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The relationship between visual enclosure for neighbourhood street walkability and elders' mental health in China: Using street view images

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ABSTRACT

Background: Neighbourhood walkability has been consistently associated with more physical activities in adults. Nevertheless, evidence of a beneficial association between walkability and older adults' mental health is still scarce in developing countries. Furthermore, walkability was often measured through Geographic Information System (GIS) methods. Recently, the methodological development in street view images, such as using Google or Tencent Street View, has offered an attractive alternative.
Methods: Using Tencent street view images and machine learning classification methods, we quantify visual enclosure for neighbourhood street walkability with the proportion of visible sky in those images. Depression and anxiety data were extracted from mental health surveys for 1231 older adults in Beijing, China in 2011. Multilevel linear regression models were used to assess the associations.
Results: Street walkability was negatively associated with Geriatric Depression Scale scores (GDS 15-item) and Geriatric Anxiety Inventory scores (GAI 20-item), and the results of different robustness checks also support this relationship. The associations were stronger for disadvantaged older adults than others.
Conclusion: The present study indicates a potential beneficial role of street walkability on mental health (depression and anxiety) in older residents, especially for disadvantaged older adults. Additional longitudinal studies are required to address some limitations of this study, such as residential self-selection bias.

1. Introduction

Depression and anxiety were the top two mental diseases (ranked third an ninth respectively) causing most disabilities worldwide according to the Global Burden of Disease Study in 2015 (Vos et al., 2016). Depression and anxiety are associated with different health problems, such as different cardiovascular diseases (Hare et al., 2014; Rumsfeld and Ho, 2005; Suls and Bunde, 2005; Sarkar

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et al. 2018) and a decreased quality of daily life (Herring et al., 2016; Ruo et al., 2003). These diseases have attracted substantial research and attention, especially in developing countries (Adjayegbewonyo et al., 2018; Wang et al., 2018a, 2018b; Yu et al., 2018). According to the latest report, the prevalence of depression disorders in China is approximately 35.7%, while the prevalence of anxiety disorders in China is approximately 18.3% (Lou et al., 2012); these findings indicate that depression and anxiety have become serious health issues in China.

Walkability has attracted substantial research and attention because it includes various aspects of the built environment, e.g., residential density, land-use mix, intersection density, presence of trees and vegetation, that promote or hinder walking and cycling in a neighbourhood (Frank et al., 2005; Su et al., 2017a). Over the past decade, a growing body of literature has proved the links between neighbourhood walkability and various health outcomes (Berke et al., 2007; Frank et al., 2006; Frank et al., 2010; Leslie and Cerin, 2008; Marshall et al., 2009; Renalds et al., 2010; Rundle et al., 2008; Sallis et al., 2009; Sturm and Cohen, 2004; Su et al., 2017a; Howell et al. 2017; Adlakha et al. 2016; Marquet et al. 2017). Two main mechanisms, namely, promoting physical activities and fostering social contacts, may explain the effect of neighbourhood walkability on health outcomes. First, with the increase of neighbourhood walkability, residents are more likely to conduct outdoor physical activities, such as walking or running, so they can lose weight (Frank et al., 2006; Rundle et al., 2008; Sun et al. 2014; Sun et al. 2016), feel more relaxed (Frank et al., 2010) and reduce stress (Berke et al., 2007; Su et al., 2017a). Additionally, neighbourhood streets and public open spaces are a good place for social contacts, so when residents have more outdoor activities, they are more likely to interact with neighbours, thereby strengthening their social ties (Berke et al., 2007; Su et al., 2017a). However, most previous studies mainly focused on the relationship between neighbourhood walkability and physical health; only one study examined the relationship between neighbourhood walkability and mental health such as depression in King County, Washington US (Berke et al., 2007).

There is another caveat in the research. The vast majority of existing studies has measured walkability on a macro scale, such as the availability of pedestrian destinations, street connectivity, or urban density in neighourhood area (Frank et al., 2005; Su et al., 2017a; Howell et al. 2017; Adlakha et al. 2016; Marquet et al. 2017). Macro-scale walkability is typically measured with Geographic Information System (GIS) or Points of Interests (POI) data, which often do not include detailed data. Macro-scale walkability was based on overhead views, and it may mismatch with the environment perceived by residents based on eye-level views (Yin and Wang, 2016).

Recent advances in computer vision and the availability of eye-level streetscape images (e.g., street view images from Google or Tencent) make it possible to objectively measure eye-level walkability for many locations worldwide. To assess eye-level walkability, researchers need to classify and quantify different features in a streetscape, such as vegetation, sky, buildings, and vehicles (Su et al., 2017a). Such methodological development has attracted great attention in recent years due to the following two reasons (Badland et al., 2010; Lu et al., 2018; Lu, 2018; Rzotkiewicz et al., 2018). First, compared with other methods, streetscape image data are objective and easy to retrieve. Second, streetscape image data often includes more detailed information about the features of landscape in street level. Thus, some researchers have focused on the measurement of neighbourhood walkability using streetscape images in recent years and pointed out some advantages (Yin and Wang, 2016). However, previous studies mainly detect objects by pixel colours in an image. This method can hardly distinguish two different types of objects in the same colour (e.g., falsely identify a green wall as vegetation). More advanced computer deep learning techniques, such as an Artificial Neural Network, may address this limitation (Yin and Wang, 2016).

In summary, three research gaps should be noted. First, previous studies mainly focused on the relationship between neighbourhood walkability and residents' physical health outcomes, and few studies paid attention to mental health, especially in developing countries. Second, previous studies mainly used GIS- or POI-based data to measure macro-scale neighbourhood walkability, so it may be different from perceived eye-level neighbourhood. Third, most previous studies mainly focus on adults (aged 18–65); few studies have focused on older adults (aged $\geq$ 60).

To address the above research gaps, we used Tencent street-view data and machine learning classification methods to measure neighbourhood walkability. Depression and anxiety data were collected with a mental health survey for older adults in Beijing, China. The present study evaluated the association between street-view neighbourhood walkability and older adults' depression and anxiety in China. Additionally, we aimed to evaluate whether neighbourhood walkability is more strongly associated with depression and anxiety for disadvantaged older adults. The conceptual framework that hypothesizes the complex linkages between visual enclosure for neighbourhood street walkability and mental health for older adults was shown in Fig. 1.

2. Materials and methods

2.1. Data

The depression and anxiety data were collected by a research team in Renmin University of China through a mental health survey between March and August 2011. This survey was conducted in Haidian District in Beijing. Haidian District is an ideal place to undertake studies on older adults' depression because of its large elderly population. From 2011 to 2015, the number of elderly adults in Haidian District increased by 20,000 per year, and the number of elderly adults in Haidian District had reached 470,000 by 2015. Participants were selected through two stages. First, 45 residential neighbourhoods were selected from 13 districts with a representative sampling technique. Second, 30 persons from each sampled neighbourhood were selected with a system sampling method. Finally, the dataset included 1231 valid participants (the total number of respondents was 1350) and the location of sampled communities was shown in Fig. 2.

Street view (SV) images are other important data in this study. As one of the largest online map service providers, Tencent Map

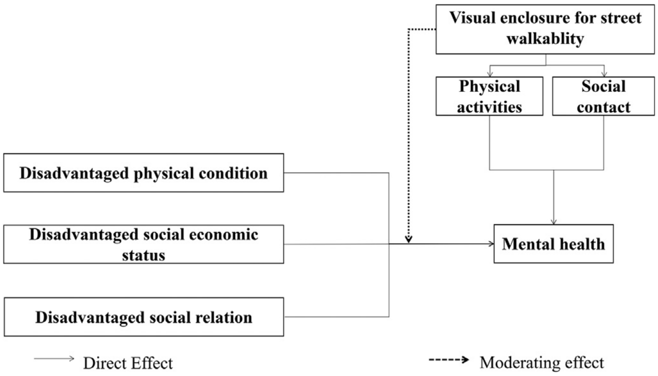

Fig. 1. Conceptual framework that hypothesizes the complex linkages between visual enclosure for neighbourhood street walkability and mental health for older adults.

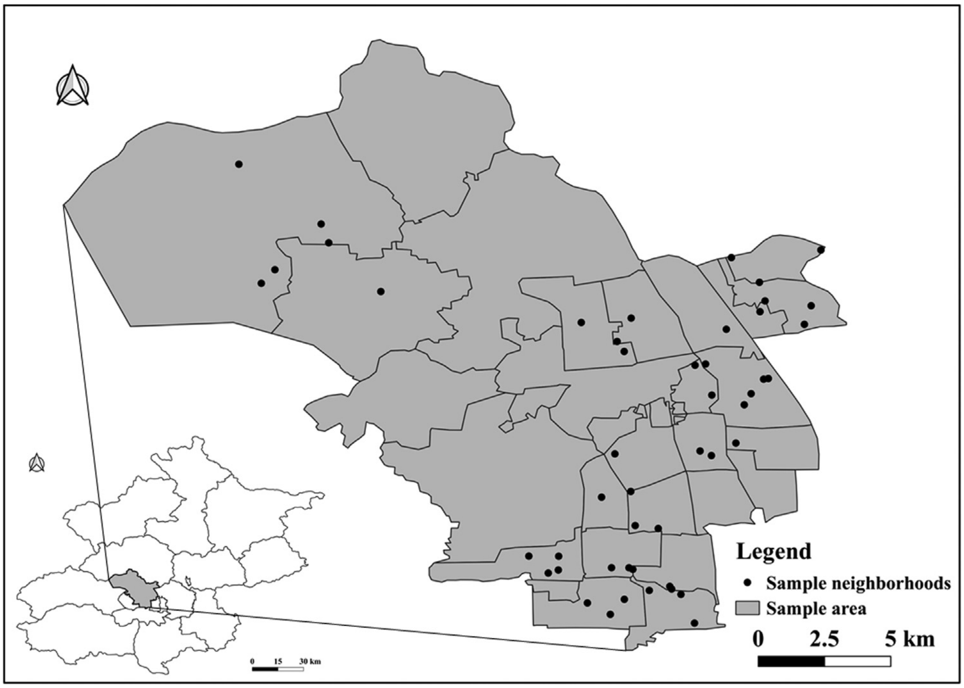

Fig. 2. The location of sampled communities in Haidian, Beijing, China.

(https://map.qq.com/), publishes street view photos from various positions with different headings and pitches along each city road in China (Dong et al., 2018; Long and Liu, 2017), similar to Google Street View. Based on the road network data (OpenStreetMap.org), we constructed our sampling points 100 m apart on each road. In our street view dataset, each sampling point captured street view images from four directions (0, 90, 180, and 270 degrees) (Fig. 3). In this study, we obtained the coordinates of the centre point in each neighbourhood (administrative unit) and made a buffer (radius of 1000 m) for each, which can be regarded as the coverage for each neighbourhood. We obtained a total of 134,000 street view images in the study area.

2.2. Outcome

The dependent variable was depression and anxiety, which was assessed using GDS by means of 15-item scores (Geriatric Depression Scale 15-item) (de Craen et al., 2003) and GAI by means of 20-item scores (Geriatric Anxiety Inventory 20-item) (Pachana et al., 2007). The GDS includes 15 questions measuring the mental state of residents over the previous week (i.e., feeling upset, feeling helpless, and feeling useless), while the GAI includes 20 questions measuring the mental condition of residents over the previous week (i.e., feeling scared, feeling nervous, and feeling worried).

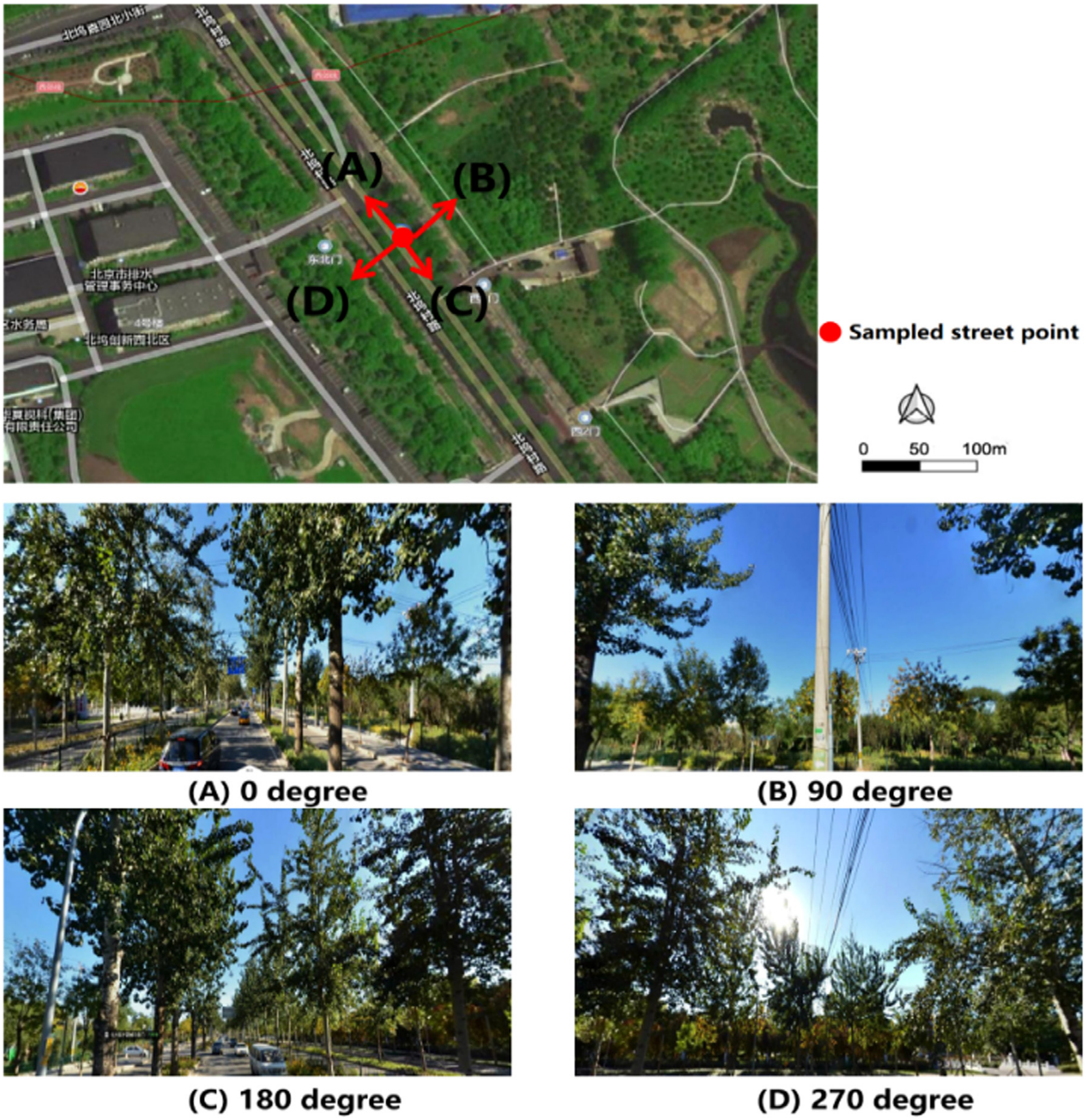

Fig. 3. The example of four degree of TSV images in an sample area.

2.3. Independent variables

2.3.1. Visual enclosure for street view walkability

In this section, we focus on measuring the urban walkability from street view images. In terms of urban walkability estimation, previous studies mainly focused on walk score data coming from POI data (Su et al., 2017a) or a company called Walk Score (Hajrasouliha and Yin, 2015; Rauterkus and Miller, 2011; Talen and Koschinsky, 2014). However, these measurements of street walkability may mismatch with what a pedstrain see in daily life (Yin and Wang, 2016). Thus, following Yin et al. (2016), we use street view data to measure visual enclosure for street walkability, and a higher proportion of sky in each of the street view picture creates a lower visual enclosure for walkability of the street, because the higher proportion of sky in each of the street view indicates that the street has less tree density, lower building heights and fewer pedestrian counts, which are associated with a reduced willingness of walking (Yin and Wang, 2016). We proposed an advanced semantic segmentation method that can accurately identify urban walkability from street view images. As illustrated in Fig. 4, we trained a deep neural network model, namely, FCN-8s (Long et al., 2015), to segment the street view images into 150 types of objects. Unlike the previous methods of extracting sky space with RGB values or a simple Artificial Neural Network, the network structure of the Fully Convolutional Network (FCN) contains only convolution layers and deconvolution layers for spatial convolution operations (Long et al., 2015). By using convolutional kernels to

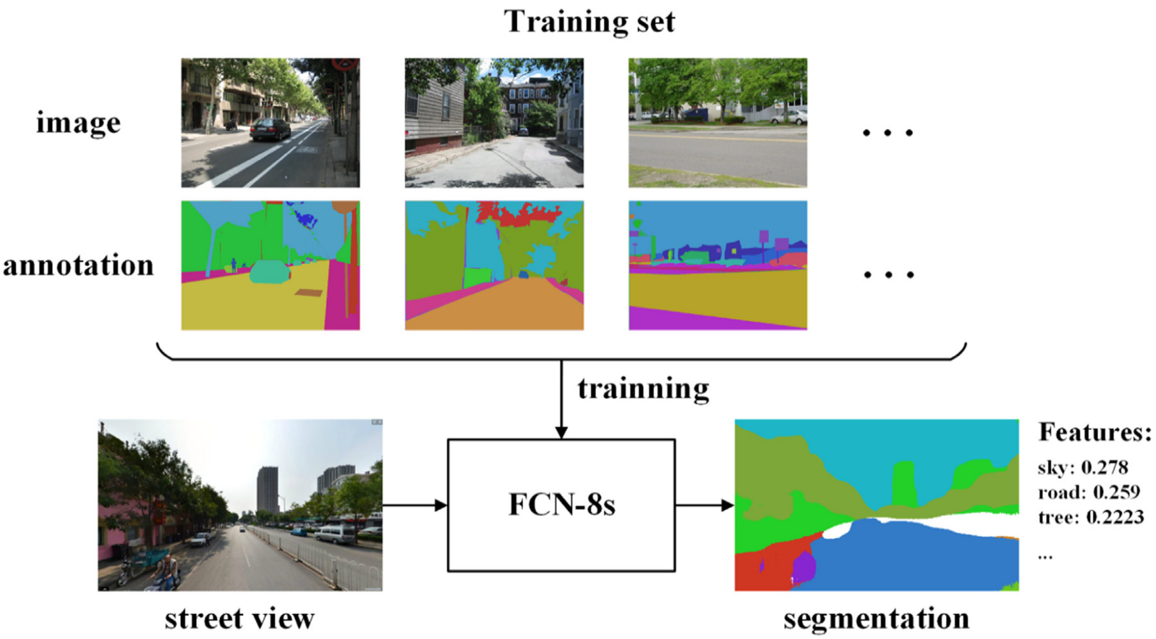

Fig. 4. The input and output of the fully convolutional network (FCN).

broaden the view fields of pixels, more neighbour information of pixels is considered, which not only improves the segmentation accuracy but also promote the generation of more formed and less sporadic results (Kang and Wang, 2014). In our study, we trained our model by using the ADE20K scene parsing data and part segmentation data (Zhou et al., 2016, 2017), which consists of 150 different categories of objects. Then, the proportions of sky area can be measured by inputting street view images into the trained model to generate segmentation results, as Eq. (1) shows and the correlation test among the proportion of sky of different angles showed that the they are significantly correlated with each other (Table 1), so taking the averaged values of street view images of four different heading angles as the final score is a suitable approach.

Yin et al. (2016) indicated that street-level greenness and building also have influence on residents' walking behavior, so we also provided the correlation tests among the proportion of sky, greenness and buildings (Table 2). Results showed that the proportion of sky is significant correlated with the proportion of buildings, so to avoid multicollinearity, we excluded the proportion of buildings in our models. In this study we mainly focus on visual enclosure for walkability, so we finally take the proportion of sky scores as the proxy for street walkablity.

The scene segmentation results of Tencent street view photos via the proposed trained FCN-8s are shown in Fig. 5.

$$P_{sky} = \frac{\sum_{i=1}^{4} NW_i}{\sum_{i=1}^{4} N_i} \tag{1}$$

where P_{sky} is the proportion of sky in a respective scene location, which is averaged by the values of street view images of four different heading angles. N_i is the total number of pixels in image i, and NW_i is number of sky pixels in image i. The estimation of sky of the street was calculated by averaging the P_{sky} of scene locations in that street. We made a buffer for each neighbourhood (1000 m) and counted the average P_{sky} within each buffer. Finally, the average P_{sky} within each buffer could be defined as the value of street walkability for each neighbourhood.

2.3.2. Individual socioeconomic status indicator

Since residents' socioeconomic status often has an impact on their health (Miao and Wu, 2016; Phelan et al., 2010), we control for this variable. Respondents' socioeconomic status was measured by their educational attainment (categorical variables). Respondents'

Table 1
Results of correlation tests: the proportion of sky of different angles.

	Sky (0°)	Sky (90°)	Sky (180°)	Sky (270°)
Sky (0 degree)	1	0.78**	0.85**	0.75**
Sky (90 degree)	0.78**	1	0.76**	0.83**
Sky (180 degree)	0.85**	0.76**	1	0.75**
Sky (270 degree)	0.75**	0.83**	0.75**	1

*p < 0.10. **p < 0.05. ***p < 0.01.

Table 2
Results of correlation tests: the proportion of sky, greenness and buildings.

	Sky	Greenness	Buildings
Sky	1	-0.461*	-0.778**
Greenness	-0.461*	1	0.55*
Buildings	-0.778**	0.55*	1

*p < 0.10. **p < 0.05. ***p < 0.01.

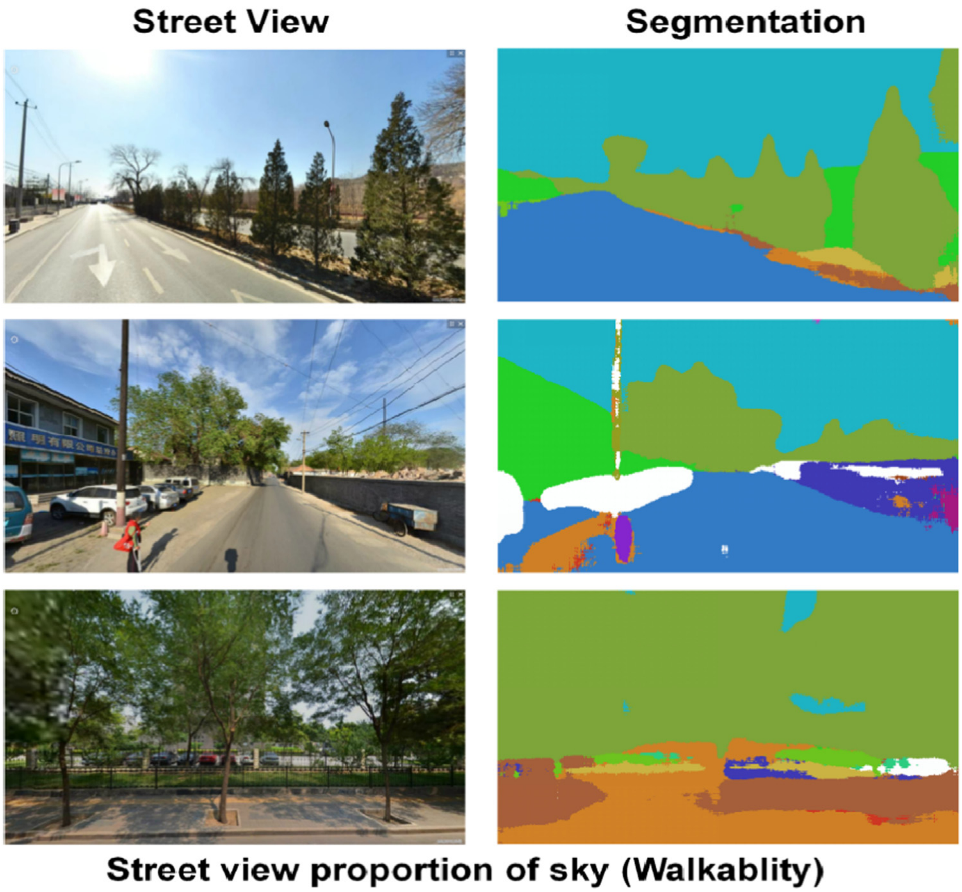

Fig. 5. The scene segmentation results of Tencent street view photos via the proposed trained FCN-8s.

educational attainment was categorized into three types, including primary school or below, high school, and college and above.

2.3.3. Indicators of individual social ties

Individuals' social ties have an influence on residents' health-related behaviours, which may affect mental health (Kawachi and Berkman, 2001; Liu et al., 2017; Seeman, 1996; Thoits, 2011). Following previous studies (Glass and Maddox, 1992; Kawachi and Berkman, 2001; Shirado et al., 2013), we measure both the quantity and quality of social ties. The quantity of social ties was measured by the number of relatives and friends they can meet or contact at least once a month, while the quality of social ties was measured by the number of relatives and friends who can offer help when respondents are in need.

2.3.4. Indicators of individual physical conditions

Residents' physical conditions also affect their mental health (Newton-Howes et al., 2006; Yu et al., 2018), so functional ability (categorized into restricted or not restricted using the Activities of Daily Living) and physical health status were also controlled. The Activities of Daily Living (ADL) is derived from 13 questions. ADL is a reliable measure of functional ability across different countries, and if respondents had problems with at least one of the activities, then they were classified as having functional restrictions (Pluijm et al., 2005). Additionally, since suffering from physical illness affects mental health (Moussavi et al., 2007), we controlled for respondents' physical health status through whether or not a respondent faces a chronic disease, including high blood disease, diabetes, etc.

2.3.5. Individual socioeconomic, demographic controlled variables

We controlled for a series of individual-level variables, including: gender (dichotomous variable), age (continuous variable), race (categorical variables), marital status (categorical variables), party membership (categorical variables), and hukou status (dichotomous variable).

2.4. Analysis

Multilevel regression models were used to assess the relation between neighbourhood walkability and depression as well as anxiety. Such models were necessary due to the hierarchical structure of data, where people are nested in neighbourhoods, otherwise biasing the model output. Precisely, the following model was estimated as follows. The measure of variance inflation factors (VIF = 1.42) was used to investigate multicollinearity among the variables. The neighbourhood-level intra-class correlation coefficient (ICC) is 0.12 (GDS) and 0.06 (GAI) in the null model (i.e., a model without covariates), indicating that GDS and GAI scores within the same neighbourhood face some correlation, confirming the application of such multi-level models rather than ordinary linear models.

First, we fitted the base model (Model 1 and Model 2) to identify the effect of the street walkability on respondents' depression and anxiety. Second, we ran two additional models (Model 3 and Model 4) to test whether the results from Model 1 were robust. Last, cross-level interaction effects were tested in Model 5 and 6 to identify whether the street walkability was more important for older respondents in disadvantaged groups.

Table 3
Descriptive statistics of variables.

Variables	Proportion/Mean (SD)
Dependent variables	
GDS Score (0–15)	3.376 (2.731)
GAI Score (0–20)	2.337 (4.292)
Street view proportion of sky	
Q1 (high walkability)	0.225 (0.012)
Q2 (middle-high walkability)	0.252 (0.007)
Q3 (middle-low walkability)	0.290 (0.014)
Q4 (low walkability)	0.357 (0.042)
Street view proportion of greenness	
Q1	0.110 (2.5)
Q2	0.156 (1.0)
Q3	0.178 (0.4)
Q4	0.215 (1.8)
Education (%)	
Primary school or below	31.192
High school	43.950
College and above	24.858
Functional ability (%)	
Restricted	54.024
Not restricted	45.976
Physical health status (%)	
With chronic disease	79.851
No chronic disease	20.149
Social ties indicators	
Social ties quantity	14.381 (25.578)
Social ties quality	10.584 (30.973)
Control variables	
Gender (%)	
Male	41.292
Female	58.708
Age	70.715 (7.031)
Race (%)	
Chinese Han	96.341
Minority	3.659
Marital status (%)	
Single, divorced, and widowed	22.335
Married and living with spouse	76.686
Married but living apart from spouse	0.979
Party membership (%)	
Party member	44.129
None party member	55.871
Hukou status (%)	
Local hukou	93.985
Non-local hukou	6.015

Table 4
Results from multilevel liner regression models for the relationship between GDS scores, GAI scores and neighbourhood street walkability among older adults.

Variable	Model 1 (DV: Depression) Coeff. (SE)	Model 2 (DV: Anxiety) Coeff. (SE)
Fixed effects		
Male (ref: female)	0.093 (0.163)	-0.443 (0.270)
Age	-0.045*** (0.013)	-0.080*** (0.020)
Education (ref: primary school or less)		
High school	0.156 (0.194)	0.252 (0.315)
College or more	0.019 (0.234)	0.056 (0.364)
Minority (ref: Han Chinese)	0.128 (0.391)	0.547 (0.637)
Marital status (ref. = single, divorced, or widowed)		
Married living with spouse	-0.328* (0.196)	-0.69 (0.322)
Married not living with spouse	0.370 (0.754)	0.289 (1.246)
Party member (ref: none-party member)	-0.478*** (0.165)	-0.854*** (0.270)
Local hukou (ref: non-local hukou)	0.396 (0.317)	0.222 (0.505)
Quantity of social ties	-0.006** (0.003)	-0.005** (0.003)
Quality of social ties	-0.008** (0.003)	-0.008** (0.004)
With physical disease (ref: without physical disease)	0.844*** (0.184)	1.147*** (0.304)
Functional ability restricted (ref: not restricted)	0.766*** (0.163)	0.984*** (0.267)
Street view proportion of greenness (ref: Q1)		
Q2	-1.179***(0.391)	-1.068(0.759)
Q3	-1.028**(0.409)	-1.207(0.788)
Q4	-1.216***(0.396)	-1.155(0.781)
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	0.981*** (0.367)	0.349** (0.173)
Q3 (middle-low walkability)	1.023** (0.391)	0.394** (0.178)
Q4 (low walkability)	1.596*** (0.389)	0.551*** (0.177)
Constant	6.891*** (1.107)	8.105*** (1.708)
Random effects		
Var (Neighbourhood-level constant)	0.533	0.077
Var (Residual)	6.094	16.984
Number of neighbourhoods	48	48
Number of respondents	1231	1231
Log-likelihood	-2887.5270	-3492.595
AIC	5818.540	7029.192

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

3. Results

3.1. Study population characteristics

Table 3 shows the main characteristics of the study population. Briefly, respondents' mean GDS score was 3.376 and their mean GAI score was 2.337, both of which can be defined as "normal". Of the respondents, 31.192% had an educational attainment of primary school or below, 43.950% had high school educational attainment, and 24.858% had college or above educational attainment. For physical condition indicators, few respondents were not functionally restricted (45.976%) or had no chronic disease (20.149%). Respondents' mean social ties quantity was 14.381, while their mean social ties quality was 10.584, which means that respondents had approximately 14 relatives and friends they can meet or contact at least once a month and nearly 11 relatives and friends who can offer help when they are in need, on average. With a higher proportion of female (58.708%), the respondents' mean age was 70.715 years. Few respondents were minority (3.659%) or married but living apart from spouse (0.979%). A high percentage were not party members (55.871%) or had local hukou (93.985%). The mean value of the first quartile (Q1) of street view greenness was 0.110, that of the second quartile (Q2) was 0.156, that of the third quartile (Q3) was 0.178 and that of the last quartile (Q4) was 0.215. Last, for the key independent variable, the mean value of the first quartile (Q1, high walkability) of street view proportion of sky was 0.225, that of the second quartile (Q2, middle-high walkability) was 0.252, that of the third quartile (Q3, middle-low walkability) was 0.290 and that of the last quartile (Q4, low walkability) was 0.357.

3.2. Multilevel results

Model 1 in Table 4 showed the relationship between street walkability, covariates and respondents' GDS scores, while Model 2 in Table 4 showed the relationship between street walkability, covariates and respondents' GAI scores. GDS scores and GAI scores decreased with respondents' age [GDS: Coeff. = −0.045, SE = 0.013; GAI: Coeff. = −0.080, SE = 0.020]. Compared with none-party members, party members had lower GDS and GAI scores [GDS: Coeff. = −0.478, SE = 0.165; GAI: Coeff. = −0.854,

Table 5
Robustness tests results from multilevel regression models for the relationship between GDS and GAI scores and neighbourhood street walkability among older adults.

	DV: Depression Coeff. (SE)	DV: Anxiety Coeff. (SE)
Variable	Model 3a	Model 4a
Street view proportion of sky	8.220*** (2.532)	4.087*** (1.645)
	Model 3b	Model 4b
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	0.824** (0.372)	0.305** (0.151)
Q3 (middle-low walkability)	1.021*** (0.395)	0.368** (0.141)
Q4 (low walkability)	1.639*** (0.394)	0.623*** (0.149)
	Model 3c	Model 4c
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	0.827** (0.373)	0.206** (0.102)
Q3 (middle-low walkability)	0.877** (0.376)	0.396*** (0.104)
Q4 (low walkability)	0.961** (0.402)	0.408*** (0.102)
	Model 3d	Model 4d
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	1.563*** (1.049-3.154)	1.765*** (1.090-3.467)
Q3 (middle-low walkability)	1.722** (1.079-3.127)	1.795*** (1.084-3.648)
Q4 (low walkability)	2.347** (1.049-3.680)	1.979*** (1.053-3.174)
	Model 3e	Model 4e
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	0.907** (0.399)	0.274** (0107)
Q3 (middle-low walkability)	1.203*** (0.424)	0.362*** (0.108)
Q4 (low walkability)	1.678*** (0.426)	0.478*** (0.106)
	Model 3f	Model 4f
Street view proportion of sky (ref: Q1 high walkability)		
Q2 (middle-high walkability)	0.914** (0.378)	0.207* (0.103)
Q3 (middle-low walkability)	1.226** (0.406)	0.381*** (0.107)
Q4 (low walkability)	1.615*** (0.403)	0.584*** (0.103)

* p < 0.10.
** p < 0 .05.
*** p < 0 .01. Models adjusted for individual-level covariates and street view proportion of greenness.

SE = 0.270]. Respondents' GDS and GAI scores decreased with quantity of social ties [GDS: Coeff. = −0.006, SE = 0.003; GAI: Coeff. = −0.005, SE = 0.003], while they also decreased with the quality of social ties [GDS: Coeff. = −0.008, SE = 0.003; GAI: Coeff. = −0.008, SE = 0.004]. Respondents with chronic disease had higher GDS and GAI scores [GDS: Coeff. = 0.844, SE = 0.184; GAI: Coeff. = 1.147, SE = 0.304] and those who were functionally restricted also had higher GDS and GAI scores [GDS: Coeff. = 0.766, SE = 0.163; GAI: Coeff. = 0.984, SE = 0.267]. Street greenness was associated with a reduction of the GDS scores. Compared with residents living in neighbourhoods in the first quartile of street view greenness, those living in neighbourhoods in the second, third and fourth quartiles of street view greenness had lower GDS scores [Q2: Coeff. = −1.179, SE = 0.391; Q3: Coeff. = −1.028, SE = 0.409; Q4: Coeff. = −1.216, SE = 0.396], but no evidence can support that street greenness was also associated with GAI scores. Most importantly, street walkability was associated with a reduction of the GDS scores. Compared with residents living in neighbourhoods in the first quartile of street view proportion of sky (high walkability), those living in neighbourhoods in the second (middle-high walkability), third (middle-low walkability) and fourth (low walkability) quartiles of street view proportion of sky had higher GDS scores [Q2: Coeff. = 0.981, SE = 0.367; Q3: Coeff. = 1.023, SE = 0.391; Q4: Coeff. = 1.596, SE = 0.389], while street walkability was also associated with a reduction in GAI scores. Compared with residents living in neighbourhoods in the first quartile of street view proportion of sky (high walkability), those living in neighbourhoods in the second (middle-high walkability), third (middle-low walkability) and fourth (low walkability) quartiles of street view proportion of sky had higher GAI scores [Q2: Coeff. = 0.349, SE = 0.173; Q3: Coeff. = 0.394, SE = 0.178; Q4: Coeff. = 0.551, SE = 0.177].

3.3. Robustness tests

Models 3 and 4 in Table 5 were used to test whether the results in Models 1 and 2 were robust. In Models 3a and 4a, we treated street walkability as a continuous variable. In Models 3b and 4b, we excluded respondents whose ages were above 85, because these respondents were at an extremely advanced age and their perception of the street view may be biased (Gascon et al., 2018). In Models 3c and 4c, we set the radius of buffer as 1000 m. In Models 3d and 4d, we set the dependent variable as a binary variable. Respondents whose GDS scores were above 8 can be regarded as having depression (Lam et al., 2004), and respondents whose GDS scores were above 10 can be regarded as having anxiety (Pachana et al., 2007), so they were regarded as treated groups. In Models 3e and 4e, we excluded respondents who had cataracts, glaucoma, AD (Alzheimer's Disease) or neuropathy, because for those who had cataracts, glaucoma, AD (Alzheimer's Disease) or neuropathy, their perception of the street view may also be biased. In Models 3f and 4f, we excluded respondents who had problem with going 3–4 lion on foot or go up and down the stairs by themselves, because these

Table 6
Relationship between GDS and GAI scores and neighbourhood street walkability among older adults in different subgroups.

	DV: Depression Coeff. (SE)	DV: Anxiety Coeff. (SE)
Variable	Model 5a	Model 6a
Street view proportion of sky (ref: Q1 high walkability) × Education (ref: primary school or less)		
Q2 (middle-high walkability) × High school	-0.067* (0.046)	-0.153 (0.157)
Q3 (middle-low walkability) × High school	-0.087** (0.047)	-0.274* (0.159)
Q4 (low walkability) × High school	-0.365*** (0.042)	-0.296* (0.166)
Q2 (middle-high walkability) × College or more	-0.451*** (0.046)	-1.230*** (0.144)
Q3 (middle-low walkability) × College or more	-0.966*** (0.047)	-1.291*** (0.146)
Q4 (low walkability) × College or more	-0.995*** (0.046)	-1.296*** (0.152)
	Model 5b	Model 6b
Street view proportion of sky (ref: Q1 high walkability) × With physical disease (ref: without physical disease)		
Q2 (middle-high walkability) × With physical disease (ref: without physical disease)	1.968 (0.692)	2.256** (1.121)
Q3 (middle-low walkability) × With physical disease (ref: without physical disease)	2.690** (0.729)	2.896** (1.212)
Q4 (low walkability) × With physical disease (ref: without physical disease)	3.452*** (0.760)	5.032*** (1.264)
	Model 5c	Model 6c
Street view proportion of sky (ref: Q1 high walkability) × Functional ability restricted (ref: not restricted)		
Q2 (middle-high walkability) × Functional ability restricted (ref: not restricted)	0.982*** (0.039)	0.648*** (0.100)
Q3 (middle-low walkability) × Functional ability restricted (ref: not restricted)	0.988*** (0.037)	0.859*** (0.088)
Q4 (low walkability) × Functional ability restricted (ref: not restricted)	0.992*** (0.041)	0.916*** (0.093)
	Model 5d	Model 6d
Street view proportion of sky (ref: Q1 high walkability) × Quantity of social ties		
Q2 (middle-high walkability) × Quantity of social ties	-0.491 (0.398)	-1.181* (0.663)
Q3 (middle-low walkability) × Quantity of social ties	-0-.895** (0.399)	-1.256* (0.664)
Q4 (low walkability) × Quantity of social ties	-1.087*** (0.401)	-1.641** (0.668)
Street view proportion of sky (ref: Q1 high walkability) × Quality of social ties		
Q2 (middle-high walkability) × Quality of social ties	-0.875*** (0.311)	-0.439 (0.519)
Q3 (middle-low walkability) × Quality of social ties	-0.957*** (0.307)	-0.958* (0.508)
Q4 (low walkability) × Quality of social ties	-1.918*** (0.328)	-2.292*** (0.546)

* $p < 0.10$.
** $p < 0 .05$.
*** $p < 0 .01$. Models adjusted for individual level covariates and street view proportion of greenness.

respondents were less likely to walk around their neighbourhood and were less influenced by street view. For all these robustness tests of the models, the relationship between neighbourhood street view proportion of sky (walkability) and respondents' GDS and GAI scores were significant, and compared with residents living in neighbourhoods in the first quartile of street view proportion of sky (high walkability), those living in neighbourhoods in the second (middle-high walkability), third (middle-low walkability) and fourth (low walkability) quartiles of street view proportion of sky had higher GDS and GAI scores.

3.4. Exploring the effect of neighbourhood street walkability on respondents' GDS and GAI scores in subgroups

The results of the cross-level interaction in Models 5 and 6 (Table 6) indicated that street walkability moderates the relationship between individuals' educational attainment, social ties and physical condition indicators and respondents' GDS and GAI scores. In Models 5a and 6a, respondents with higher education attainment were less influenced by street walkability, which means that neighbourhood street walkability was more protective for less educated respondents. In Models 5b and 6b, respondents with physical disease were more influenced by street walkability, which means that neighbourhood street walkability was more protective for respondents with physical disease. In Models 5c and 6c, respondents who were functionally restricted were more influenced by street walkability, which means that neighbourhood street walkability was more protective for respondents who were functionally restricted. In Models 5d and 6d, respondents who had higher quantity and quality of social ties were less influenced by street walkability, which means that neighbourhood street walkability was more protective for respondents who were functionally restricted. Thus, higher street walkability was more important for older respondents in disadvantaged groups (e.g., less educated, with physical disease, functionally restricted, lower quantity and quality of social ties).

4. Discussion

Few studies have examined neighbourhood walkability-mental health associations, especially for older adults. Even fewer studies have assessed walkability with eye-level streetscape images. A previous study has proved that a higher proportion of sky in each street view image is associated with lower probability of walking, because a higher proportion of sky indicates lower urban density, fewer pedestrian destinations as well as less urban greenness (Yin and Wang, 2016). Therefore, the proportion of sky in a streetscape image is a suitable measurement of eye-level neighbourhood walkability.

This study showed a potential beneficial role of eye-level neighbourhood walkability on depression and anxiety in older adults. These results can be explained by two mechanisms, including physical activity and social contacts. First, the most popular outdoor physical activity for old adults in China is walking around the neighbourhood (Hallal et al., 2012), so with the decreased neighbourhood walkability, older residents may decrease their outdoor activities, such as walking. Second, neighbourhood streets are also an important social space for older adults in China, because of their limited functional abilities (Deng et al., 2010). Thus, the decrease of neighbourhood walkability may reduce older residents' opportunities for social contact.

The results of robustness tests confirmed that the neighbourhood walkability-mental health associations for older adults were relatively robust compared with the results for adults (Frank et al., 2010; Su et al., 2017a). The reasons may be that older adults may have limited mobility, so they are more exposed to the neighbourhood environment compared with the adults who can travel for a long distance for daily activities. Previous studies support the fact that young adults are exposed to an array of urban environments, including neighbourhoods, workplaces and destinations for leisure purposes (Helbich, 2018; Pearce et al., 2016; Schönfelder and Axhausen, 2003; Xiao et al. 2017; Xiao et al. 2019). Additionally, older adults have a stronger sense of place attachment compared with young adults, so they are more likely to be influenced by their neighbourhood environment (Wiles et al., 2009; Wiles et al., 2012).

The cross-level interaction effect suggested that the effects of eye-level neighbourhood walkability on older adults' depressive symptom may vary across different subgroups. Neighbourhood walkability is even more beneficial for older adults who are in disadvantaged groups, such as being less educated, with physical disease, with functional disability, and with lower quantity and quality of social ties. Older residents who are less educated, with lower quantity and quality of social ties, may be unaware of current health-related information, so they have poorer health (Niedzwiedz et al., 2016). However, living in neighbourhood with higher wallablity, residents are more likely to have social contact around neighbourhood (Su et al., 2016; Su et al., 2017a), so not only can they strengthen their social ties with their neighbours, but also they can get more health-related information through social contact. Hence, older residents who are with physical disease or being functionally restricted are more influenced by neighbourhood walkability, because they can not travel for a long distance which limits their activity spaces and make them to be confined to the areas surrounding their residence (Wiles et al., 2009; Wiles et al., 2012; Su et al., 2017b; Su et al., 2017c). Also, they may take less physical activities to avoid being hurt due to physical disadvantages (Nelson et al., 2007). However, living in neighbourhood with higher walkability, older adults may take more low-intensity exercise around neighbourhood, since their neighbours may also take more physical activities and can offer them help. Thus, those older residents who are in disadvantaged groups may be more influenced by neighbourhood walkablity.

Some limitations of this study should be noted. Street walkablity is a composite index, but we only measure one of the most important aspects of it (visual enclosure) by using street view data, so more and other indicators from street views may be needed to improve the reliability of the measurement of walkability in future studies. The street views are obtained in 2012 while the survey data were collected in 2011. There was a mismatch between those data, because of rapid urbanization in Beijing during 2011–2012. Our cross-sectional study design cannot infer any causal relationship between neighbourhood walkability and older adults' depression and anxiety, so further longitudinal studies are needed. The sample is not representative enough, because Beijing is one of the most developed cities in China, so the relationship for older people in rural areas or underdeveloped areas in China is still unclear. We have not yet explored the mechanisms through which neighbourhood walkability has an effect on older adults' depression and anxiety. Physical activities may play in the underlaying mechanisms. However, the data were not collected in our survey. Last, our survey was collected in 2011 and we do not have pedestrian volume and Walk Score data at that time, so further study should compare the result of traditional measurement of walkablity and eye-level walkablity.

5. Conclusion

The present study indicates a potential beneficial role of street walkability on mental health (depression and anxiety) in older residents. The results also prove that these associations are relatively robust compared with previous studies. Furthermore, street walkability has strong associations for older adults in disadvantaged groups, such as those with less education, chronic physical diseases, limited functional ability, or weak social ties. Further studies are required to address some of the remaining limitations in this research, including the design of longitudinal studies and unravelling the potential mediating mechanisms.

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The datasets generated and/or analysed in the current study are available in the repository [http://cnsda.ruc.edu.cn/index.php?r=projects/view&id=60493698].

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Conflict of interest

None.

References

Adjayegbewonyo, K., Kawachi, I., Subramanian, S.V., Avendano, M., 2018. High social trust associated with increased depressive symptoms in a longitudinal South African sample. Social. Sci. Med. 197, 127–135.

Adlakha, D., Hipp, J.A., Brownson, R.C., 2016. Neighborhood-based differences in walkability, physical activity, and weight status in India. J. Transp. Health 3 (4), 485–499.

Badland, H.M., Opit, S., Witten, K., Kearns, R.A., Mavoa, S., 2010. Can virtual streetscape audits reliably replace physical streetscape audits? J. Urban Health 87 (6), 1007–1016.

Berke, E.M., Gottlieb, L.M., Moudon, A.V., Larson, E.B., 2007. Protective association between neighborhood walkability and depression in older men. J. Am. Geriatr. Soc. 55 (4), 526–533.

de Craen, A.J., Heeren, T., Gussekloo, J., 2003. Accuracy of the 15-item geriatric depression scale (GDS-15) in a community sample of the oldest old. Int. J. Geriatr. psychiatry 18 (1), 63–66.

Deng, J., Hu, J., Wu, W., Dong, B., Wu, H., 2010. Subjective well-being, social support, and age-related functioning among the very old in China. Int. J. Geriatr. psychiatry 25 (7), 697–703.

Dong, R., Zhang, Y., Zhao, J., 2018. How green are the streets within the sixth ring road of Beijing? An analysis based on tencent street view pictures and the green view index. Int. J. Environ. Res. Public Health 15 (7), 1367.

Frank, L.D., Schmid, T.L., Sallis, J.F., Chapman, J., Saelens, B.E., 2005. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. Am. J. Prev. Med. 28 (2), 117–125.

Frank, L.D., Sallis, J.F., Conway, T.L., Chapman, J.E., Saelens, B.E., Bachman, W., 2006. Many pathways from land use to health: associations between neighborhood walkability and active transportation, body mass index, and air quality. J. Am. Plan. Assoc. 72 (1), 75–87.

Frank, L.D., Sallis, J.F., Saelens, B.E., Leary, L., Cain, K., Conway, T.L., Hess, P.M., 2010. The development of a walkability index: application to the neighborhood quality of life study. Br. J. Sport. Med. 44 (13), 924–933.

Gascon, M., Sánchez-Benavides, G., Dadvand, P., Martínez, D., Gramunt, N., Gotsens, X., Crous-Bou, M., 2018. Long-term exposure to residential green and blue spaces and anxiety and depression in adults: a cross-sectional study. Environ. Res. 162, 231–239.

Glass, T.A., Maddox, G.L., 1992. The quality and quantity of social support: stroke recovery as psycho-social transition. Social. Sci. Med. 34 (11), 1249–1261.

Hajrasouliha, A., Yin, L., 2015. The impact of street network connectivity on pedestrian volume. Urban Stud. 52 (13), 2483–2497.

Hallal, P.C., Andersen, L.B., Bull, F.C., Guthold, R., Haskell, W., Ekelund, U., Group, L.P.A.S.W., 2012. Global physical activity levels: surveillance progress, pitfalls, and prospects. Lancet 380 (9838), 247–257.

Hare, D.L., Toukhsati, S.R., Johansson, P., Jaarsma, T., 2014. Depression and cardiovascular disease: a clinical review. Eur. Heart J. 35 (21), 1365–1372.

Helbich, M., 2018. Toward dynamic urban environmental exposure assessments in mental health research. Environ. Res. 161, 129–135.

Herring, M.P., Johnson, K.E., O'connor, P.J., 2016. Exercise training and health-related quality of life in generalized anxiety disorder. Psychol. Sport Exerc. 27, 138–141.

Howell, N.A., Farber, S., Widener, M.J., Booth, G.L., 2017. Residential or activity space walkability: what drives transportation physical activity? J. Transp. Health 7, 160–171.

Kang, K., Wang, X., 2014. Fully Convolutional Neural Networks for Crowd Segmentation. Comput. Sci. 49 (1), 25–30.

Kawachi, I., Berkman, L.F., 2001. Social ties and mental health. J. Urban Health 78 (3), 458–467.

Lam, T., Li, Z., Ho, S., Chan, W., Ho, K., Li, M., Leung, G., 2004. Smoking and depressive symptoms in Chinese elderly in Hong Kong. Acta Psychiatr. Scand. 110 (3), 195–200.

Leslie, E., Cerin, E., 2008. Are perceptions of the local environment related to neighbourhood satisfaction and mental health in adults? Prev. Med 47 (3), 273–278.

Liu, Y., Zhang, F., Liu, Y., Li, Z., Wu, F., 2017. The effect of neighbourhood social ties on migrants' subjective wellbeing in Chinese cities. Habitat Int. 66, 86–94.

Long, J., Shelhamer, E., & Darrell, T., 2015. Fully convolutional networks for semantic segmentation. Paper Presented at the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition.

Long, Y., Liu, L., 2017. How green are the streets? An analysis for central areas of Chinese cities using tencent street view. PLoS One 12 (2), e0171110.

Lou, P., Zhu, Y., Chen, P., Zhang, P., Yu, J., Zhang, N., Zhao, J., 2012. Prevalence and correlations with depression, anxiety, and other features in outpatients with chronic obstructive pulmonary disease in China: a cross-sectional case control study. BMC Pulm. Med. 12 (1), 53.

Lu, Y., Sarkar, C., Xiao, Y., 2018. The effect of street-level greenery on walking behavior: evidence from Hong Kong. Social. Sci. Med. 208, 41–49.

Lu, Y., 2018. The Association of urban greenness and walking behavior: using Google street view and deep learning techniques to estimate residents' exposure to urban greenness. Int. J. Environ. Res. Public Health 15 (8), 1576.

Marquet, O., Hipp, J.A., Miralles-Guasch, C., 2017. Neighborhood walkability and active ageing: a difference in differences assessment of active transportation over ten years. J. Transp. Health 7, 190–201.

Marshall, J.D., Brauer, M., Frank, L.D., 2009. Healthy neighborhoods: walkability and air pollution. Environ. Health Perspect. 117 (11), 1752.

Miao, J., Wu, X.G., 2016. Urbanization, socioeconomic status and health disparity in China. Health Place 42, 87–95. https://doi.org/10.1016/j.healthplace.2016.09.008.

Moussavi, S., Chatterji, S., Verdes, E., Tandon, A., Patel, V., Ustun, B., 2007. Depression, chronic diseases, and decrements in health: results from the world health surveys. Lancet 370 (9590), 851–858.

Nelson, M.E., Rejeski, W.J., Blair, S.N., Duncan, P.W., Judge, J.O., King, A.C., Castaneda-Sceppa, C., 2007. Physical activity and public health in older adults: recommendation from the American college of sports medicine and the american heart association. Circulation 116 (9), 1094.

Newton-Howes, G., Tyrer, P., Johnson, T., 2006. Personality disorder and the outcome of depression: meta-analysis of published studies. Br. J. Psychiatry 188 (1), 13–20.

Niedzwiedz, C.L., Richardson, E.A., Tunstall, H., Shortt, N.K., Mitchell, R.J., Pearce, J.R., 2016. The relationship between wealth and loneliness among older people across Europe: is social participation protective? Prev. Med 91, 24–31.

Pachana, N.A., Byrne, G.J., Siddle, H., Koloski, N., Harley, E., Arnold, E., 2007. Development and validation of the geriatric anxiety inventory. Int. Psychogeriatr. 19 (1), 103–114.

Pearce, J., Shortt, N., Rind, E., Mitchell, R., 2016. Life course, green space and health: incorporating place into life course epidemiology. Int. J. Environ. Res. Public Health 13 (3), 331.

Phelan, J.C., Link, B.G., Tehranifar, P., 2010. Social conditions as fundamental causes of health inequalities: theory, evidence, and policy implications. J. Health Social. Behav. 51 (1_suppl), S28.

Pluijm, S., Bardage, C., Nikula, S., Blumstein, T., Jylhä, M., Minicuci, N., Group, C.S.W., 2005. A harmonized measure of activities of daily living was a reliable and valid instrument for comparing disability in older people across countries. J. Clin. Epidemiol. 58 (10), 1015–1023.

Rauterkus, S.Y., Miller, N., 2011. Residential land values and walkability. J. Sustain. Real. Estate 3 (1), 23–43.

Renalds, A., Smith, T.H., Hale, P.J., 2010. A systematic review of built environment and health. Fam. Community Health 33 (1), 68–78.

Rumsfeld, J.S., Ho, P.M., 2005. Depression and cardiovascular disease:a call for recognition. Circulation 111 (3), 250–253.

Rundle, A., Neckerman, K.M., Freeman, L., Lovasi, G.S., Purciel, M., Quinn, J., Weiss, C., 2008. Neighborhood food environment and walkability predict obesity in New York City. Environ. Health Perspect. 117 (3), 442–447.

Ruo, B., Rumsfeld, J.S., Hlatky, M.A., Liu, H., Browner, W.S., Whooley, M.A., 2003. Depressive symptoms and health-related quality of life: the heart and soul study. JAMA 290 (2), 215–221.

Rzotkiewicz, A., Pearson, A.L., Dougherty, B.V., Shortridge, A., Wilson, N., 2018. Systematic review of the use of Google Street View in health research: major themes, strengths, weaknesses and possibilities for future research. Health Place 52, 240–246.

Sallis, J.F., Saelens, B.E., Frank, L.D., Conway, T.L., Slymen, D.J., Cain, K.L., Kerr, J., 2009. Neighborhood built environment and income: examining multiple health

outcomes. Social. Sci. Med. 68 (7), 1285–1293. https://doi.org/10.1016/j.socscimed.2009.01.017.
Sarkar, C., Webster, C., Gallacher, J., 2018. Residential greenness and prevalence of major depressive disorders: a cross-sectional, observational, associational study of 94879 adult UK Biobank participants. Lancet Planet. Health 2, e162–e173.
Schönfelder, S., Axhausen, K.W., 2003. Activity spaces: measures of social exclusion? Transp. policy 10 (4), 273–286.
Seeman, T.E., 1996. Social ties and health: the benefits of social integration. Ann. Epidemiol. 6 (5), 442–451.
Shirado, H., Fu, F., Fowler, J.H., Christakis, N.A., 2013. Quality versus quantity of social ties in experimental cooperative networks. Nat. Commun. 4, 2814.
Sturm, R., Cohen, D.A., 2004. Suburban sprawl and physical and mental health. Public Health 118 (7), 488–496.
Su, S., Zhang, Q., Pi, J., Wan, C., Weng, M., 2016. Public health in linkage to land use: theoretical framework, empirical evidence, and critical implications for reconnecting health promotion to land use policy. Land Use Policy 57, 605–618.
Su, S., Pi, J., Xie, H., Cai, Z., Weng, M., 2017a. Community deprivation, walkability, and public health: highlighting the social inequalities in land use planning for health promotion. Land Use Policy 67, 315–326.
Su, S., Li, Z., Xu, M., Cai, Z., Weng, M., 2017b. A geo-big data approach to intra-urban food deserts: transit-varying accessibility, social inequalities, and implications for urban planning. Habitat Int. 64, 22–40.
Su, S., Gong, Y., Tan, B., Pi, J., Weng, M., Cai, Z., 2017c. Area social deprivation and public health: analyzing the spatial non-stationary associations using geographically weighed regression. Social. Indic. Res. 133 (3), 819–832.
Suls, J., Bunde, J., 2005. Anger, anxiety, and depression as risk factors for cardiovascular disease: the problems and implications of overlapping affective dispositions. Psychol. Bull. 131 (2), 260.
Sun, G., Oreskovic, N.M., Lin, H., 2014. How do changes to the built environment influence walking behaviors? A longitudinal study within a university campus in Hong Kong. Int. J. health Geogr. 13 (1), 28.
Sun, G., Zacharias, J., Ma, B., Oreskovic, N.M., 2016. How do metro stations integrate with walking environments? Results from walking access within three types of built environment in Beijing. Cities 56, 91–98.
Talen, E., Koschinsky, J., 2014. The neighborhood quality of subsidized housing. J. Am. Plan. Assoc. 80 (1), 67–82.
Thoits, P.A., 2011. Mechanisms linking social ties and support to physical and mental health. J. health Social. Behav. 52 (2), 145–161.
Vos, T., Allen, C., Arora, M., Barber, R.M., Bhutta, Z.A., Brown, A., Chen, A.Z., 2016. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the global burden of disease study 2015. Lancet 388 (10053), 1545–1602.
Wang, R., Xue, D., Liu, Y., Chen, H., Qiu, Y., 2018a. The relationship between urbanization and depression in China: the mediating role of neighborhood social capital. Int. J. Equity Health 17 (1), 105. https://doi.org/10.1186/s12939-018-0825-x.
Wang, R., Xue, D., Liu, Y., Liu, P., Chen, H., 2018b. The Relationship between air pollution and depression in China: is neighbourhood social capital protective? Int. J. Environ. Res. Public Health 15 (6), 1160.
Wiles, J.L., Allen, R.E., Palmer, A.J., Hayman, K.J., Keeling, S., Kerse, N., 2009. Older people and their social spaces: a study of well-being and attachment to place in Aotearoa New Zealand. Social. Sci. Med. 68 (4), 664–671.
Wiles, J.L., Leibing, A., Guberman, N., Reeve, J., Allen, R.E., 2012. The meaning of "aging in place" to older people. Gerontologist 52 (3), 357–366.
Xiao, Y., Wang, Z., Li, Z.G., Tang, Z.L., 2017. An assessment of urban park access in Shanghai - implications for the social equity in urban China. Landsc. Urban Plan. 157, 383–393.
Xiao, Y., Wang, D., Fang, J., 2019. Exploring the disparities in park access through mobile phone data: evidence from Shanghai, China. Landsc. Urban Plan. 181, 80–91.
Yin, L., Wang, Z., 2016. Measuring visual enclosure for street walkability: using machine learning algorithms and Google street view imagery. Appl. Geogr. 76, 147–153.
Yu, W., Singh, S.S., Calhoun, S., Zhang, H., Zhao, X., Yang, F., 2018. Generalized anxiety disorder in urban China: prevalence, awareness, and disease burden. J. Affect. Disord. 234, 89–96.
Zhou, B., Zhao, H., Puig, X., Fidler, S., Barriuso, A., Torralba, A., 2016. Semantic understanding of scenes through the ADE20K dataset. arXiv Prepr. arXiv 1608, *05442*.
Zhou, B., Zhao, H., Puig, X., Fidler, S., Barriuso, A., & Torralba, A., 2017. Scene parsing through ade20k dataset. Paper Presented at the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition.