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A systematic review of the relationship between objective measurements of the urban environment and psychological distress

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ABSTRACT

The urban environment has become the main place that people live and work. As a result it can have profound impacts on our health. While much of the literature has focused on physical health, less attention has been paid to the possible psychological impacts of the urban environment. In order to understand the potential relevance and importance of the urban environment to population mental health, we carried out a systematic review to examine the associations between objective measurements of the urban environment and psychological distress, independently of the individual's subjective perceptions of the urban environment.

11 peer-reviewed papers published in English between January 2000 and February 2012 were identified. All studies were cross-sectional. Despite heterogeneity in study design, the overall findings suggested that the urban environment has measurable associations with psychological distress, including housing with deck access, neighbourhood quality, the amount of green space, land-use mix, industry activity and traffic volume. The evidence supports the need for development of interventions to improve mental health through changing the urban environment. We also conclude that new methods for measuring the urban environment objectively are needed which are meaningful to planners. In particular, future work should look at the spatial-temporal dynamic of the urban environment measured in Geographical Information System (GIS) in relation to psychological distress.

1. Introduction

Good mental health and well-being is of great importance to a healthy and productive society. Psychological distress as a leading cause of morbidity and disability has been recognised as a substantial public health problem (Weich, 1997; HM Government, 2011), and accounts for most of the community burden of poor mental health (Goldberg and Huxley, 1980; Craig and Boardman, 1997; HM Government, 2011). Over the last twenty years there has been an increasing interest in the role of 'place' in explaining the widely observed geographical variation in population mental health status, with a focus on aspects of the small-area social environment such as economic activity, social and material deprivation and social cohesion (Macintyre et al., 1993; Paykel et al., 2000; Pickett and Pearl, 2001; Macintyre et al., 2002; Stafford and Marmot, 2003; Fone and Dunstan, 2006; Fone et al., 2007a; Fone et al., 2007b; Fone et al., 2014). Other studies suggest that the urban environment plays an important role along with individual and social factors. The urban environment here refers the physical form of a place which includes land use pattern, built features and the transportation system (Handy et al., 2002; Brownson et al., 2009). Together these elements may affect mental health through four possible mechanisms, including 1) as physiological stressors, 2) through social networks and support, 3) via symbolic effects played by architecture and planning and social labelling, and 4) via the planning process (Halpern, 1995).

Although eight reviews that have at least partly addressed the relationships between the urban environment and psychological distress have been published (Judd et al., 2002; Evans, 2003; Evans et al., 2003; Clark et al., 2006; Cutrona et al., 2006; Truong and Ma, 2006; Kim, 2008; Diez Roux and Mair, 2010), they have important limitations. First, only three were systematic reviews. Systematic reviews are a standard tool in medical research evidence synthesis to collect and appraise research evidence but only recently has this method been applied in cross-disciplinary work to build up a robust body of evidence (Weaver et al., 2002).

Second, a cross-disciplinary approach was not usually taken. Expertise in characterising the urban environment comes from geography, urban planning and architecture whereas expertise in measuring

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mental health is mainly in medical and psychological disciplines (Weaver et al., 2002). Of these three systematic reviews, one searched two medical databases (PubMed and PsycINFO) using MeSH (Medical Subject Headings) between 1980 and 2006 (Truong and Ma, 2006) one focused on PubMed (1966–2008) and the Social Sciences citation Index database (1956–2008) (Kim, 2008), and the third searched seven databases (1990–2005) (Clark et al., 2006).

Third, results may be limited by same-source bias as the majority of studies included in the review used self-reported measurement for both environmental variables and mental health outcomes (Campbell, 1982; Diez Roux and Mair, 2010). Although symptom severity of mental health can be measured in population surveys using validated and reliable questionnaire instruments, such as the General Health Questionnaire (GHQ) (Goldberg and Williams, 1988) and the Center for Epidemiologic Studies Depression Scale (CES-D) (Radloff, 1977), the measurement of the urban environment is much less robust and consistent. It is likely that an individual with poor mental health may report a general tendency towards negative perceptions of other measures when using self-reported methods. For example, Macleod et al. (2002)) found a strong and substantial relation between self-reported stress and self-reported symptoms of coronary heart disease. People who were depressed may be more likely to report that their neighbourhood had problems or low levels of social cohesion (Echeverría et al., 2008). Another limitation of self-reported methods is the difficulty of distinguishing personal perceptions with objective reality as health predictors. With the aim of improving mental health, the reported results can be difficult to translate into modification of the urban environment.

A cross-disciplinary approach to systematic reviews with an objective measure of the urban environment is clearly essential to obtain an unbiased picture of studies on the urban environment and psychological distress. Therefore, we have undertaken a cross-disciplinary systematic review of the relationship between objective measurements of the urban environment and psychological distress. It is worth noting that urban environment also includes some aspects of the "natural" environment (e.g. parks, green space) which are significantly modified by people in the context of a city and urbanised area. In this review, we include factors that might also be included in the social environment such as perceived safety which is related to the urban environment (Davison and Lawson, 2006).

2. Method

The systematic review was carried out using the PRISMA methodology (Liberati et al., 2009). The search strategy was formulated using a combination of keywords after inter-disciplinary consultation and agreement between a group with expertise in social science, epidemiology, planning and geography. Psychological distress was defined in this study as the common symptoms of depression and anxiety, but not psychiatric conditions classified as severe mental illness such as schizophrenia and schizoaffective disorder. We used the keywords "psychological distress", "psychological stress", "depression" "depressive disorder", "depressed", "anxiety", "anxious", or "common mental disorder" combined with "housing condition*", "housing quality", "built environment", "urban environment", "physical environment", "local environment", "open space", "public space", density, infrastructure*, facility, facilities, accessibility, walkable, walkability, neighborhood*, neighbourhood*, building*, transport, transportation, safety, crime, "land use" or land use in eight inter-disciplinary databases (Medline, Embase, Web of Science, PsycINFO, Scopus, CINAL, ASSIA and Open SIGLE) searching for papers published in English between January 2000 and February 2012.

The search identified 23,101 articles with an additional 16 articles identified from citation lists. After removing duplicates, 12,507 studies remained. The inclusion criteria were:

1) Quantitative human studies within a defined geographical setting.
2) Using objective measures of the urban environment - either by independent observation or Geographic Information System (GIS).
3) Using measures of anxiety, depression, psychological stress and common mental disorder.

We excluded opinion, review and comment articles, as well as studies without any geographical component, qualitative studies and studies that did not measure psychological distress and/or examine some aspect of the urban environment. Studies examining the distinctions between urban and rural areas were not included for reviewing in this paper, as the definitions of urban and rural areas used were generally based on population density, which varied based on geographic locations. Among 12,507 potential papers identified, 304 papers were selected for full-text assessment after screening the titles and abstracts. To ensure the screening process was accurate, 5% (626) of 12,507 titles and abstracts were randomly selected and were screened independently by a second reviewer. The level of agreement was high with three papers subject to disagreement on the inclusion criteria. This was resolved by discussion. The internal validation Kappa score was 0.93. After full-text assessment, 293 papers did not meet the inclusion criteria, leaving 11 studies included in the review (Fig. 1).

We assessed the methodological quality of each included paper using a critical appraisal pro-forma developed and validated by the Health Evidence Bulletin Wales project (Weightman et al., 2004), which is adopted from Critical Appraisal Skills Programme (CASP) and National Collaboration Centre for Environmental Health (see http://hebw.cf.ac.uk/methodology). The data abstracted included epidemiological parameters and applied urban planning concepts to assess the way in which the urban environment was measured and validated. Descriptive and outcome data were extracted, including sample size, response rate, age group, analytic framework and study design, definition of the spatial scale, methods of measuring the urban environment, validation of measures of the urban environment, methods of measuring psychological distress, validation of measures of psychological distress, adjusted confounders and the results (Table 1).

3. Results

In total, 11 papers based on 10 studies were selected. The disciplinary areas in which they were published were geography (3 articles),

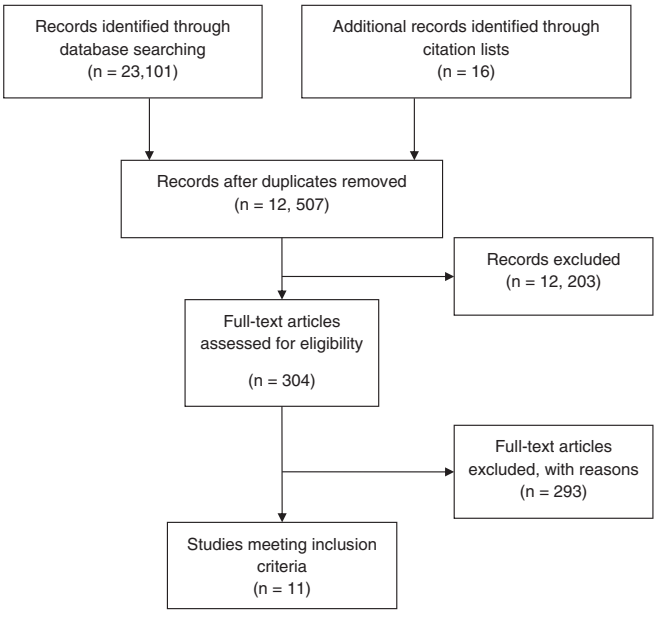

Fig. 1. Flow chart.

Table 1
Summary of the 11 studies.

(1) Independent observational measures of the urban environment studies.

Author year	Data set, source, and years	Sample size/response rate (individual level)	Age range (years)/mean age/SD age range	Analytical framework and study design/alpha level	Spatial scale: definition of geographic unit	Methods of measurement: measures of the urban environment	Psychological outcome: methods of measurement	Adjusted confounders	Results
(Weich et al., 2001)	A questionnaire survey in London	1902 residents of two inner city electoral wards in North London/64%	16 +/NA/NA	Logistic regression models/0.05	Neighbourhood: a housing area was defined as a geographically bounded area in which the majority of the housing was homogeneous in form and character.	**BESSC**: 1) items included the predominant form, height and age of housing, number of dwellings and type of access, provision of gardens, use of public space, amount of derelict land, security, and accessibility of local shops and amenities, 2) features of the built environment (e.g. the proportion of space used in particular ways), and 3) the distance from the centre of the 'housing area' to a range of amenities (e.g. bus stop).	Depression: CES-D;	Clustering of respondents within housing areas (and wards),	Y: statistically significant association between the prevalence of depression and living in housing areas where (1) most properties had deck access, (2) properties were mainly built after 1940, (3) fewer than 25% of homes had a private garden, (4) there was a shared recreational space and (5) many patches of graffiti were observed.
(Weich et al., 2002)	A questionnaire survey in London	1887 residents from two electoral wards in north London/61%	16 +/NA/NA	Logistic regression/0.05	Neighbourhood: housing areas was defined as a geographically bounded area in which the majority of the housing was homogeneous in form and character;	**BESSC**: items include the predominant form, height and age of housing, number of dwellings and type of access, provision of gardens, use of public space, amount of derelict land, security and distances to local shops and amenities	Depression: CES-D;	Age, gender, individual and household-level risk factors, structural housing problems and floor of residence	Y: statistically significant associations were found between the prevalence of depression and living in housing areas characterised by properties with predominantly deck access (odds ratio = 1.28, 95% CI 1.03–1.58; p = 0.02) and of recent (post-1969) construction.
(Araya et al., 2007)	Survey conducted 1996–1998 in Santiago, Chile	3087 adults living in private households in Santiago/90%	16–64/36.9/13.8	Multilevel linear regression/0.05	Neighbourhood: approximately ten small contiguous streets	**BEAT**: 1) general quality of the area (including width and maintenance of sidewalks, state of front gardens, tress on sidewalks, dirtiness of street, stray dogs, signs for orientation, public signs, security badges on house, guards), 2) facilities, noise and traffic in the area, 3) public green areas, 4) empty sites.	CMD: CIS-R;	Age, gender, presence of disease, income, education, marital status, housing type, number of supportive individuals and alcohol use; Area-level variable episodes of violent crime	Y: There was a significant association between the quality of the built environment of small geographical sectors and the presence of common mental disorders among its residents; the better the quality of the built environment, the lower the scores for psychiatric symptoms.
(Thomas et al., 2007)	Housing and neighbourhood and health (HANAH) survey in 2001 in Wales	1058 residents in Neath Port Talbot County Borough in South Wales/66%	16–75/NA/NA	Multilevel linear modelling/0.05	Neighbourhood: postcode area (unit)	**REAT**: 1) residential quality (property vandalism, stray dogs, presence of hedges and fences, garden and property maintenance, presence of recreational space, the predominant outlook, green space or buildings and density of housing).	CMD: GHQ;	Age, gender, working status, financial status, unaffordable items, proportion income from benefits, crowding in house, level of social support, socio-economic deprivation category	N: no significant association between residential environmental quality or geographical accessibility and symptoms of common mental disorder. It was likely that the psychosocial environment is more important than the physical environment in relation to mental health.
(Brown et al., 2009)	"The Hispanic Elders Behavioural Health Study" in East Little Havana, Florida 2000–2002	273 low SES Hispanic elder/52%	70 +/NA/NA	Structural equation modelling	Neighbourhood: Block level	**UMBECS**: architectural features such as above grade, stop, porch, ground floor parking, window are, low sill height windows, distance between the building to the street	Depression: CES-D; Anxiety: Spielberger State Anxiety Inventory;	Age, gender, education, income and functional status	Y: Architectural features of the front entrance such as porches that promote visibility were associated with perceived social support. This in turn was associated with reduced psychological distress
(Mair et al., 2010)	Chicago Community Adult Health	3105 adults in 343 neighbourhood	18 +/42.5/NA	Two-level gender-stratified regression/0.05	Neighbourhood: a standard block includes four streets and eight	**SSO**: **physical disorder** is a nine-item scale that captures the extent of graffiti, litter, abandoned cars, broken	Depression: CES-D;	Age, marital status, education, income, race/ethnicity	Y: Neighbourhood stressors (physical disorders and decay) were significantly associated with higher

Study	clusters in Chicago/72%			street sides	glass, and other similar types of negative neighbourhood contamination; **SSO**: **physical decay** is a five-item scale that describes the deterioration and abandonment of residential, commercial, and recreational buildings on a block.				levels of depressive symptoms after adjusting for individual-level factors.

(2) GIS measurement of the urban environment (6 studies)

Author year	Data set, source, and years	Sample size/response rate (individual level)	Age range (years)/mean age/SD age range	Analytic framework and study design/alpha level	Spatial scale: definition of geographic unit	Methods of measurement: measures of the urban environment	Type of mental illness: Methods of measurement	Adjusted confounders	Results
(Downey and Van Willigen, 2005)	The 1995 Community, Crime, and Health Survey, 1990 U.S. Census data and 1995 Toxic Release Inventory (TRI) data	1210 English speaking adults in Illinois/50%	18 +/NA/NA	Ordinary least squares regression/0.05	Neighbourhood: 0.25 km radius buffer and census track	1) The number of TRI facilities 2) the pounds of waste generated	Depression: CES-D;	Age, ethnic (black, Hispanic) sex, married, parent, employed, family income, and home owner	Y: residential proximity to industrial activity (Industrial pollution and hazardous waste, industry activity) has a negative impact on mental health. This impact is both direct and mediated by individuals' perceptions of neighbourhood disorder and personal powerlessness, and the impact is greater for minorities and the poor than it is for whites and wealthier individuals.
(Berke et al., 2007)	The adult changes in thought study, in King County, Washington, 2001–2003	740 men 65 +, cognitive intact, living in the same home for at least 2 years/38%	65 +/78.2/6.1	Logistic regression models/0.05	Neighbourhood: Buffer radii of 100, 500, and 1000 m around home	Average walkability score within the buffer;	Depression: CES-D;	Age, income, education, chronic disease burden score, living alone, self-reported ethnicity, self-reported walking activity and smoking.	Y: There was significant association between neighbourhood walkability and depressive symptoms in men. The odds ratio for the interquartile range (25th to 75th percentile) of walkability score was 0.31 to 0.33. This indicating a protective association with neighbourhood walkability. This association was not significant in women.
(Thomas et al., 2007)	Housing and neighbourhood and health (HANAH) survey in 2001 in Wales	1058 residents in Neath Port Talbot County Borough in South Wales/66%	16–75/46/NA	Multilevel linear and logistic regressions/0.05	Neighbourhood: postcode area (unit)	Geographically accessibility score for facilities at postcode level	CMD: GHQ;	Age, gender, working status, financial status, unaffordable items, proportion income from benefits, crowding in house, level of social support, socio-economic deprivation category, Residential Environment Assessment Tool score	N: no significant association between residential environmental quality or geographical accessibility and symptoms of common mental disorder. It is likely that the psychosocial environment was more important than the physical environment in relation to mental health.
(Maas et al., 2009)	2nd Dutch National Survey in General Practice (DNSGP-2), data from 96 practices that recorded morbidity for a full period of 12 months, National Land Cover Classification database (LGN4) in 2001	345,143 adults/NA	All ages/NA/NA	Multilevel logistic regression/0.01	Neighbourhood: 1 km and 3 km radius around the postal code coordinates of each household	The total percentage of green space in the respondents' living environment was measured within a 1 km radius and within a 3 km radius around the postcode centroid of a respondent's home	Depression: ICPC code P03 & P76; Anxiety: ICPC code P01 & P74	Age, gender, level of education, health insurance situation, work situation, and urbanicity.	Y: The annual prevalence rate of anxiety disorder and depression was lower in living environments with more green space in a 1 km radius.

(continued on next page)

Table 1 (*continued*)

(2) GIS measurement of the urban environment (6 studies)

Author year	Data set, source, and years	Sample size/response rate (individual level)	Age range (years)/mean age/SD age range	Analytic framework and study design/alpha level	Spatial scale: definition of geographic unit	Methods of measurement: measures of the urban environment	Type of mental illness: Methods of measurement	Adjusted confounders	Results
(Yang and Matthews, 2010)	The Philadelphia Health Management Corporation's (PHMC) in 2006	4905 adults from 158 neighbourhoods in Philadelphia County/NA	18+/NA/NA	Multilevel linear regression/0.05	Neighbourhood: census tract (unit)	The presence of hazardous waste sites and traffic volume.	Psychological stress: self-rated stress;	Age, gender, race, marital status, employment status, education, poverty, food insecurity	Y: The number of TRI sites within a neighbourhood was positively correlated with individual stress, even after controlling for other covariates. This relationship echoes the hazardous waste syndrome and reflects that a visible potential threat to individual
(Saarloos et al., 2011)	Health in Men study in Western Australia, 2001	5218 older men/NA	69+/NA/NA	Logistic regression models/0.05	Neighbourhood: CCD – census collection district (unit)	Walkability, street connectivity, residential density, land-use mix, the availability of 5 types of land use (retail, other retail, offices/business, health/well-being/community services, entertainment/recreation/culture);	Depression: GDS;	Area: neighbourhood socioeconomic status, neighbourhood population age composition; Individual: age, place of birth, education level, living arrangement, psychosocial factors, health factors, smoking	Y: higher degrees of land use mix and retail availability were associated with higher odds of depression.

Abbreviation: SD: standard deviation; NA: unknown; GIS: Geographic Information System; BESSC: Built Environment Site Survey Checklist; BEAT: Built Environment Assessment Tool; REAT: Residential Environment Assessment Tool; UMBECS: University of Miami Built Environment Coding System; SSO: Systematic Social Observation; CES-D: Center for Epidemiologic Studies Depression Scale; CIS-R: the Revised Clinical interview schedule; GHQ: the General Health Questionnaire; GDS: 15-item Geriatric Depression Scale; ICPC: International Classification of Primary Care; TRI: toxic release inventory; DVMT: daily vehicle miles travelled.

sociology (1), psychology (4) and medicine (3). Those studies were conducted in only a small number of cities, including five papers set in the USA, three in the UK, one in the Netherlands, one in Australia and one in Chile. The characteristics of selected 11 papers were listed in Table 1 and the effect sizes of outcomes in Table 2.

3.1. Research question

Of 11 papers reviewed, three aimed to develop assessment tools to examine the associations between residential environment quality and depression (Weich et al., 2002; Araya et al., 2007; Thomas et al., 2007); one paper was primarily interested in whether improvements in the housing and neighbourhood environment would improve depression (Weich et al., 2001); three articles examined the effect of particular environmental attributions on psychological distress, including exposure to industrial activity (Downey and Van Willigen, 2005), green space around home (Maas et al., 2009), architectural features which promote social interactions (Brown et al., 2009), walkability and land use mix (Berke et al., 2007, Saarloos et al., 2011), and two articles looked at the effects of both the physical and social environment (e.g. social support, social ties, and social participation) on psychological stress (Mair et al., 2010; Yang and Matthews, 2010).

3.2. Study design, sample size and response rate

All studies were cross-sectional (Table 1). Seven articles used single-level multi-variable regression models (e.g. logistic, linear or ordinary least squares regression). Five studies used newer analytical methods, including four papers employed multi-level regression models (Araya et al., 2007; Thomas et al., 2007; Maas et al., 2009; Yang and Matthews, 2010), and one used structural equation modelling to test direct and indirect effects of architectural features on depression and anxiety via social interactions (Brown et al., 2009).

The largest sample was a Dutch population based study (n = 345,143) (Maas et al., 2009), where the other sample sizes varied from 273 Hispanic elders with low SES (Brown et al., 2009) to 4905 adults from Philadelphia, US (Yang and Matthews, 2010). Only one study did not report the sampling method (Yang and Matthews, 2010), whereas the others used random sampling method. The response rates ranged from 38% (Berke et al., 2007) to 90% (Araya et al., 2007). One study obtained a response rate of <50% (Berke et al., 2007) and two studies did not report the response rate (Maas et al., 2009; Yang and Matthews, 2010).

3.3. Confounding variables

All studies adjusted for potential confounders at the individual level, including age, gender, race/ethnicity, income, marital status and education. One article further adjusted for area-level variables (e.g. neighbourhood socioeconomic status, population age composition) (Saarloos et al., 2011).

3.4. The definitions of neighbourhood

Eleven papers looked at the effect of neighbourhood-level variables on psychological distress. Although the definition and size of neighbourhoods varied widely, neighbourhood was commonly described as a place where participants were resident in a locality (e.g. postcode area, street and block). Three studies used administratively defined units as proxies for neighbourhood. Among them, one study examined a small-sized area, the British postcode area (Thomas et al., 2007), which is often a single street and identifies an average of 15 addresses. The other two studies looked at mid-sized areas. For instance, the US Census tract (Yang and Matthews, 2010) and the Census Collection District (CCD) in Australia (Saarloos et al., 2011) were defined as neighbourhood. Typically, a census tract in the US has 4000 to 6000 people, and a CCD has an average of 255 dwellings. Seven studies defined their own neighbourhoods using a variety of different definitions, including: (1) a housing area that was geographically bounded and in which the majority of the housing was homogeneous in form and character (Weich et al., 2001; Weich et al., 2002), (2) buffer zones, such as a 0.25 km (Downey and Van Willigen, 2005), 100 m, 500 m and 1000 m (Berke et al., 2007), 1 km and 3 km (Maas et al., 2009) radius around a participant's home), and 3) street block, such as approximately ten small contiguous streets (Araya et al., 2007) or another definition requiring four streets and eight street sides (Mair et al., 2010).

3.5. Measurement of the urban environment

Two methods were used to measure the urban environment objectively; namely independent observational measures and Geographic Information System (GIS). Only one paper used a combination of two methods (Thomas et al., 2007). Five papers carried out independent rating which used people external to the investigated areas to walk through the neighbourhood in order to evaluate the urban environment (Weich et al., 2001; Weich et al., 2002; Araya et al., 2007; Thomas et al., 2007; Mair et al., 2010).

Five instruments have been developed to objectively measure the urban environment. They are the Built Environment Site Survey Checklist (BESSC) and the Residential Environment Assessment Tool (REAT) in the UK, the Built Environment Assessment Tool (BEAT) in Chile, and the University of Miami Built Environment Coding System (UMBECS) and the Systematic Social Observation (SSO) in the US. Each instrument measured a range of between 5 and 52 items. Inter-observer reliability is the primary form of reliability assessed and reported. Inter-item correlations (e.g. Cronbach's alpha) and factor analysis were also used as reliability measures and to identify useful groupings of items. REAT reported the highest inter-rater reliability with the lowest value (0.58) occurring for the condition of paths, compared to only 15 out of 31 items obtaining a satisfactory kappa statistic (>=0.5) in BESSC, and only 25 out of 52 items loaded into four main factors in BEAT.

Six papers used GIS to objectively measure the urban environment. The variables used included traffic volume (Yang and Matthews, 2010), counts of TRI (toxic release inventory) sites and waste sites (Downey and Van Willigen, 2005; Yang and Matthews, 2010), the amount of green space nearby (Maas et al., 2009), distance to facilities (Thomas et al., 2007), neighbourhood walkability score (Berke et al. 2007; Saarloos et al., 2011), connectivity (Saarloos et al., 2011) and land use mix (Saarloos et al., 2011).

Six papers applied a multivariable environmental indicator (Weich et al., 2001; Weich et al., 2002; Araya et al., 2007; Thomas et al., 2007; Brown et al., 2009; Mair et al., 2010). Of the multivariable indicators, common concepts included neighbourhood disorder, quality, problems, or physical decay. The most common measurement items included data on rubbish, abandoned buildings, graffiti/vandalism, maintenance-level of houses/buildings, crime and safety, accessibility to local amenities and noise.

3.6. Measurement of psychological distress

Most papers (9/11) only examined one mental health outcome, and two looked at two mental health outcomes (Brown et al., 2009; Maas et al., 2009). Among the 11 papers, eight examined the relationships between the urban environment and depression (Weich et al., 2001; Weich et al., 2002; Downey and Van Willigen, 2005; Araya et al., 2007; Berke et al., 2007; Brown et al., 2009; Maas et al., 2009; Mair et al., 2010; Saarloos et al., 2011), two the urban environment and anxiety (Brown et al., 2009; Maas et al., 2009), two the urban environment and common mental disorders of mixed anxiety and depression (Araya et al., 2007; Thomas et al., 2007), and one the urban environment and psychological stress (Yang and Matthews, 2010).

Table 2
Effect sizes of outcomes.

Author year	Outcome measures	Environmental variables	Results	p value
Architectural design				
(Weich et al., 2001)	CES-D score	Most properties had deck access (vs. other types of access)	OR (95% CI) 1.57 (1.05, 2.34)	0.03
(Weich et al., 2001)	CES-D score	Properties were built 1940–1969 (vs. pre-1940)	OR (95% CI) 1.88 (1.18, 3.00)	0.009
(Weich et al., 2001)	CES-D score	Properties were built 1970 or later (vs. pre-1940)	OR (95% CI) 2.36 (1.53, 3.65)	***
(Weich et al., 2001)	CES-D score	Fewer than 25% of homes had a private garden	OR (95% CI) 1.75 (1.07, 2.85)	0.03
(Weich et al., 2001)	CES-D score	No shared recreational space (vs. any)	OR (95% CI) 0.52 (0.32, 0.84)	0.008
(Weich et al., 2001)	CES-D score	Many patches of graffiti were observed (vs. none)	OR (95% CI) 2.12 (1.25, 3.59)	0.006
(Weich et al., 2002)	CES-D score	Living in housing areas characterised by properties with predominantly deck access	OR (95% CI) 1.28 (1.03, 1.58)	0.002
(Weich et al., 2002)	CES-D score	Living in housing recent construction	OR (95% CI) 1.43 (1.06, 1.91)	0.002
(Brown et al., 2009)	CES-D score + Spielberger State Anxiety Inventory score	Front entrance Ground floor parking Windows	β −0.13 0.31 0.27	*
Land use				
(Maas et al., 2009)	The annual prevalence rate of depression	Percentage of green space in 1 km radius	OR (95% CI) 0.96 (0.95, 0.98)	**
(Maas et al., 2009)	The annual prevalence rate of anxiety disorder	Percentage of green space in 1 km radius	OR (95% CI) 0.95(0.94, 0.97)	**
(Yang and Matthews, 2010)	Stress level 1 (no stress)- 10 (an extreme amount of stress)	Neighbourhood TRI	β 0.0494	*
(Saarloos et al., 2011)	Depression (yes vs. no)	Degrees of land use mix	OR (95% CI) T1 (low): 1 T2: 1.54 (1.10, 2.16) T3 (high): 1.52 (1.08, 2.14)	*
(Saarloos et al., 2011)	Depression (yes vs. no)	Retail availability (yes vs. no)	OR (95% CI) 1.40 (1.04, 1.90)	*
(Araya et al., 2007)	CIS-R score	Empty sites	β (95% CI) 0.17 (0.06, 0.28)	0.002
Walkability, connectivity and accessibility				
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 100 m of buffer around the subject's home	OR (95% CI) M 0.31 (0.12, 0.81)	0.02
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 500 m of buffer around the subject's home	OR (95% CI) M 0.32 (0.13, 0.80)	0.02
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 1000 m of buffer around the subject's home	OR (95% CI) M 0.33 (0.14, 0.82)	0.02
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 100 m of buffer around the subject's home	OR (95% CI) F 0.98 (0.61, 1.59)	0.95
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 500 m of buffer around the subject's home	OR (95% CI) F 0.96 (0.55, 1.59)	0.88
(Berke et al., 2007)	CES-D scores (>16 vs. <=16)	Interquartile range of walkability scores (25th–75th percentile) within 1000 m of buffer around the subject's home	OR (95% CI) F 0.89 (0.51, 1.55)	0.68
(Thomas et al., 2007)	GHQ score	Geographical accessibility score	AMD (95% CI) Score < 25 (ref) Score 25–31: 0.23 (−0.82, 1.34) Score 32+: −0.21 (−1.16, 0.75)	NA
(Yang and Matthews, 2010)	Stress level 1 (no stress) - 10 (an extreme amount of stress)	Neighbourhood DVMT	β 0.0976	**
Neighbourhood and housing quality				
(Araya et al., 2007)	CIS-R score	General quality	β (95% CI) −0.30 (−0.49, −0.11)	0.002
(Mair et al., 2010)	CES-D score	Neighbourhood physical disorder	AMD (95% CI) F 0.08 (0.05, 0.12) M 0.04 (0.00, 0.09) F/M ratio = 2	*
(Mair et al., 2010)	CES-D score	Neighbourhood physical decay	AMD (95% CI) F 0.05 (0.02, 0.09) M 0.05 (0.00, 0.09) F/M ratio = 1	*
(Downey and Van Willigen, 2005)	Number of depressive symptoms	Average waste in a tract	β 0.003	*
(Thomas et al., 2007)	GHQ score	REAT score	AMD (95% CI)	NA

Table 2 (*continued*)

Author year	Outcome measures	Environmental variables	Results	p value
			Score <21 (ref) Score 21–27.5: 0.18 (−1.07, 0.72) Score 28+: 0.06 (−0.88, 0.96)	

Abbreviation: TRI: toxic release inventory; DVMT: daily vehicle miles travelled; Q: quartile; T: tertile; AMD: adjusted mean difference; CI: confidence interval; OR: odds ratio; β: standardized coefficient; F: female, M: male; F/M ratio: female/male ratio.

* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

A variety of tools to assess mental health were used in the reviewed articles. The majority of studies used standard, well validated instruments such as the CES-D, the GHQ, Geriatric Depression Scale (GDS), Revised Clinical Interview Schedule (CIS-R), International Classification of Primary Care (ICPC) codes and Spielberger state anxiety inventory. One study used self-designed questionnaires for measuring psychological distress (Yang and Matthews, 2010). In both studies the validity of those measurement were not documented.

3.7. Urban environment features and psychological distress

3.7.1. Architectural design

Three studies (Table 2) examined the architectural design of buildings and housing in relation to psychological distress: three studies focused on depression (Weich et al., 2001; Weich et al., 2002; Brown et al., 2009) and one on anxiety (Brown et al., 2009). In particular, the prevalence of depression was higher for those living in neighbourhoods where the housing was characterised as 1) properties of recent construction (post-1969), 2) predominant deck access (a means of access to flats above ground level of which front door opens onto a long corridor), 3) fewer than one-quarter of homes with a private garden, 4) a shared recreational space (Weich et al., 2001; Weich et al., 2002). Architectural features of the front entrance such as porches that promote visibility were associated with reduced depression and anxiety after controlling for demographics via perceived social support (Brown et al., 2009).

3.7.2. Land use

A Dutch study found a greater amount of green space within a 1 km radius around residents' homes was significantly associated with a lower prevalence of anxiety and depression (Maas et al., 2009). Industrial land in the US (e.g. density of industrial activities and sites in a neighbourhood) had a negative impact on residents' psychological distress (Yang and Matthews, 2010). Higher degrees of land use mix were associated with higher odds of depression among older men in the US, independent of street connectivity and residential density, and retail availability was associated with a 40% increase in the odds of depression (95% CI = 4% − 90%) (Saarloos et al., 2011). However, Araya et al. found a surprising association between fewer empty sites in the neighbourhood and more common mental disorder in Chile (Araya et al., 2007), using a validated measure.

3.7.3. Walkability, connectivity and accessibility

Two studies explored walkability in relation to depression among older men (Berke et al., 2007; Saarloos et al., 2011). Berke et al. found a significant association between poor walkability and depression in older men in the US, while no significant relationship was found in Australia (Saarloos et al., 2011). Substantial variation also occurred within walkability measures in these two studies: one used the composite score of street connectivity, residential density and land-use mix in each person's CCD neighbourhood (Saarloos et al., 2011), the other was based on variables associated with individual destinations (e.g. proximity to grocery stores) and clusters of commercial destinations, residential density and block size in proximity to a subject's home using 100, 500, and 1000 m buffers (Berke et al., 2007). Only one study examined the distance to the nearest facilities and reported that distance to the nearest facilities within a neighbourhood was not significantly associated with common mental disorder (Thomas et al., 2007) in Wales. Only one study examined traffic as a single variable and found increased traffic volume (measured by a neighbourhood's daily vehicle miles travelled) was associated with increased psychological distress (Yang and Matthews, 2010). One other study included traffic as a part of composite variable (Araya et al., 2007).

3.7.4. Neighbourhood and housing quality

Three studies looking at residential quality examined the relationship between living in neighbourhoods with a poor quality urban environment and the presence of common mental disorder (Araya et al., 2007; Thomas et al., 2007), or the prevalence of depression (Mair et al., 2010). Among these articles, one did not find any significant associations (Thomas et al., 2007). Similar observational instruments were applied in studies in Wales, UK (Araya et al., 2006) and Santiago, Chile (Araya et al., 2007). The study set in in Wales used the REAT instrument and assessed the more private and residential aspects of the urban environment such as houses, gardens or housing density, while the BEAT instrument used in Santiago (Araya et al., 2007), adapted from REAT, extended the assessment to a wider area, which included other aspects of the urban environment such as roads, pavements and public facilities (Araya et al., 2007). In the Welsh study, no significant association was found between neighbourhood quality/accessibility and GHQ scores after adjusting for individual variables (Thomas et al., 2007). In the much larger study in Chile there was a significant association between the quality of the urban environment of small geographical sectors and the presence of common mental disorder among its residents (Araya et al., 2007). It was suggested that the more homogeneous neighbourhoods used in the Chile study might be the best explanation for the difference between the two studies.

4. Discussion

This systematic review examined the role of the urban environment as an aspect of place and its effect on psychological distress using a cross-disciplinary methodology (Weaver et al., 2002). In particular we focused on studies using objective measurements of the urban environment. This is because that majority of studies to date used self-reported methods to obtain mental health status, behaviour and environmental variables. The results could be limited by same-source bias associated with self-reporting methods, as people who are depressed and anxious may be more likely to report negative perceptions of the urban environment.

In total, 11 papers based on 10 studies across four different disciplines were identified that applied an objective measurement to assess

the urban environment. Most of the research reviewed has been carried out in the US and Europe. The range of environmental characteristics examined included architectural design, land use, walkability, connectivity and accessibility, neighbourhood and housing quality. All studies are cross-sectional and no studies examined the longitudinal effects of the objectively measured urban environment on psychological distress. This research gap needs to be addressed in future longitudinal research.

The overall findings suggested that some aspects of the urban environment measured objectively have significant associations with psychological distress. These include, for example, architectural features (such as housing with deck access), the quality of the neighbourhood, the amount of green space, land-use mix, industrial activity and traffic volume (Table 2). This is consistent with the finding with other reviews which included self-reported measurement of the urban environment. The effect of the urban environment on psychological distress can operate both through the individual level (e.g. individual's perceptions), and through "neighbourhood effects". Only one study identified in this review explored the neighbourhood effect of the urban environment on psychological distress, independent of individual's perceptions. Berke et al. (2007) found a significant association between poor neighbourhood walkability and more depression in men only without adjusting for the individual's attitude to walking. The extent to whether the urban environment has neighbourhood effects on psychological distress needs to be further investigated.

There was no common method in assessing the urban environment. Five independent observational audit tools have been used, each with a strong geographical context. This type of measurement is particularly useful in assessing architectural design, features and landscape maintenance, whereas measures of other variables, such as the functions of open space in BESSC, tend to be less reliable. This method is labour intensive and time consuming in collecting data compared with GIS-derived measures. Six papers used multivariate indicators, which address generic problems such as "neighbourhood disorder" and "quality of area". The use of multivariate indicators makes it difficult to identify factors that could be addressed by the planning process directly and so the implications of these results need to be interpreted with some caution. Six papers used a GIS measurement of the urban environment. There is a large degree of variability of GIS measurement used in the review, which included land-use mix, walkability, connectivity, access to facilities, street pattern, traffic volume and density of industry activities and sites. Therefore developing standardized objective measurements that can be applied across studies would be an important advance to understand the effects of the urban environment on psychological distress (Mair et al., 2008).

The spatial scale at which contextual factors may have an impact on psychological distress is unclear. The hypothesis is that mental health is influenced not only by the immediate neighbourhood, but also by its surrounding area. Multilevel modelling has been used to examine the effects of different scales of urban environment in relation to psychological distress (Araya et al., 2007; Thomas et al., 2007; Maas et al., 2009; Mair et al., 2010; Yang and Matthews, 2010) but the results are inconclusive and more research is needed. The size of a neighbourhood used in studies included range from the street where people live to a 3 km radius buffer around where people live. The uncertainty about what spatial scales may be relevant to mental health still remains. A second uncertainty arises because the heterogeneity of the urban environment might vary by geographical and cultural context (Macintyre et al., 2002). This can be seen as a possible explanation for difference between two studies employed similar methods (Araya et al., 2007; Thomas et al., 2007).

Although most of studies found significant associations between the urban environment and psychological distress, the underlying mechanisms remain unclear. There are several possible causal pathways. For example, physical features such as graffiti, rubbish, traffic and hazardous waste sites may act as visual cues and stressors (Weich et al., 2001; Araya et al., 2007), physical stressors may operate through individual's perceptions of environment (Mair et al., 2010), whereas the absence of features such as green space may limit stress recovery and reduction of adverse effects of the urban environment (Maas et al., 2009). Urban environmental characteristics which improve social interaction and support are associated with reduced psychological distress via social support and networks which act as a coping mechanism to reduce stress (Brown et al., 2009). Two studies explored the association between mental health, the physical environment and the social environment (Mair et al., 2010; Yang and Matthews, 2010). Both studies found that both social and physical environments are associated with mental health status, after concurrent adjustment. In other words, both social and physical environment may operate independently of each other on psychological distress. Furthermore, other mechanisms may exist as some aspects of the urban environment can be hypothesised to be related to psychological distress directly or via interplay with the social environment. The underlying mechanisms and pathways need further research.

Most of the studies identified focused on depression and only two studies examined mixed depression and anxiety (Brown et al., 2009; Maas et al., 2009). Maas et al. (2009) found that the prevalence of anxiety, but not depression, was lower in living environments with 10% more green space than average within a 3 km radius around the home address, while the prevalence of both anxiety and depression was lower within a 1 km radius. This is currently not enough evidence to distinguish the effects of the urban environment on anxiety and depression separately, although as these symptoms often co-exist this may not be easy to determine. Although it is well known that the prevalence of psychological distress varies by gender and age, there were only two papers that had separate female and male results. One of those papers (Mair et al., 2010) reported mean difference, whereas the other (Berke et al., 2007) used the odds ratio, which made it impossible to calculate female/male ratio.

The evidence suggests that the environment in relation to psychological distress is mainly defined as a place geographically around the home or administrative area of residence. However, the environment we encounter daily is far more complex and the relevant exposures could arise from the environment around schools or workplaces that are far away from homes and where people spend significant amounts of time. The urban environment based on an individual's daily activities may affect psychological distress more than a common neighbourhood definition for all people living in the same general area. Further work can also look at the spatial-temporal dynamic as the changes occur in both the urban environment and the individual over the time. Currently few data are available and there is a clear need for studies of spatio-temporal dynamics in relation to mental health.

In conclusion, despite large heterogeneity in study designs, the overall findings suggested that the urban environment has measurable associations with psychological distress. However, a major limitation of this evidence is that all included studies were cross-sectional; they can identify associations between the characteristics of the urban environment and psychological distress but not the direction of causation. We also conclude that new methods for objectively measuring the urban environment are needed which are meaningful to planners as well as residents. In particular, future work should look at the spatial-temporal dynamic of the urban environment in relation to psychological distress in longitudinal studies.

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