fully-adjusted | M1b: Initial | M2b: Fully-adjusted | | |
| Age (centred, in 10 years) | 1.60 (1.33-1.91) | 1.41 (1.18-1.69) | 1.62 (1.35-1.93) | 1.43 (1.19-1.72) | 1.43 (1.20-1.72) | 1.49 (1.22-1.83) |
| Age$^2$ (centred, in 10 years) | 1.31 (1.20-1.43) | 1.29 (1.18-1.41) | 1.32 (1.20-1.44) | 1.29 (1.18-1.41) | 1.29 (1.18-1.41) | 1.34 (1.21-1.48) |
| Gender (ref: Female) | 0.29 (0.26-0.33) | 0.34 (0.30-0.39) | 0.30 (0.26-0.34) | 0.34 (0.30-0.39) | 0.35 (0.30-0.39) | 0.43 (0.37-0.50) |
| Birth cohort (ref: After 1945) | | | | | | |
| 1919 and 1928 | 0.78 (0.46-1.31) | 0.60 (0.36-1.02) | 0.76 (0.45-1.28) | 0.59 (0.35-1.00) | 0.59 (0.35-1.00) | 0.53 (0.30-0.96) |
| 1929 and 1938 | 1.15 (0.84-1.57) | 0.97 (0.70-1.34) | 1.14 (0.84-1.57) | 0.96 (0.70-1.32) | 0.95 (0.69-1.32) | 0.95 (0.67-1.36) |
| 1939 and 1945 | 1.14 (0.92-1.42) | 1.01 (0.81-1.26) | 1.14 (0.92-1.42) | 1.01 (0.81-1.26) | 1.00 (0.80-1.25) | 1.04 (0.81-1.33) |
| Attrition during follow-up (ref: No attrition) | | | | | | |
| Dropped out | 1.09 (0.85-1.40) | 0.99 (0.77-1.27) | 1.06 (0.83-1.37) | 0.99 (0.77-1.27) | 0.97 (0.76-1.25) | 1.04 (0.79-1.38) |
| Deceased | 2.37 (1.77-3.16) | 1.83 (1.37-2.45) | 2.36 (1.77-3.16) | 1.83 (1.37-2.45) | 1.84 (1.38-2.46) | 2.01 (1.45-2.78) |
| Born in the country (ref: No) | | 0.69 (0.54-0.88) | | 0.69 (0.54-0.88) | 0.69 (0.54-0.88) | 0.78 (0.59-1.03) |
| Education (ref: Tertiary) | | | | | | |
| Primary | | 0.79 (0.68-0.92) | | 0.78 (0.67-0.91) | 0.78 (0.67-0.91) | 0.70 (0.60-0.82) |
| Secondary | | 0.79 (0.65-0.96) | | 0.78 (0.64-0.95) | 0.78 (0.64-0.95) | 0.70 (0.57-0.86) |
| Equalized household net wealth (ref: Low) | | | | | | |
| Medium | | 0.85 (0.74-0.98) | | 0.86 (0.75-0.99) | 0.86 (0.74-0.99) | 0.93 (0.79-1.10) |
| High | | 0.71 (0.61-0.82) | | 0.72 (0.62-0.83) | 0.71 (0.62-0.83) | 0.79 (0.67-0.93) |
| Health Behaviours index | | 4.55 (3.59-5.77) | | 4.54 (3.58-5.76) | 4.55 (3.59-5.77) | 4.24 (3.27-5.51) |
| Living status (ref: Living alone) | | 1.04 (0.92-1.18) | | 1.05 (0.92-1.19) | 1.04 (0.92-1.19) | 1.17 (1.01-1.36) |
| Labour market status (ref: Employed) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Out of the labour force | | 2.10 (1.72-2.56) | | 2.07 (1.70-2.53) | 2.09 (1.71-2.55) | 2.31 (1.86-2.88) |
| Unemployed | | 2.01 (1.46-2.76) | | 1.98 (1.44-2.73) | 1.99 (1.45-2.73) | 1.96 (1.36-2.82) |
| Retired | | 1.63 (1.35-1.97) | | 1.61 (1.33-1.95) | 1.62 (1.33-1.96) | 1.84 (1.49-2.27) |
| ADL (ref: No restrictions) | | 1.96 (1.56-2.45) | | 1.94 (1.55-2.44) | 1.93 (1.54-2.42) | 1.55 (1.20-2.02) |
| IADL (ref: No restrictions) | | 2.06 (1.70-2.49) | | 2.07 (1.71-2.50) | 2.05 (1.69-2.48) | 1.52 (1.22-1.90) |
| Type of residence (ref: Rural) | | 1.08 (0.93-1.24) | | 0.95 (0.83-1.09) | 1.03 (0.89-1.18) | 0.99 (0.85-1.16) |
| Access to services (ref: No) | 0.82 (0.72-0.92) | 0.84 (0.74-0.96) | | | 0.83 (0.73-0.95) | 0.79 (0.68-0.91) |
| Neighbourhood nuisances (ref: No) | | | 1.44 (1.26-1.63) | 1.40 (1.23-1.59) | 1.40 (1.23-1.59) | 1.37 (1.19-1.58) |
| Baseline depression (wave 1 or 2) | | | | | | 8.41 (6.91-10.23) |

ADL: activities of daily living. IADL: instrumental activities of daily living. CI: confidence intervals. OR: odds ratios.

**Supplementary Table 4.6**: Interaction effects of childhood socioeconomic conditions and neighbourhood conditions on depression among 10328 older European adults, with adjustment for type of residence (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Type of residence (ref: Rural) | 1.00 (0.86-1.17) | 1.01 (0.87-1.18) | 0.93 (0.81-1.08) | 0.99 (0.85-1.16) |
| Access to services (ref: No) | 0.81 (0.70-0.94) | 1.07 (0.79-1.46) | | 1.06 (0.78-1.45) |
| Neighbourhood nuisances (ref: No) | 1.36 (1.17-1.56) | | 0.92 (0.66-1.28) | 0.98 (0.70-1.37) |
| CSCs (ref: Most disadvantaged) | | | | |
| Disadvantaged | 0.81 (0.66-0.99) | 0.83 (0.60-1.16) | 0.66 (0.52-0.83) | 0.71 (0.50-1.00) |
| Middle | 0.58 (0.48-0.72) | 0.76 (0.55-1.06) | 0.53 (0.42-0.67) | 0.71 (0.51-1.00) |
| Advantaged | 0.52 (0.41-0.66) | 0.75 (0.51-1.10) | 0.44 (0.34-0.58) | 0.68 (0.45-1.00) |
| Most advantaged | 0.48 (0.34-0.68) | 0.98 (0.54-1.79) | 0.37 (0.25-0.55) | 0.64 (0.34-1.21) |
| Access to services x CSCs | | | | |
| Access x Disadvantaged | | 0.97 (0.64-1.47) | | 0.95 (0.63-1.43) |
| Access x Middle | | 0.69 (0.46-1.02) | | 0.70 (0.47-1.03) |
| Access x Advantaged | | 0.61 (0.39-0.96) | | 0.59 (0.37-0.93) |
| Access x Most advantaged | | 0.41 (0.21-0.83) | | 0.50 (0.25-1.01) |
| Neighbourhood nuisances x CSCs | | | | |
| Nuisances x Disadvantaged | | | 1.87 (1.22-2.86) | 1.73 (1.13-2.65) |
| Nuisances x Middle | | | 1.30 (0.86-1.97) | 1.23 (0.81-1.86) |
| Nuisances x Advantaged | | | 1.64 (1.02-2.62) | 1.57 (0.98-2.52) |
| Nuisances x Most advantaged | | | 2.45 (1.21-4.98) | 2.34 (1.15-4.75) |

All models are adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression. Abbreviations: CI, confidence intervals; CSC, childhood socioeconomic conditions; OR, odds ratios

**Supplementary Table 4.7:** Depression by neighbourhood conditions among 7928 older European adults free of depression at baseline (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | Access to services | | Neighbourhood nuisances | | M3: Access and nuisances |
|---|---|---|---|---|---|
| | M1a: Initial | M2a: Fully-adjusted | M1b: Initial | M2b: Fully-adjusted | |
| Age (centred, in 10 years) | 1.83 (1.48-2.26) | 3.20 (2.12-4.83) | 3.60 (2.39-5.40) | 2.48 (1.65-3.74) | 3.21 (2.13-4.85) |
| Age² (centred, in 10 years) | 1.34 (1.21-1.49) | 1.88 (1.53-2.31) | 1.87 (1.52-2.29) | 1.85 (1.51-2.28) | 1.86 (1.52-2.29) |
| Gender (ref: Female) | 0.43 (0.37-0.49) | 0.45 (0.32-0.63) | 0.46 (0.34-0.62) | 0.41 (0.29-0.58) | 0.46 (0.33-0.64) |
| Birth cohort (ref: After 1945) | | | | | |
| 1919 and 1928 | 0.61 (0.33-1.12) | 0.10 (0.03-0.35) | 0.09 (0.03-0.32) | 0.18 (0.05-0.63) | 0.10 (0.03-0.35) |
| 1929 and 1938 | 1.07 (0.75-1.54) | 0.48 (0.22-1.04) | 0.48 (0.23-1.01) | 0.76 (0.35-1.67) | 0.47 (0.22-1.03) |
| 1939 and 1945 | 1.07 (0.84-1.37) | 0.89 (0.51-1.53) | 0.88 (0.52-1.49) | 1.01 (0.58-1.76) | 0.83 (0.48-1.44) |
| Attrition during follow-up (ref: No attrition) | | | | | |
| Dropped out | 1.17 (0.88-1.56) | 1.35 (0.75-2.43) | 1.61 (0.91-2.86) | 1.19 (0.65-2.19) | 1.51 (0.85-2.68) |
| Deceased | 2.18 (1.56-3.03) | 2.27 (1.08-4.76) | 2.76 (1.33-5.74) | 1.64 (0.76-3.52) | 2.29 (1.09-4.81) |
| Born in the country (ref: No) | | 0.88 (0.45-1.73) | | 1.07 (0.53-2.18) | 0.82 (0.42-1.60) |
| Education (ref: Tertiary) | | | | | |
| Primary | | 1.03 (0.70-1.52) | | 0.86 (0.58-1.25) | 0.99 (0.68-1.45) |
| Secondary | | 0.89 (0.55-1.45) | | 0.72 (0.44-1.18) | 0.89 (0.55-1.44) |
| Equalized household net wealth (ref: Low) | | | | | |
| Medium | | 0.97 (0.66-1.43) | | 0.69 (0.47-1.03) | 0.92 (0.62-1.36) |
| High | | 0.79 (0.53-1.16) | | 0.80 (0.54-1.19) | 0.75 (0.51-1.11) |
| Health Behaviours index | | 5.50 (3.07-9.85) | | 5.85 (3.23-10.61) | 5.28 (2.95-9.44) |
| Living status (ref: Living alone) | | 1.18 (0.83-1.67) | | 1.30 (0.91-1.86) | 1.08 (0.76-1.53) |
| Labour market status (ref: Employed) | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Out of the labour force | | 2.15 (1.28-3.61) | | 2.52 (1.49-4.29) | 2.17 (1.30-3.64) |
| Unemployed | | 1.99 (0.83-4.79) | | 6.82 (2.94-15.83) | 1.90 (0.79-4.58) |
| Retired | | 1.65 (1.02-2.67) | | 2.04 (1.24-3.35) | 1.59 (0.98-2.58) |
| ADL (ref: No restrictions) | | 2.23 (1.03-4.82) | | 3.02 (1.37-6.65) | 2.09 (0.97-4.52) |
| IADL (ref: No restrictions) | | 1.80 (0.97-3.34) | | 1.78 (0.95-3.34) | 1.84 (0.99-3.40) |
| Access to services (ref: No) | 0.87 (0.75-1.00) | 0.87 (0.62-1.21) | | | 0.82 (0.59-1.15) |
| Neighbourhood nuisances (ref: No) | | | 1.51 (1.08-2.11) | 1.46 (1.04-2.06) | 1.46 (1.05-2.04) |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; CI, confidence intervals; OR, odds ratios.

**Supplementary Table 4.8**: Interaction effects of childhood socioeconomic conditions and neighbourhood conditions on depression among 7928 older European adults free of depression at baseline (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | 0.90 (0.64-1.25) | 1.50 (0.70-3.21) | | 1.46 (0.68-3.16) |
| Neighbourhood nuisances (ref: No) | 1.48 (1.06-2.07) | | 0.98 (0.43-2.22) | 1.38 (0.60-3.16) |
| CSCs (ref: Most disadvantaged) | | | | |
| Disadvantaged | 0.80 (0.49-1.31) | 1.02 (0.44-2.34) | 0.62 (0.35-1.11) | 1.13 (0.47-2.71) |
| Middle | 0.56 (0.35-0.91) | 0.87 (0.39-1.93) | 0.52 (0.30-0.91) | 0.93 (0.40-2.15) |
| Advantaged | 0.47 (0.27-0.81) | 0.98 (0.39-2.46) | 0.40 (0.21-0.76) | 1.02 (0.39-2.69) |
| Most advantaged | 0.38 (0.17-0.85) | 0.49 (0.11-2.18) | 0.30 (0.12-0.77) | 0.56 (0.12-2.65) |
| Access to services x CSCs | | | | |
| Access x Disadvantaged | | 0.72 (0.26-1.97) | | 0.55 (0.20-1.52) |
| Access x Middle | | 0.52 (0.20-1.36) | | 0.50 (0.19-1.30) |
| Access x Advantaged | | 0.37 (0.13-1.08) | | 0.36 (0.12-1.06) |
| Access x Most advantaged | | 0.65 (0.12-3.61) | | 0.62 (0.11-3.43) |
| Neighbourhood nuisances x CSCs | | | | |
| Nuisances x Disadvantaged | | | 2.23 (0.78-6.37) | 1.49 (0.51-4.33) |
| Nuisances x Middle | | | 1.21 (0.45-3.25) | 0.86 (0.31-2.35) |
| Nuisances x Advantaged | | | 1.51 (0.49-4.66) | 1.11 (0.35-3.47) |
| Nuisances x Most advantaged | | | 1.92 (0.36-10.20) | 1.26 (0.23-6.88) |

All models are adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living and instrumental activities of daily living.

Abbreviations: CI, confidence intervals; CSC, childhood socioeconomic conditions; OR, odds ratios

**Supplementary Table 4.9:** Depression with age slopes by neighbourhood conditions among 10328 older European adults (OR with 95% CI), Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | Access to services | | Neighbourhood nuisances | | M3: Access and nuisances | M4: Control for baseline depression |
|---|---|---|---|---|---|---|
| | M1a: Initial | M2a: Fully-adjusted | M1b: Initial | M2b: Fully-adjusted | | |
| Age (centred, in 10 years) | 1.58 (1.30-1.93) | 1.35 (1.11-1.65) | 1.67 (1.40-2.01) | 1.47 (1.22-1.77) | 1.42 (1.16-1.74) | 1.41 (1.12-1.76) |
| Age² (centred, in 10 years) | 1.30 (1.19-1.42) | 1.28 (1.17-1.40) | 1.31 (1.20-1.43) | 1.29 (1.18-1.41) | 1.28 (1.17-1.40) | 1.32 (1.20-1.46) |
| Gender (ref: Female) | 0.30 (0.26-0.34) | 0.34 (0.30-0.39) | 0.30 (0.26-0.34) | 0.35 (0.30-0.39) | 0.35 (0.30-0.39) | 0.44 (0.38-0.51) |
| Birth cohort (ref: After 1945) | | | | | | |
| 1919 and 1928 | 0.80 (0.48-1.34) | 0.61 (0.36-1.04) | 0.79 (0.47-1.32) | 0.61 (0.36-1.02) | 0.61 (0.36-1.02) | 0.59 (0.33-1.06) |
| 1929 and 1938 | 1.19 (0.87-1.62) | 0.99 (0.72-1.36) | 1.19 (0.87-1.62) | 0.99 (0.72-1.37) | 0.99 (0.72-1.36) | 1.03 (0.73-1.47) |
| 1939 and 1945 | 1.15 (0.93-1.43) | 1.01 (0.81-1.25) | 1.16 (0.94-1.44) | 1.02 (0.82-1.26) | 1.01 (0.81-1.26) | 1.02 (0.80-1.30) |
| Attrition during follow-up (ref: No attrition) | | | | | | |
| Dropped out | 1.09 (0.85-1.39) | 1.00 (0.78-1.27) | 1.05 (0.82-1.35) | 0.98 (0.76-1.25) | 0.99 (0.77-1.26) | 1.03 (0.79-1.36) |
| Deceased | 2.27 (1.70-3.02) | 1.75 (1.31-2.33) | 2.27 (1.71-3.03) | 1.77 (1.33-2.35) | 1.76 (1.32-2.35) | 1.87 (1.36-2.59) |
| Born in the country (ref: No) | | 0.65 (0.51-0.83) | | 0.66 (0.51-0.84) | 0.65 (0.51-0.84) | 0.76 (0.57-1.00) |
| Education (ref: Tertiary) | | | | | | |
| Primary | | 0.80 (0.69-0.93) | | 0.79 (0.68-0.92) | 0.80 (0.69-0.93) | 0.70 (0.60-0.82) |
| Secondary | | 0.77 (0.63-0.93) | | 0.75 (0.62-0.91) | 0.76 (0.63-0.92) | 0.66 (0.54-0.81) |
| Equalized household net wealth (ref: Low) | | | | | | |
| Medium | | 0.84 (0.73-0.97) | | 0.86 (0.75-0.99) | 0.86 (0.75-0.99) | 0.94 (0.80-1.10) |
| High | | 0.71 (0.62-0.82) | | 0.73 (0.63-0.84) | 0.73 (0.63-0.84) | 0.81 (0.69-0.96) |
| Health Behaviours index | | 4.63 (3.66-5.86) | | 4.59 (3.63-5.81) | 4.61 (3.64-5.83) | 4.30 (3.33-5.57) |
| Living in couple (ref: Living alone) | | 1.04 (0.92-1.18) | | 1.05 (0.93-1.19) | 1.04 (0.92-1.18) | 1.17 (1.01-1.35) |
| Labour market status (ref: Employed) | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Out of the labour force | | 2.05 (1.68-2.50) | | 2.03 (1.66-2.47) | 2.03 (1.67-2.48) | 2.26 (1.82-2.81) |
| Unemployed | | 2.00 (1.46-2.74 | | 1.97 (1.44-2.69) | 1.98 (1.45-2.71) | 1.91 (1.33-2.72) |
| Retired | | 1.62 (1.34-1.95) | | 1.59 (1.32-1.93) | 1.59 (1.32-1.92) | 1.81 (1.48-2.23) |
| ADL (ref: No restrictions) | | 1.94 (1.55-2.43) | | 1.93 (1.54-2.41) | 1.91 (1.53-2.39) | 1.55 (1.20-2.01) |
| IADL (ref: No restrictions) | | 2.06 (1.70-2.49) | | 2.08 (1.72-2.51) | 2.06 (1.70-2.49) | 1.53 (1.23-1.90) |
| Access to services (ref: No) | 0.82 (0.72-0.93) | 0.88 (0.77-1.00) | | | 0.85 (0.75-0.97) | 0.81 (0.70-0.93) |
| Access to services x Age | 1.00 (0.88-1.13) | 1.05 (0.93-1.20) | | | 1.06 (0.93-1.20) | 1.08 (0.93-1.25) |
| Neighbourhood nuisances (ref: No) | | | 1.36 (1.19-1.55) | 1.32 (1.16-1.51) | 1.34 (1.17-1.53) | 1.30 (1.12-1.51) |
| Neighbourhood nuisances x Age | | | 0.84 (0.73-0.96) | 0.87 (0.77-1.00) | 0.87 (0.76-0.99) | 0.87 (0.75-1.02) |
| Baseline depression (wave 1 or 2) | | | | | | 8.37 (6.90-10.15) |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; CI, confidence intervals; OR, odds ratios.

**Supplementary Table 4.10**: Interaction effects of childhood socioeconomic conditions and neighbourhood conditions on depression with age slopes (OR with 95% CI) among 10328 older European adults, Survey of Health, Ageing and Retirement in Europe, 2004/2005-2015

| Variable | M5: Without interaction | M6a: Access to services interaction | M6b: Neighbourhood nuisances interaction | M7: Access and nuisances interactions |
|---|---|---|---|---|
| Access to services (ref: No) | 0.81 (0.70-0.94) | 1.10 (0.82-1.48) | | 1.13 (0.84-1.52) |
| Access to services x Age | 1.02 (0.88-1.18) | 0.87 (0.62-1.21) | | 0.86 (0.61-1.21) |
| Neighbourhood nuisances (ref: No) | 1.29 (1.11-1.49) | | 0.94 (0.68-1.30) | 0.88 (0.64-1.22) |
| Neighbourhood nuisances x Age | 0.86 (0.74-1.00) | | 0.94 (0.64-1.37) | 0.95 (0.65-1.39) |
| CSCs (ref: Most disadvantaged) | | | | |
| Disadvantaged | 0.81 (0.67-0.99) | 0.88 (0.63-1.23) | 0.66 (0.52-0.83) | 0.76 (0.54-1.08) |
| Middle | 0.58 (0.47-0.71) | 0.77 (0.54-1.08) | 0.54 (0.43-0.69) | 0.71 (0.50-1.02) |
| Advantaged | 0.52 (0.41-0.65) | 0.72 (0.48-1.09) | 0.44 (0.33-0.59) | 0.64 (0.42-0.97) |
| Most advantaged | 0.47 (0.34-0.66) | 0.50 (0.24-1.04) | 0.37 (0.24-0.56) | 0.42 (0.20-0.89) |
| CSCs x Age | | | | |
| Disadvantaged x Age | | 1.06 (0.74-1.52) | 1.10 (0.85-1.41) | 1.12 (0.77-1.62) |
| Middle x Age | | 1.01 (0.71-1.43) | 1.16 (0.91-1.48) | 1.02 (0.72-1.47) |
| Advantaged x Age | | 1.08 (0.73-1.61) | 1.14 (0.87-1.50) | 1.03 (0.68-1.54) |
| Most advantaged x Age | | 0.60 (0.30-1.21) | 1.14 (0.77-1.69) | 0.62 (0.30-1.28) |
| Access to services x CSCs | | | | |
| Access x Disadvantaged | | 0.84 (0.56-1.27) | | 0.79 (0.52-1.19) |
| Access x Middle | | 0.66 (0.44-1.00) | | 0.65 (0.43-0.98) |
| Access x Advantaged | | 0.61 (0.38-0.99) | | 0.58 (0.36-0.94) |
| Access x Most advantaged | | 0.81 (0.36-1.83) | | 0.77 (0.34-1.74) |
| Access to services x CSCs x Age | | | | |
| Access x Disadvantaged x Age | | 0.98 (0.63-1.53) | | 0.99 (0.63-1.55) |

| | | | |
|---|---|---|---|
| Access x Middle x Age | 1.17 (0.76-1.80) | | 1.20 (0.78-1.86) |
| Access x Advantaged x Age | 1.14 (0.70-1.86) | | 1.17 (0.72-1.91) |
| Access x Most advantaged x Age | 2.20 (0.99-4.92) | | 2.24 (1.00-5.01) |
| Neighbourhood nuisances x CSCs | | | |
| Nuisances x Disadvantaged | | 1.73 (1.13-2.65) | 1.81 (1.18-2.79) |
| Nuisances x Middle | | 1.18 (0.77-1.81) | 1.27 (0.83-1.95) |
| Nuisances x Advantaged | | 1.64 (1.00-2.67) | 1.75 (1.07-2.86) |
| Nuisances x Most advantaged | | 1.96 (0.91-4.24) | 2.13 (0.99-4.60) |
| Neighbourhood nuisances x CSCs x Age | | | |
| Nuisances x Disadvantaged x Age | | 0.94 (0.58-1.51) | 0.90 (0.56-1.46) |
| Nuisances x Middle x Age | | 0.91 (0.57-1.44) | 0.90 (0.56-1.44) |
| Nuisances x Advantaged x Age | | 1.16 (0.69-1.95) | 1.08 (0.64-1.82) |
| Nuisances x Most advantaged x Age | | 0.85 (0.38-1.86) | 0.84 (0.38-1.85) |

All models were adjusted for age, age$^2$, gender, birth cohort, attrition during follow-up, born in the country, education, equalized household net wealth, health behaviours, living status, labour market status, activities of daily living, instrumental activities of daily living and baseline depression.
Abbreviations: CI, confidence intervals; CSC, childhood socioeconomic conditions; OR, odds ratios

**Supplementary Table 4.11:** Variance inflation factors exploring multicollinearity between independent variables

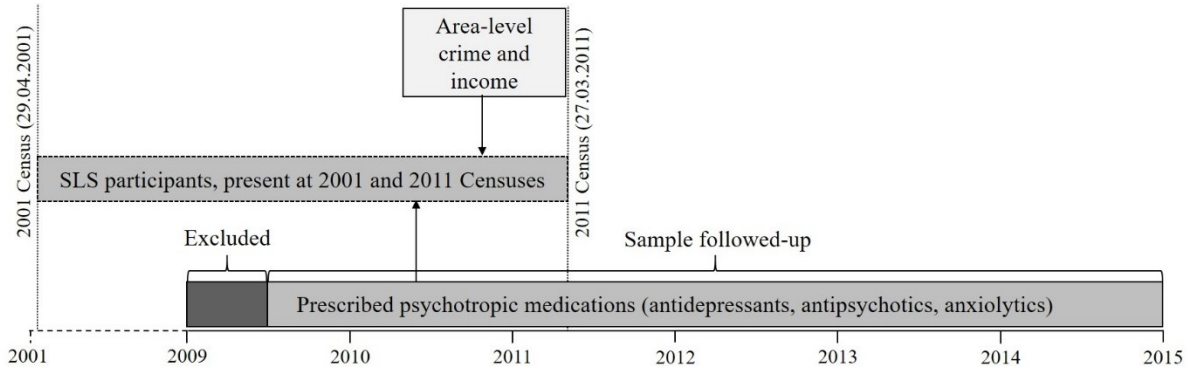
| Variable | VIF | 1/VIF |
|---|---|---|
| Age (centred, in 10 years) | 23.39 | 0.042747 |
| Age$^2$ (centred, in 10 years) | 11.35 | 0.088108 |
| Gender (ref: Female) | 1.18 | 0.847661 |
| Birth cohort (ref: After 1945) | | |
| 1919 and 1928 | 7.93 | 0.126033 |
| 1929 and 1938 | 7.11 | 0.140676 |
| 1939 and 1945 | 3.01 | 0.331999 |
| Attrition during follow-up (ref: No attrition) | | |
| Dropped out | 1.01 | 0.992289 |
| Deceased | 1.06 | 0.945118 |
| Born in the country (ref: No) | 1.01 | 0.986056 |
| Education (ref: Tertiary) | | |
| Primary | 1.62 | 0.618976 |
| Secondary | 1.73 | 0.579086 |
| Equalized household net wealth (ref: Low) | | |
| Medium | 1.52 | 0.659329 |
| High | 1.62 | 0.618464 |
| Health Behaviours index | 1.05 | 0.951563 |
| Living status (ref: Living alone) | 1.14 | 0.880661 |
| Labour market status (ref: Employed) | | |
| Out of the labour force | 1.57 | 0.637157 |
| Unemployed | 1.09 | 0.919540 |
| Retired | 2.61 | 0.383315 |
| ADL (ref: No restrictions) | 1.19 | 0.840501 |
| IADL (ref: No restrictions) | 1.25 | 0.802666 |
| Access to services (ref: No) | 1.02 | 0.979201 |
| Neighbourhood nuisances (ref: No) | 1.02 | 0.983470 |
| Baseline depression (wave 1 or 2) | 1.14 | 0.876967 |
| **Mean** | **3.33** | |

Abbreviations: ADL, activities of daily living; IADL, instrumental activities of daily living; VIF, variance inflation factor

## 8.4 Appendix Four: Supplementary Material for Chapter 5

**Contents**

**Supplementary Figure 5.1:** Study design presenting data sources and data linkage[a]




[a] Individuals with prescribed medications in the first 6 months were excluded from the sample. SLS, Scottish Longitudinal Study

**Supplementary Table 5.1:** Medications grouped by the three main types of psychotropic drugs

| Antidepressants (BNF 4.3) | Antipsychotics (BNF 4.2) |
|---|---|
| **1. Monoamine-oxidase inhibitors** | **1. Antipsychotic depot injections** |
| Moclobemide | Flupentixol |
| Phenelzine | Flupentixol Decanoate |
| Tranylcypromine | Fluphenazine Decanoate |
| **2. Selective serotonin re-uptake inhibitors** | Haloperidol Decanoate |
| Citalopram | Paliperidone |
| Escitalopram | Pipotiazine Palmitate |
| Fluoxetine | Risperidone |
| Fluvoxamine Maleate | Zuclopenthixol |
| Paroxetine | **2. Antipsychotic drugs** |
| Sertraline | Amisulpride |
| **3. Tricyclic & related antidepressant drugs** | Aripiprazole |
| Amitriptyline[a] | Benperidol |
| Amitriptyline Hydrochloride[a] | Chlorpromazine Hydrochloride |
| Clomipramine Hydrochloride | Clozapine |
| Dosulepin Hydrochloride | Flupentixol |
| Doxepin | Fluphenazine Hydrochloride |
| Imipramine Hydrochloride | Haloperidol |
| Lofepramine | Levomepromazine |
| Mianserin Hydrochloride | Olanzapine |
| Nortriptyline[a] | Paliperidone |
| Trazodone Hydrochloride | Pericyazine |
| Trimipramine | Perphenazine |
| **4. Other antidepressant drugs** | Pimozide |
| Agomelatine | Promazine Hydrochloride |
| Duloxetine | Quetiapine |
| Flupentixol | Risperidone |
| Mirtazapine | Sulpiride |
| Reboxetine | Thioridazine |
| Tryptophan | Trifluoperazine |
| Venlafaxine | Zotepine |
| **Anxiolytics (BNF 4.1.2)** | Zuclopenthixol |
| Buspirone Hydrochloride | **3. Drugs used for mania and hypomania** |
| Chlordiazepoxide | Lithium Carbonate |
| Diazepam | Lithium Citrate |
| Lorazepam | Sodium Valproate |
| Meprobamate | |
| Oxazepam | |

Source: Scottish Longitudinal Study

[a] Prescriptions with ≤30mg per day were excluded.

**Supplementary Table 5.2:** Description of the covariates[a]

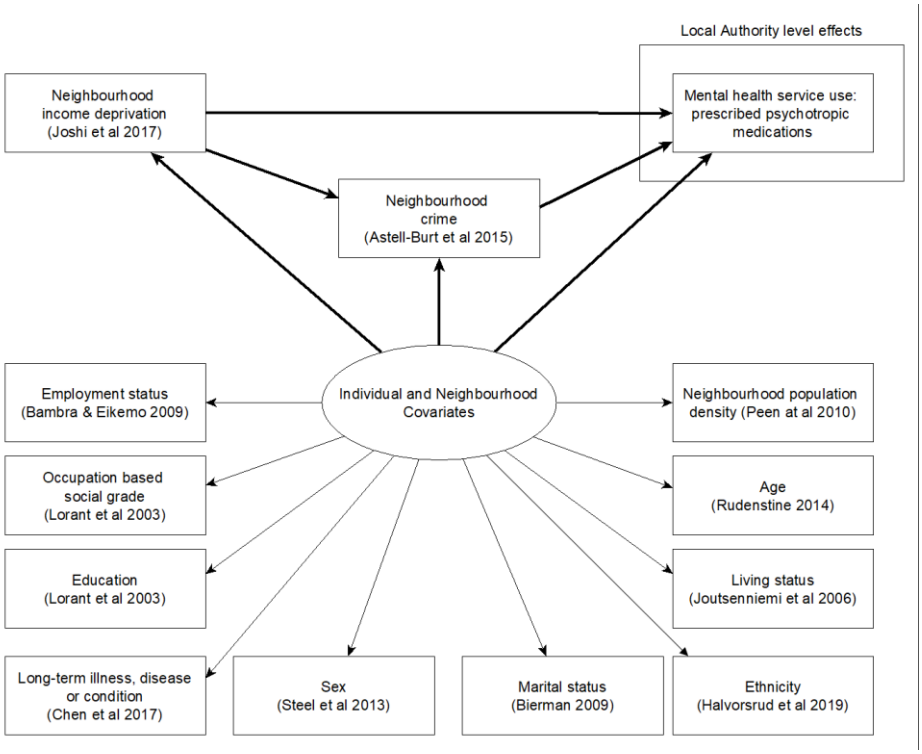
| Variable | Description |
|---|---|
| Sex | Male, Female |
| Age, years | 24–33, 34–43, 44–53, 54–63, 64–73, 74–83, >84 in 2009 |
| Ethnicity | |
| White | White Scottish, Other White British, White Irish, Other White |
| Non-white | Any Mixed Background, Indian, Pakistani, Bangladeshi, Other South Asian, Caribbean, African, Black Scottish or Other Black, Chinese, Other Ethnic Group |
| Social grade[b] | |
| AB | Higher or intermediate managerial, administrative or professional |
| C1 | Supervisory, clerical and junior managerial, administrative and professional |
| C2 | Skilled manual workers |
| D | Semi-skilled and unskilled manual workers |
| E | State pensioners, casual and lowest grade workers, unemployed with state benefits only |
| Educational attainment | |
| No qualification | No professional, vocational or academic qualifications |
| Level 1 | O Grade, Standard Grade, Access 3 Cluster, Intermediate 1 or 2, GCSE, CSE, Senior Certificate or equivalent; GSVQ Foundation or Intermediate, SVQ level 1 or 2, SCOTVEC Module, City and Guilds Craft or equivalent; Other school qualifications not already mentioned (including foreign qualifications) |
| Level 2 | SCE Higher Grade, Higher, Advanced Higher, CSYS, A Level, AS Level, Advanced Senior Certificate or equivalent; GSVQ Advanced, SVQ level 3, ONC, OND, SCOTVEC National Diploma, City and Guilds Advanced Craft or equivalent |
| Level 3 | HNC, HND, SVQ level 4 or equivalent; Other post-school but pre-Higher Education qualifications not already mentioned (including foreign qualifications) |
| Level 4 | Degree, Postgraduate qualifications, Masters, PhD, SVQ level 5 or equivalent; Professional qualifications (for example, teaching, nursing, accountancy); Other Higher Education qualifications not already mentioned (including foreign qualifications) |
| Employment status | |
| In employment | Economically active: In employment (part-time, full-time) |
| Retired | Economically inactive: Retired |
| Out of labour force | Economically inactive: Student; Looking after home or family; Long-term sick or disabled; Other |

| | |
|---|---|
| Unemployed | Economically active: Unemployed (Seeking work and available to start in 2 weeks or waiting to start a job already obtained) |
| Marital status | |
| Married | Married; In a registered same-sex civil partnership |
| Single | Never married and never registered a same-sex civil partnership |
| Separated | Separated, but still legally married; Separated, but still legally in a same-sex civil partnership |
| Divorced | Divorced; Formerly in a same-sex civil partnership which is now legally dissolved |
| Widowed | Widowed; Surviving partner from a same-sex civil partnership |
| Living status | |
| Alone | One Person Household |
| With others | Other Households |
| Long-term illness, disease or condition | "Do you have any of the following conditions which have lasted, or are expected to last, at least 12 months?" |
| Yes | Has a long-term illness, disease or condition |
| No | Does not have a long-term illness, disease or condition |

[a] Source: https://sls.lscs.ac.uk/variables

[b] http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/

**Supplementary Figure 5.2**: Conceptual diagram

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**Supplementary Table 5.3** Fully-adjusted models on new antidepressants and antipsychotics prescriptions (*n*=129,945)

| Variable | Antidepressants medication | | | Antipsychotics medication | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | P-value | OR | 95% CI | P-value |
| Gender | | | | | | |
| Male | Ref | | | Ref | | |
| Female | 1.86 | 1.80-1.91 | 0.000 | 0.84 | 0.76-0.92 | 0.000 |
| Age, years | | | | | | |
| 24–33 | Ref | | | Ref | | |
| 34–43 | 1.00 | 1.95-1.05 | 0.973 | 0.81 | 0.65-0.99 | 0.044 |
| 44–53 | 0.98 | 0.93-1.03 | 0.358 | 0.89 | 0.72-1.09 | 0.255 |
| 54–63 | 0.77 | 0.73-0.82 | 0.000 | 0.81 | 0.64-1.02 | 0.068 |
| 64–73 | 0.78 | 0.72-0.84 | 0.000 | 1.45 | 1.11-1.88 | 0.006 |
| 74–83 | 0.83 | 0.77-0.91 | 0.000 | 3.07 | 2.34-4.01 | 0.000 |
| ≥84 | 0.80 | 0.71-0.90 | 0.000 | 6.04 | 4.51-8.09 | 0.000 |
| Ethnicity | | | | | | |
| White | Ref | | | Ref | | |
| Non-White | 0.81 | 0.72-0.92 | 0.001 | 1.03 | 0.65-1.61 | 0.907 |
| Missing | 1.10 | 1.01-1.19 | 0.026 | 1.17 | 0.93-1.47 | 0.194 |
| Social Grade | | | | | | |
| AB | Ref | | | Ref | | |
| C1 | 1.17 | 1.11-1.22 | 0.000 | 0.84 | 0.71-1.00 | 0.047 |
| C2 | 1.19 | 1.13-1.25 | 0.000 | 0.99 | 0.83-1.19 | 0.956 |
| D | 1.32 | 1.25-1.39 | 0.000 | 1.15 | 0.96-1.36 | 0.128 |
| F | 1.34 | 1.23-1.46 | 0.000 | 1.54 | 1.23-1.92 | 0.000 |
| Educational attainment | | | | | | |
| No qualification | Ref | | | Ref | | |
| Level 1 | 0.93 | 0.90-0.97 | 0.001 | 0.93 | 0.81-1.06 | 0.275 |
| Level 2 | 0.82 | 0.78-0.86 | 0.000 | 0.79 | 0.65-0.95 | 0.015 |
| Level 3 | 0.87 | 0.83-0.92 | 0.000 | 0.76 | 0.62-0.94 | 0.013 |
| Level 4 | 0.73 | 0.69-0.76 | 0.000 | 0.82 | 0.70-0.96 | 0.014 |
| Employment status | | | | | | |
| Employed | Ref | | | Ref | | |
| Retired | 1.10 | 1.04-1.16 | 0.001 | 1.95 | 1.61-2.37 | 0.000 |
| Out of labour force | 1.68 | 1.60-1.76 | 0.000 | 3.37 | 2.88-3.95 | 0.000 |
| Unemployed | 1.67 | 1.55-1.80 | 0.000 | 2.41 | 1.86-3.13 | 0.000 |
| Marital status | | | | | | |
| Married | Ref | | | Ref | | |
| Single | 0.94 | 0.90-0.98 | 0.003 | 1.39 | 1.19-1.63 | 0.000 |
| Separated | 1.51 | 1.40-1.62 | 0.000 | 1.55 | 1.18-2.03 | 0.002 |
| Divorced | 1.31 | 1.24-1.38 | 0.000 | 1.27 | 1.05-1.53 | 0.015 |
| Widowed | 0.96 | 0.91-1.03 | 0.248 | 1.05 | 0.89-1.25 | 0.559 |
| Living status | | | | | | |
| Living with others | Ref | | | Ref | | |
| Living alone | 1.00 | 0.96-1.04 | 0.989 | 1.06 | 0.92-1.22 | 0.400 |
| Long-term illness, disease or condition | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| No | Ref | | | Ref | | |
| Yes | 1.58 | 1.53-1.63 | 0.000 | 1.58 | 1.43-1.74 | 0.000 |
| Area population density | 1.01 | 1.00-1.01 | 0.009 | 1.00 | 0.98-1.02 | 0.986 |
| Area income deprivation | | | | | | |
| Low | Ref | | | Ref | | |
| Moderate | 1.11 | 1.07-1.15 | 0.000 | 1.08 | 0.95-1.22 | 0.265 |
| High | 1.23 | 1.17-1.29 | 0.000 | 1.12 | 0.96-1.32 | 0.158 |
| Area crime levels | | | | | | |
| Low | Ref | | | Ref | | |
| Moderate | 1.01 | 0.97-1.04 | 0.697 | 1.00 | 0.88-1.14 | 0.961 |
| High | 1.05 | 1.00-1.10 | 0.039 | 1.20 | 1.03-1.39 | 0.016 |

Source: Scottish Longitudinal Study. OR, Odds Ratio; CI, Confidence Interval.

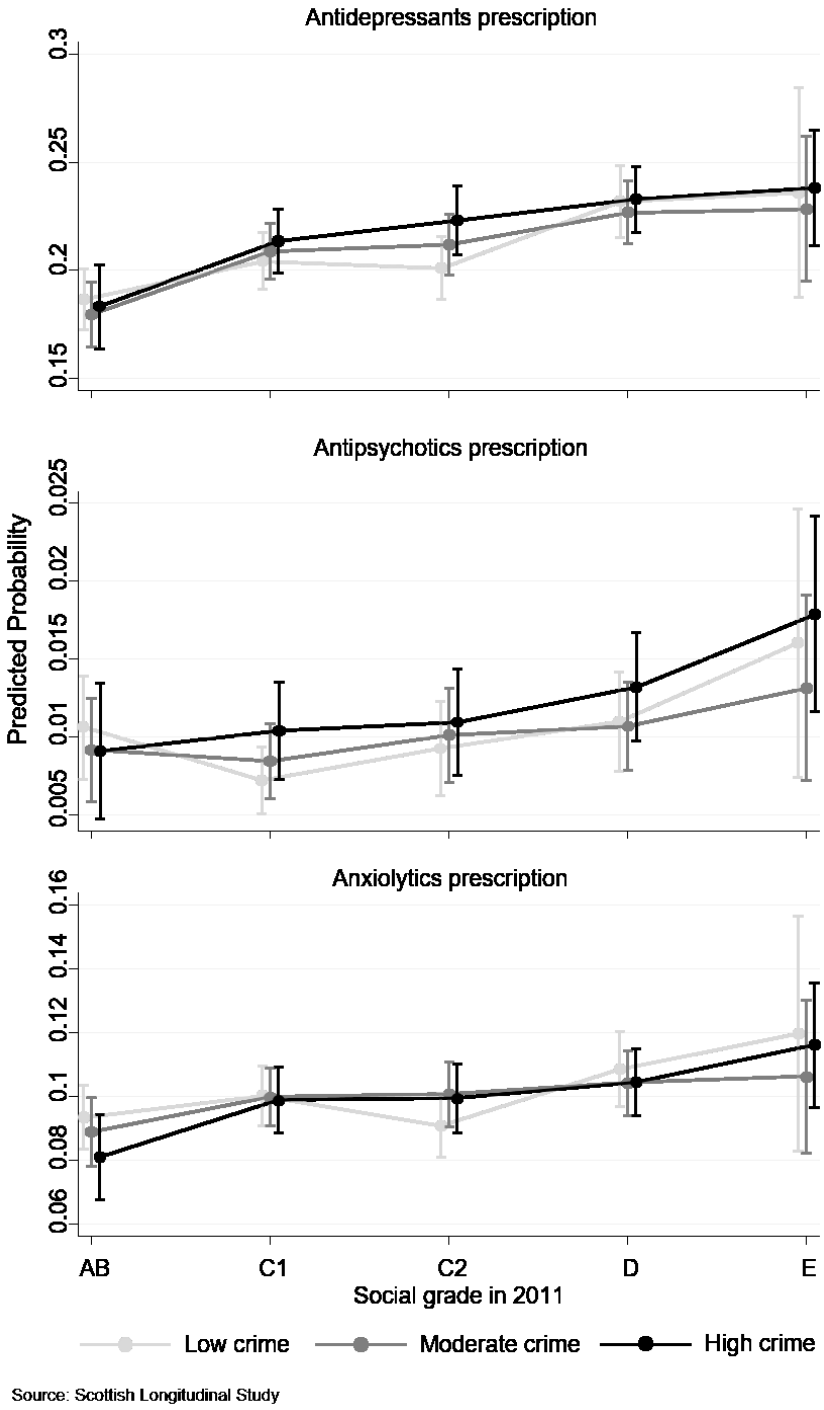
**Supplementary Table 5.4** Fully-adjusted models on new anxiolytics, and 'antidepressants or anxiolytics' prescriptions (*n*=129,945)

| Variable | Anxiolytics medication | | | Antidepressants or anxiolytics medication | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | p-value | OR | 95% CI | p-value |
| Gender | | | | | | |
| Male | Ref | | | Ref | | |
| Female | 1.67 | 1.61-1.73 | 0.000 | 1.84 | 1.79-1.88 | 0.000 |
| Age, years | | | | | | |
| 24–33 | Ref | | | Ref | | |
| 34–43 | 1.04 | 0.98-1.11 | 0.212 | 1.03 | 0.98-1.08 | 0.204 |
| 44–53 | 0.96 | 0.90-1.03 | 0.235 | 1.00 | 0.95-1.05 | 0.969 |
| 54–63 | 0.82 | 0.76-0.89 | 0.000 | 0.81 | 0.77-0.86 | 0.000 |
| 64–73 | 0.79 | 0.72-0.88 | 0.000 | 0.81 | 0.76-0.87 | 0.000 |
| 74–83 | 0.76 | 0.68-0.85 | 0.000 | 0.84 | 0.78-0.91 | 0.000 |
| ≥84 | 0.70 | 0.59-0.82 | 0.000 | 0.81 | 0.72-0.90 | 0.000 |
| Ethnicity | | | | | | |
| White | Ref | | | Ref | | |
| Non-White | 0.70 | 0.58-0.83 | 0.000 | 0.77 | 0.69-0.87 | 0.000 |
| Missing | 1.06 | 0.95-1.18 | 0.316 | 1.09 | 1.01-1.18 | 0.031 |
| Social Grade | | | | | | |
| AB | Ref | | | Ref | | |
| C1 | 1.13 | 1.06-1.19 | 0.000 | 1.15 | 1.10-1.20 | 0.000 |
| C2 | 1.09 | 1.02-1.17 | 0.008 | 1.16 | 1.10-1.21 | 0.000 |
| D | 1.20 | 1.12-1.28 | 0.000 | 1.27 | 1.22-1.34 | 0.000 |
| F | 1.30 | 1.17-1.45 | 0.000 | 1.32 | 1.22-1.43 | 0.000 |
| Educational attainment | | | | | | |
| No qualification | Ref | | | Ref | | |
| Level 1 | 0.98 | 0.92-1.03 | 0.375 | 0.95 | 0.92-0.99 | 0.012 |
| Level 2 | 0.85 | 0.79-0.91 | 0.000 | 0.83 | 0.79-0.87 | 0.000 |
| Level 3 | 0.88 | 0.82-0.95 | 0.001 | 0.88 | 0.84-0.92 | 0.000 |
| Level 4 | 0.79 | 0.75-0.84 | 0.000 | 0.74 | 0.71-0.77 | 0.000 |
| Employment status | | | | | | |
| Employed | Ref | | | Ref | | |
| Retired | 1.10 | 1.03-1.19 | 0.007 | 1.09 | 1.04-1.15 | 0.001 |
| Out of labour force | 1.42 | 1.34-1.51 | 0.000 | 1.64 | 1.56-1.71 | 0.000 |
| Unemployed | 1.29 | 1.16-1.43 | 0.000 | 1.59 | 1.48-1.71 | 0.000 |
| Marital status | | | | | | |
| Married | Ref | | | Ref | | |
| Single | 0.92 | 0.87-0.97 | 0.005 | 0.92 | 0.89-0.96 | 0.000 |
| Separated | 1.23 | 1.12-1.35 | 0.000 | 1.45 | 1.35-1.55 | 0.000 |
| Divorced | 1.14 | 1.07-1.22 | 0.000 | 1.26 | 1.20-1.32 | 0.000 |
| Widowed | 0.90 | 0.83-0.98 | 0.017 | 0.96 | 0.90-1.02 | 0.166 |
| Living status | | | | | | |
| Living with others | Ref | | | Ref | | |
| Living alone | 0.95 | 0.90-1.01 | 0.105 | 0.97 | 0.93-1.02 | 0.208 |
| Long-term illness, disease or condition | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| No | Ref | | | Ref | | |
| Yes | 1.44 | 1.38-1.50 | 0.000 | 1.60 | 1.55-1.65 | 0.000 |
| Area population density | 1.01 | 1.00-1.01 | 0.158 | 1.01 | 1.00-1.01 | 0.008 |
| Area income deprivation | | | | | | |
| Low | Ref | | | Ref | | |
| Moderate | 1.06 | 1.01-1.12 | 0.016 | 1.10 | 1.06-1.14 | 0.000 |
| High | 1.09 | 1.02-1.16 | 0.009 | 1.19 | 1.14-1.25 | 0.000 |
| Area crime levels | | | | | | |
| Low | Ref | | | Ref | | |
| Moderate | 1.00 | 0.95-1.05 | 0.915 | 1.01 | 0.97-1.04 | 0.641 |
| High | 0.99 | 0.93-1.05 | 0.630 | 1.04 | 0.99-1.08 | 0.098 |

Source: Scottish Longitudinal Study. OR, Odds Ratio; CI, Confidence Interval.

**Supplementary Figure 5.3** Adjusted predictions for new psychotropic medications by social grade and crime levels (*n*=129,945)




Source: Scottish Longitudinal Study

Models were adjusted for gender, age, ethnicity, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition, area population density and area income deprivation; and corrected for multiple comparison (Bonferroni correction). AB, Higher or intermediate managerial, administrative or professional grade; C1, Supervisory, clerical and junior managerial, administrative and professional; C2, Skilled manual workers; D, Semi-skilled and unskilled manual workers; E, State pensioners, casual and lowest grade workers, unemployed with state benefits only.

**Supplementary Table 5.5** Associations between crime, area income deprivation and at least six new psychotropic prescriptions (*n*=129,945)

| Variable | | Model 1[a] | Model 2[b] | Model 3[c] | Model 3: Male | Model 3: Female |
|---|---|---|---|---|---|---|
| **Antidepressants** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.18 (1.13-1.24)** | **1.07 (1.02-1.12)** | 1.01 (0.96-1.06) | 1.03 (0.94-1.12) | 0.99 (0.93-1.05) |
| | High | **1.45 (1.38-1.52)** | **1.16 (1.10-1.22)** | 1.03 (0.97-1.10) | 1.07 (0.96-1.18) | 1.01 (0.93-1.08) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.13 (1.08-1.19)** | **1.10 (1.01-1.20)** | **1.15 (1.07-1.22)** |
| | High | | | **1.24 (1.16-1.33)** | **1.15 (1.03-1.29)** | **1.28 (1.18-1.39)** |
| $ICC_{Local\ Authority}$ | | 0.22 (0.11-0.45) | 0.13 (0.05-0.30) | 0.12 (0.05-0.28)[d] | 0.08 (0.01-0.53)[d] | 0.14 (0.05-0.41)[d] |
| **Antipsychotics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.34 (1.09-1.65)** | 1.16 (0.94-1.43) | 1.13 (0.90-1.41) | 1.02 (0.73-1.44) | 1.21 (0.89-1.64) |
| | High | **2.29 (1.88-2.79)** | **1.60 (1.30-1.98)** | **1.57 (1.22-2.03)** | **1.58 (1.10-2.29)** | **1.52 (1.08-2.15)** |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | 1.13 (0.90-1.42) | 1.26 (0.90-1.76) | 1.05 (0.78-1.42) |
| | High | | | 1.04 (0.79-1.37) | 1.19 (0.79-1.78) | 0.92 (0.64-1.32) |
| $ICC_{Local\ Authority}$ | | 1.01 (0.30-3.35) | 1.45 (0.54-3.85) | 1.41 (0.52-3.80) | 2.22 (0.73-6.55) | 0.39 (0.01-15.40)[d] |
| **Anxiolytics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.22 (1.07-1.39)** | 1.08 (0.94-1.23) | 1.01 (0.87-1.16) | 1.03 (0.82-1.30) | 0.98 (0.82-1.18) |
| | High | **1.34 (1.17-1.54)** | 0.99 (0.86-1.15) | 0.90 (0.75-1.07) | 0.95 (0.72-1.26) | 0.86 (0.69-1.07) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.18 (1.02-1.37)** | 1.19 (0.94-1.51) | 1.18 (0.98-1.43) |
| | High | | | **1.21 (1.01-1.46)** | 1.18 (0.88-1.59) | 1.25 (0.98-1.58) |
| $ICC_{Local\ Authority}$ | | 0.68 (0.26-1.77) | 0.54 (0.17-1.70) | 0.49 (0.14-1.67) | 0.01 (0.00-1.00)[d] | 0.52 (0.12-2.21) |

Source: Scottish Longitudinal Study. ICC, intraclass correlation coefficient.

Note: Boldface indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Estimates are expressed in OR with 95% CI.

[a] Model 1: Adjusted for gender and age.
[b] Model 2: Model 1 + adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition and area population density.
[c] Model 3: Model 3 + adjusted for area income deprivation.
[d] Likelihood ratio test could not detect random effects variance

**Supplementary Table 5.6** Associations between crime, area income deprivation and new prescriptions for 'antidepressants or anxiolytics' (*n*=129,945)

| Variable | | Model 1[a] | Model 2[b] | Model 3[c] | Model 3: Male | Model 3: Female |
|---|---|---|---|---|---|---|
| **Antidepressants or anxiolytics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.15 (1.12-1.19)** | **1.06 (1.03-1.09)** | 1.01 (0.97-1.04) | 1.01 (0.96-1.06) | 1.01 (0.96-1.05) |
| | High | **1.36 (1.32-1.41)** | **1.14 (1.10-1.18)** | 1.04 (0.99-1.08) | 1.02 (0.96-1.09) | 1.04 (0.98-1.10) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.10 (1.06-1.14)** | **1.09 (1.04-1.15)** | **1.10 (1.05-1.15)** |
| | High | | | **1.19 (1.14-1.25)** | **1.14 (1.06-1.22)** | **1.22 (1.15-1.30)** |
| $ICC_{Local\ Authority}$ | | 0.22 (0.12-0.39) | 0.16 (0.09-0.31) | 0.15 (0.08-0.29) | 0.11 (0.04-0.30)[d] | 0.16 (0.08-0.34) |

Source: Scottish Longitudinal Study. ICC, intraclass correlation coefficient.

Note: Boldface indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Estimates are expressed in OR with 95% CI.

[a] Model 1: Adjusted for gender and age.

[b] Model 2: Model 1 + adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition and area population density.

[c] Model 3: Model 3 + adjusted for area income deprivation.

[d] Likelihood ratio test could not detect random effects variance

**Supplementary Table 5.7** Associations between crime, area income deprivation and new prescriptions among adults, who stayed in the same residential area during the study (*n*=90,637)

| Variable | | Model 1[a] | Model 2[b] | Model 3[c] | Model 3: Male | Model 3: Female |
|---|---|---|---|---|---|---|
| **Antidepressants** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.16 (1.12-1.21)** | **1.07 (1.03-1.12)** | 1.02 (0.98-1.06) | 0.99 (0.93-1.06) | 1.03 (0.98-1.09) |
| | High | **1.36 (1.31-1.42)** | **1.15 (1.10-1.20)** | 1.05 (0.99-1.11) | 1.00 (0.92-1.09) | 1.07 (1.00-1.15) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | **1.11 (1.06-1.16)** | **1.13 (1.05-1.21)** | **1.10 (1.04-1.17)** |
| | High | | | **1.18 (1.12-1.26)** | **1.17 (1.06-1.28)** | **1.19 (1.11-1.29)** |
| $ICC_{Local\ Authority}$ | | 0.38 (0.21-0.71) | 0.27 (0.14-0.54) | 0.24 (0.12-0.49) | 0.16 (0.05-0.52) | 0.23 (0.10-0.51) |
| **Antipsychotics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | 1.15 (0.99-1.33) | 1.05 (0.90-1.22) | 1.01 (0.86-1.20) | 1.15 (0.91-1.47) | 0.90 (0.72-1.13) |
| | High | **1.43 (1.23-1.67)** | 1.16 (0.98-1.36) | 1.09 (0.90-1.33) | **1.39 (1.04-1.85)** | 0.88 (0.67-1.16) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | 1.09 (0.92-1.29) | 0.99 (0.78-1.26) | 1.18 (0.93-1.49) |
| | High | | | 1.11 (0.90-1.38) | 1.05 (0.78-1.43) | 1.14 (0.84-1.53) |
| $ICC_{Local\ Authority}$ | | 1.60 (0.71-3.59) | 1.79 (0.82-3.86) | 1.81 (0.83-3.88) | 3.07 (1.38-6.69) | 1.27 (0.34-4.67) |
| **Anxiolytics** | | | | | | |
| Crime level | Low | Ref | Ref | Ref | Ref | Ref |
| | Moderate | **1.07 (1.02-1.13)** | 1.02 (0.97-1.08) | 1.00 (0.94-1.06) | 0.97 (0.88-1.06) | 1.02 (0.94-1.09) |
| | High | **1.13 (1.06-1.19)** | 1.01 (0.95-1.07) | 0.98 (0.91-1.05) | 0.95 (0.84-1.07) | 0.99 (0.91-1.09) |
| Income deprivation | Low | | | Ref | Ref | Ref |
| | Moderate | | | 1.06 (0.99-1.12) | 1.08 (0.98-1.18) | 1.04 (0.97-1.13) |
| | High | | | 1.07 (0.99-1.15) | 1.06 (0.93-1.20) | 1.06 (0.97-1.17) |
| $ICC_{Local\ Authority}$ | | 0.40 (0.21-0.75) | 0.40 (0.21-0.77) | 0.40 (0.21-0.77) | 0.39 (0.15-1.00) | 0.46 (0.23-0.91) |

Source: Scottish Longitudinal Study. ICC, intraclass correlation coefficient.
Note: Boldface indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Estimates are expressed in OR with 95% CI.
[a] Model 1: Adjusted for gender and age.
[b] Model 2: Model 1 + adjusted for ethnicity, social grade, educational attainment, employment status, marital status, living status, having a long-term illness, disease or condition and area population density.
[c] Model 3: Model 3 + adjusted for area income deprivation.

**Supplementary Table 5.8:** Variance inflation factors exploring multicollinearity between independent variables

| Variable | VIF | 1/VIF |
|---|---|---|
| Gender | | |
| Male | Ref | |
| Female | 1.06 | 0.945992 |
| Age, years | | |
| 24–33 | Ref | |
| 34–43 | 2.02 | 0.496090 |
| 44–53 | 2.35 | 0.424995 |
| 54–63 | 2.65 | 0.377413 |
| 64–73 | 3.66 | 0.272894 |
| 74–83 | 3.00 | 0.333414 |
| ≥84 | 1.66 | 0.602710 |
| Ethnicity | | |
| White | Ref | |
| Non-White | 1.01 | 0.990741 |
| Missing | 1.01 | 0.987965 |
| Social Grade | | |
| AB | Ref | |
| C1 | 2.08 | 0.481217 |
| C2 | 2.18 | 0.459111 |
| D | 2.37 | 0.421804 |
| F | 1.39 | 0.719562 |
| Educational attainment | | |
| No qualification | Ref | |
| Level 1 | 2.37 | 0.421323 |
| Level 2 | 1.74 | 0.576230 |
| Level 3 | 1.41 | 0.708546 |
| Level 4 | 1.33 | 0.751811 |
| Employment status | | |
| Employed | Ref | |
| Retired | 3.25 | 0.307746 |
| Out of labour force | 1.14 | 0.878426 |
| Unemployed | 1.05 | 0.949093 |
| Marital status | | |
| Married | Ref | |
| Single | 1.72 | 0.579954 |
| Separated | 1.10 | 0.909996 |
| Divorced | 1.25 | 0.797121 |
| Widowed | 1.85 | 0.539446 |
| Living status | | |

| | | |
|---|---|---|
| Living with others | Ref | |
| Living alone | 1.76 | 0.566948 |
| Long-term illness, disease or condition | | |
| No | Ref | |
| Yes | 1.10 | 0.908443 |
| Area population density | 1.12 | 0.890243 |
| Area income deprivation | | |
| Low | Ref | |
| Moderate | 1.57 | 0.635640 |
| High | 2.21 | 0.451957 |
| Area crime levels | | |
| Low | Ref | |
| Moderate | 1.55 | 0.643408 |
| High | 2.36 | 0.423436 |
| **Mean** | **1.82** | |

Abbreviations: VIF, variance inflation factor.

## 8.5 Appendix Five: Supplementary Material for Chapter 6

**Contents**

**Supplementary Table 6.1:** Description of the covariates.[a]

| Variable | Description |
|---|---|
| Sex in 2001 | Male, Female |
| Age in 2001 | Derived from the date of birth question |
| Ethnicity in 2001 | |
| White | White Scottish, Other White British, White Irish, Other White |
| Non-white | Any Mixed Background, Indian, Pakistani, Bangladeshi, Other South Asian, Caribbean, African, Black Scottish or Other Black, Chinese, Other Ethnic Group |
| Educational attainment 2001/2011 | |
| No qualification | No professional, vocational or academic qualifications |
| Level 1 | O Grade, Standard Grade, Access 3 Cluster, Intermediate 1 or 2, GCSE, CSE, Senior Certificate or equivalent; GSVQ Foundation or Intermediate, SVQ level 1 or 2, SCOTVEC Module, City and Guilds Craft or equivalent; Other school qualifications not already mentioned (including foreign qualifications) |
| Level 2 | SCE Higher Grade, Higher, Advanced Higher, CSYS, A Level, AS Level, Advanced Senior Certificate or equivalent; GSVQ Advanced, SVQ level 3, ONC, OND, SCOTVEC National Diploma, City and Guilds Advanced Craft or equivalent |
| Level 3 | HNC, HND, SVQ level 4 or equivalent; Other post-school but pre-Higher Education qualifications not already mentioned (including foreign qualifications) |
| Level 4 | Degree, Postgraduate qualifications, Masters, PhD, SVQ level 5 or equivalent; Professional qualifications (for example, teaching, nursing, accountancy); Other Higher Education qualifications not already mentioned (including foreign qualifications) |
| Social class based on occupation 2001 | |
| I/II | Professional, managerial and technical occupations |
| IIIN | Skilled non-manual occupations |
| IIIM | Skilled manual occupations |
| IV | Partly skilled occupations |
| V | Unskilled occupations |
| Other | Non-resident students and people who never worked |
| Social grade in 2011[b] | |
| AB | Higher or intermediate managerial, administrative or professional |
| C1 | Supervisory, clerical and junior managerial, administrative and professional |
| C2 | Skilled manual workers |
| D | Semi-skilled and unskilled manual workers |

| | | |
|---|---|---|
| | E | State pensioners, casual and lowest grade workers, unemployed with state benefits only |
| Employment status 2001/2011 | | |
| | In employment | Economically active: In employment (part-time, full-time) |
| | Retired | Economically inactive: Retired |
| | Out of labour force | Economically inactive: Student; Looking after home or family; Long-term sick or disabled; Other |
| | Unemployed | Economically active: Unemployed (Seeking work and available to start in 2 weeks or waiting to start a job already obtained) |
| Marital status in 2001/2011 | | |
| | Married | Married; In a registered same-sex civil partnership |
| | Single | Never married and never registered a same-sex civil partnership |
| | Separated | Separated, but still legally married; Separated, but still legally in a same-sex civil partnership |
| | Divorced | Divorced; Formerly in a same-sex civil partnership which is now legally dissolved |
| | Widowed | Widowed; Surviving partner from a same-sex civil partnership |
| Living status in 2001/2011 | | |
| | Alone | One Person Household |
| | With others | Other Households |
| Long-term illness in 2001 | | |
| | Yes | Has a long-term illness, health problem or disability which limits daily activities or work (including problems which are due to old age) |
| | No | Does not a long-term illness, health problem or disability which limits daily activities or work (including problems which are due to old age) |

[a] Source: https://sls.lscs.ac.uk/variables

[b] http://www.nrs.co.uk/nrs-print/lifestyle-and-classification-data/social-grade/

**Supplementary Table 6.2**: Sample size and percentage of individuals with mental health problems by age and moving status.

| | **Total sample** (n=112 251) | | **Stayers** (n=80 958) | | **Past movers**[a] (n=15 940) | | **Recent movers**[b] (n=15 353) | |
|---|---|---|---|---|---|---|---|---|
| | n | % of cases | n | % of cases | n | % of cases | n | % of cases |
| **Self-reported mental-health** | | | | | | | | |
| 16-30 years old | 30000[c] | 5 | 15000[c] | 5 | 7000[c] | 5 | 8000[c] | 7 |
| 31-45 years old | 45000[c] | 6 | 34000[c] | 5 | 6000[c] | 6 | 5000[c] | 9 |
| 46-60 years old | 37000[c] | 4 | 32000[c] | 4 | 3000[c] | 5 | 2000[c] | 6 |
| **Antidepressant prescriptions** | | | | | | | | |
| 16-30 years old | 30000[c] | 12 | 15000[c] | 12 | 7000[c] | 12 | 8000[c] | 13 |
| 31-45 years old | 45000[c] | 15 | 34000[c] | 14 | 6000[c] | 16 | 5000[c] | 21 |
| 46-60 years old | 37000[c] | 15 | 32000[c] | 15 | 3000[c] | 19 | 2000[c] | 20 |
| **Antipsychotic prescriptions** | | | | | | | | |
| 16-30 years old | 30000[c] | 1 | 15000[c] | 1 | 7000[c] | 1 | 8000[c] | 1 |
| 31-45 years old | 45000[c] | 1 | 34000[c] | 1 | 6000[c] | 1 | 5000[c] | 3 |
| 46-60 years old | 37000[c] | 1 | 32000[c] | 1 | 3000[c] | 1 | 2000[c] | 2 |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001.

[a] Main residential location changed between 2004/06 and 2007/09.

[b] Main residential location changed between 2007/09 and 2010/12.

[c] Numbers are rounded to avoid risk of disclosure.

**Supplementary Table 6.2** Average crime exposure and change in crime exposure per age groups and residential status.

| | **Total sample (n=112 251)** | | **Stayers (n=80 958)** | | **Past movers[a] (n=15 940)** | | **Recent movers[b] (n=15 353)** | |
|---|---|---|---|---|---|---|---|---|
| | Average crime exposure (SD) | Change in crime exposure (2007/09-2010/12) | Average crime exposure (SD) | Change in crime exposure (2007/09-2010/12) | Average crime exposure (SD) | Change in crime exposure (2004/06-2007/09) | Average crime exposure (SD) | Change in crime exposure (2007/09-2010/12) |
| Total sample | 44.2 (47.1) | -6.9 (25.5) | 42.3 (47.3) | -6.2 (15.3) | 47.3 (44.6) | -9.0 (57.0) | 51.3 (47.9) | -9.3 (51.6) |
| 16-30 years old | 49.2 (53.2) | -8.3 (34.4) | 46.8 (57.5) | -6.8 (17.3) | 49.6 (47.6) | -10.1 (64.1) | 53.3 (49.4) | -10.3 (55.0) |
| 31-45 years old | 42.8 (45.5) | -6.6 (22.6) | 41.4 (45.6) | -6.1 (15.1) | 45.3 (42.6) | -8.2 (50.8) | 49.4 (47.1) | -8.7 (47.3) |
| 46-60 years old | 41.9 (43.4) | -6.1 (19.3) | 41.1 (43.5) | -6.0 (14.4) | 45.4 (39.9) | -7.1 (47.8) | 48.6 (44.0) | -7.0 (48.4) |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001. SD, Standard deviation.

[a] Main residential location changed between 2004/06 and 2007/09.

[b] Main residential location changed between 2007/09 and 2010/12.

**Supplementary Table 6.4** Sensitivity analysis presenting main findings further adjusted for data zone-level average income deprivation and change in income deprivation.

| | Total sample (n=112 251) | | Stayers (n=80 958) | | Past movers[a] (n=15 940) | | Recent movers[b] (n=15 353) | |
|---|---|---|---|---|---|---|---|---|
| | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2004/06}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) |
| **Self-reported mental-health** | | | | | | | | |
| 16-30 years old | **1.42 (1.08-1.87)** | 1.01 (0.99-1.04) | **1.39 (1.00-1.94)** | 1.08 (0.98-1.20) | 1.20 (0.66-2.18) | 1.01 (0.96-1.06) | 1.39 (0.91-2.11) | 1.00 (0.96-1.04) |
| 31-45 years old | 1.01 (0.84-1.23) | 1.04 (0.99-1.08) | 0.94 (0.74-1.20) | 0.99 (0.90-1.09) | 0.94 (0.53-1.68) | 1.03 (0.96-1.11) | 0.99 (0.59-1.66) | *1.06 (0.99-1.13)* |
| 46-60 years old | 1.11 (0.87-1.42) | 0.98 (0.94-1.03) | 1.09 (0.83-1.42) | 0.96 (0.87-1.05) | 1.11 (0.54-2.31) | 1.02 (0.95-1.09) | 0.55 (0.21-1.39) | 0.99 (0.90-1.10) |
| All ages | 1.12 (0.95-1.33) | 1.02 (0.99-1.04) | 1.07 (0.90-1.27) | 1.00 (0.93-1.08) | 1.08 (0.75-1.55) | 1.01 (0.98-1.04) | 1.07 (0.74-1.56) | 1.02 (0.99-1.05) |
| **Antidepressants medication** | | | | | | | | |
| 16-30 years old | 1.03 (0.86-1.24) | 1.01 (0.99-1.03) | 1.07 (0.86-1.34) | **1.07 (1.02-1.12)** | 0.90 (0.60-1.34) | 1.01 (0.97-1.05) | 0.91 (0.69-1.20) | 0.99 (0.96-1.03) |
| 31-45 years old | 0.98 (0.87-1.10) | 1.00 (0.96-1.03) | 0.90 (0.77-1.06) | 0.99 (0.92-1.05) | 0.87 (0.65-1.17) | 1.02 (0.98-1.05) | 1.29 (0.86-1.93) | 1.00 (0.96-1.03) |
| 46-60 years old | 1.05 (0.94-1.18) | 0.98 (0.95-1.02) | 1.06 (0.95-1.19) | 0.97 (0.92-1.01) | 1.00 (0.58-1.72) | 0.96 (0.89-1.03) | **0.55 (0.34-0.89)** | 1.00 (0.93-1.08) |
| All ages | 1.02 (0.93-1.12) | 1.00 (0.98-1.02) | 1.00 (0.91-1.10) | 0.99 (0.96-1.02) | 0.92 (0.71-1.20) | 1.00 (0.98-1.03) | 0.94 (0.75-1.18) | 0.99 (0.96-1.03) |
| **Antipsychotics medication** | | | | | | | | |
| 16-30 years old | 1.27 (0.78-2.05) | 1.01 (0.92-1.11) | 1.39 (0.67-2.87) | 1.24 (0.89-1.74) | 1.46 (0.47-4.54) | 1.04 (0.98-1.10) | 0.87 (0.37-2.07) | 0.94 (0.88-1.02) |
| 31-45 years old | 1.15 (0.72-1.83) | *1.10 (1.00-1.21)* | 1.02 (0.63-1.68) | 1.03 (0.88-1.22) | 0.75 (0.22-2.62) | 1.04 (0.93-1.16) | 1.95 (0.71-5.36) | **1.14 (1.03-1.26)** |
| 46-60 years old | 1.53 (1.04-2.26) | 1.05 (0.96-1.15) | **1.80 (1.13-2.87)** | 1.14 (0.95-1.37) | 0.46 (0.10-2.10) | 0.96 (0.83-1.10) | 0.63 (0.16-2.45) | 1.04 (0.89-1.22) |
| All ages | **1.27 (1.01-1.59)** | **1.05 (1.00-1.10)** | **1.37 (1.03-1.82)** | 1.10 (0.98-1.24) | 0.93 (0.47-1.86) | 1.02 (0.95-1.09) | 1.21 (0.64-2.28) | 1.05 (0.98-1.12) |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001. Bold text indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Average crime exposure is log10-transformed, change in crime exposure is standardized. Models were fitted with logistic regression applying cluster robust estimation at local authority level; estimates are expressed in OR with 95% CI. All models included average and change variables at the same time, and were adjusted for sex, age (and age-squared in the non-stratified total sample), 2001 baseline covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness), psychiatric inpatient service use in 2001/03, 2001 – 2011 change indicators (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and social grade in 2011.

[a] Main residential location changed between 2004/06 and 2007/09.

[b] Main residential location changed between 2007/09 and 2010/12.

**Supplementary Table 6.5:** Sensitivity analysis presenting main findings among individuals who stayed at the same residential data zone during the entire study period.

| | **Stayers (n=71 000)[a]** | |
|---|---|---|
| | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) |
| **Self-reported mental-health** | | |
| 16-30 years old | **1.72 (1.29-2.30)** | *1.10 (0.99-1.22)* |
| 31-45 years old | **1.29 (1.03-1.62)** | 1.01 (0.91-1.11) |
| 46-60 years old | **1.32 (1.07-1.63)** | 0.95 (0.86-1.06) |
| All ages | **1.38 (1.20-1.59)** | 1.01 (0.93-1.09) |
| **Antidepressants medication** | | |
| 16-30 years old | **1.39 (1.15-1.66)** | *1.05 (0.99-1.12)* |
| 31-45 years old | **1.18 (1.05-1.34)** | 1.00 (0.93-1.08) |
| 46-60 years old | **1.26 (1.15-1.38)** | 0.97 (0.93-1.02) |
| All ages | **1.26 (1.17-1.35)** | 1.00 (0.96-1.03) |
| **Antipsychotics medication** | | |
| 16-30 years old | 1.17 (0.71-1.92) | 1.12 (0.75-1.66) |
| 31-45 years old | 1.13 (0.74-1.73) | 1.07 (0.89-1.28) |
| 46-60 years old | **1.45 (1.05-2.00)** | 1.14 (0.96-1.34) |
| All ages | **1.28 (1.02-1.60)** | 1.10 (0.98-1.25) |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001. Bold text indicates significant associations ($p<0.05$), italic trend-wise ($p<0.1$). Average crime exposure is log10-transformed, change in crime exposure is standardized. Models were fitted with logistic regression applying cluster robust estimation at local authority level; estimates are expressed in OR with 95% CI. All models included average and change variables at the same time, and were adjusted for sex, age (and age-squared in the non-stratified total sample), 2001 baseline covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness), psychiatric inpatient service use in 2001/03, 2001 – 2011 change indicators (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and social grade in 2011.

[a] Number is rounded to avoid risk of disclosure.

**Supplementary Table 6.6** Sensitivity analysis presenting main findings after excluding participants with psychiatric inpatient service use in 2001/09 and psychotropic medications in 2009.

| | **Total sample (n=93 000)[a]** | | **Stayers** | | **Past movers[a]** | | **Recent movers[b]** | |
|---|---|---|---|---|---|---|---|---|
| | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2004/06}$) | Average crime exposure ($\bar{x}$) | Change in crime exposure ($x_{\Delta 2010/12}$) |
| **Self-reported mental-health** | | | | | | | | |
| 16-30 years old | **1.68 (1.28-2.21)** | 1.03 (0.99-1.07) | **1.76 (1.16-2.68)** | 1.08 (0.92-1.26) | 1.48 (0.84-2.62) | *1.05 (1.00-1.11)* | 1.54 (0.83-2.88) | 1.02 (0.96-1.09) |
| 31-45 years old | **1.84 (1.40-2.43)** | 1.05 (0.98-1.12) | **1.77 (1.27-2.46)** | 1.02 (0.83-1.25) | 1.55 (0.79-3.05) | 1.00 (0.94-1.06) | *1.87 (0.93-3.74)* | *1.08 (1.00-1.17)* |
| 46-60 years old | **1.50 (1.05-2.14)** | 0.99 (0.91-1.07) | 1.34 (0.93-1.93) | 0.90 (0.75-1.07) | 1.25 (0.63-2.49) | 1.06 (0.98-1.14) | 2.47 (0.58-10.54) | 1.01 (0.82-1.25) |
| All ages | **1.71 (1.44-2.04)** | 1.03 (0.99-1.06) | **1.66 (1.33-2.07)** | 1.00 (0.88-1.14) | **1.59 (1.09-2.30)** | **1.03 (1.00-1.06)** | **1.73 (1.08-2.78)** | *1.04 (0.99-1.08)* |
| **Antidepressants medication** | | | | | | | | |
| 16-30 years old | **1.20 (1.02-1.41)** | 1.03 (0.99-1.06) | **1.27 (1.01-1.60)** | **1.12 (1.04-1.21)** | 1.26 (0.92-1.73) | 1.01 (0.97-1.05) | 1.00 (0.75-1.34) | 1.02 (0.98-1.06) |
| 31-45 years old | **1.22 (1.07-1.39)** | 0.99 (0.95-1.03) | *1.16 (0.99-1.35)* | 0.99 (0.87-1.13) | 1.29 (0.91-1.83) | 0.97 (0.94-1.01) | **1.53 (1.04-2.25)** | 1.00 (0.96-1.04) |
| 46-60 years old | *1.19 (0.99-1.41)* | 0.98 (0.91-1.07) | **1.26 (1.04-1.54)** | 1.01 (0.91-1.11) | 0.85 (0.51-1.42) | **0.92 (0.85-1.00)** | 0.64 (0.31-1.34) | 0.99 (0.87-1.12) |
| All ages | **1.22 (1.12-1.34)** | 1.01 (0.98-1.03) | **1.24 (1.14-1.35)** | 1.03 (0.96-1.10) | **1.21 (1.00-1.46)** | *0.98 (0.96-1.00)* | 1.09 (0.85-1.39) | 1.01 (0.97-1.04) |
| **Antipsychotics medication** | | | | | | | | |
| 16-30 years old | **3.26 (1.03-10.27)** | 0.97 (0.85-1.11) | **4.55 (1.31-15.88)** | **1.59 (1.07-2.37)** | [d] | [d] | [d] | [d] |
| 31-45 years old | **2.16 (1.04-4.47)** | 1.03 (0.86-1.23) | 1.58 (0.60-4.16) | 0.94 (0.77-1.15) | [d] | [d] | [d] | [d] |
| 46-60 years old | 1.34 (0.29-6.18) | 0.81 (0.60-1.07) | 1.15 (0.20-6.65) | 0.94 (0.37-2.41) | [d] | [d] | [d] | [d] |
| All ages | **2.33 (1.22-4.44)** | 0.96 (0.91-1.02) | 2.07 (0.84-5.07) | 1.05 (0.72-1.53) | [d] | [d] | [d] | [d] |

Source: Scottish Longitudinal Study.

Note: Age cohorts relate to age in 2001. Bold text indicates significant associations ($p < 0.05$), italic trend-wise ($p < 0.1$). Average crime exposure is log10-transformed, change in crime exposure is standardized. Models were fitted with Poisson regression applying cluster robust estimation at local authority level; estimates are expressed in IRR with 95% CI. All models included average and change variables at the same time, and were adjusted for sex, age (and age-squared in the non-stratified total sample), 2001 baseline covariates (ethnicity; education; social class; employment; marital status; living status; long-term illness), psychiatric inpatient service use in 2001/03, 2001 – 2011 change indicators (gained higher level of education; separated, divorced or widowed; started to live alone; became unemployed or left labour force) and social grade in 2011.

[a] Number is rounded to avoid risk of disclosure.

[b] Main residential location changed between 2004/06 and 2007/09.

[c] Main residential location changed between 2007/09 and 2010/12.

[d] Could not be estimated because of the very low number of cases.

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