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Research Article

Neighborhood Built Environment and Late-Life Depression: A Multilevel Path Analysis in a Chinese Society

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Abstract

Objectives: Neighborhood built environments (BEs) are increasingly recognized as being associated with late-life depression. However, their pathways are still understudied. This study investigates the mediating effects of physical and social activities (PA and SA) and functional ability (FA) in the relationships between BEs and late-life depression.

Methods: We conducted a cross-sectional analysis with data from 2,081 community-dwellers aged 65 years and older in Hong Kong in 2014. Two road-network-based service area buffers (200- and 500-m buffers) adjusted by terrain and slope from participants' residences were created to define the scope of neighborhoods. BEs comprised population density in District Council Constituency Areas, urban greenness, land-use diversity, and neighborhood facilities within 200- and 500-m buffers. Multilevel path analysis models were used.

Results: More urban greenness within both buffers and more commercial facilities within a 500-m buffer were directly associated with fewer depressive symptoms. SA mediated the relationship between the number of community facilities and depressive symptoms within a 200-m buffer. Neighborhood urban greenness and the number of commercial facilities had indirect associations on depressive symptoms within a 500-m buffer, which were mediated by FA.

Discussion: Our findings have implications for the ecological model of aging. The mediating effects of SA and FA underscore the importance of promoting active social lifestyles and maintaining FA for older adults' mental health in high-density cities. Policy implications on how to build age-friendly communities are discussed.

Keywords: Age-friendliness, Living environments, Mental health, Multilevel models

Depression is a common mental health condition among older adults (Horackova et al., 2019). The prevalence of depressive symptoms ranges from 4.0% to 22.9% among older adults in community settings (Meeks et al., 2011). A range of risk factors for late-life depression has been identified, including lack of physical activities, social isolation, and functional limitations (Chen et al., 2012). However, most studies have focused on individual-level

factors without considering the potential impacts of neighborhood environments on late-life depression.

The ecological theory of aging holds that older adults are particularly affected by their immediate built environments (BEs; Lawton & Nahemow, 1973) due to their tendency to spend more time in their neighborhoods compared to younger people and their declining age-related capacities (Lawton & Nahemow, 1973). Therefore, it is imperative to understand the associations between the BEs and the well-being of older people, particularly those who are physically frail and mentally unwell. To this end, an increasing number of environmental gerontology studies have begun examining associations between neighborhood BEs and late-life depression (Barnett et al., 2018). BEs are defined as the human-made spaces in which people live on a day-to-day basis (Roof & Oleru, 2008), comprising at least four dimensions: *density*, such as population density; *design*, such as urban greenness; *diversity*, such as land-use patterns; and *destination*, indicating the availability of facilities (Ewing et al., 2015; Zhang, Ye et al., 2019).

However, existing evidence regarding the impact of BEs on older adults' mental health remains inconclusive. While some studies have shown that higher population density, more urban greenness, more land-use diversity, and more facilities in neighborhoods are positively associated with older adults' mental health (de Keijzer et al., 2020; Sarkar et al., 2018), others have shown negative or no significant associations between land-use diversity and mental health (Rosso et al., 2013; Zhang, Zhou et al., 2019).

While some studies have established positive associations between BEs and older adults' mental health, the underlying pathways are less well understood. Nevertheless, the ecological model of aging (Lawton & Nahemow, 1973) provides insights into potential pathways as to how BEs may affect older adults' mental health. Two potential pathways have been identified: *enabling* and *compensatory processes* (Scharlach, 2017).

Most previous studies emphasized *enabling process* as a pathway between BEs and late-life depression (Cerin, Lee et al., 2013), theorizing that well-designed BEs can promote and stimulate older adults' *capacity-enhancing behaviors*, defined as physical and social activities (PA and SA) in this study, thereby leading to better mental health (Lawton & Nahemow, 1973). More studies have shown that older adults can maintain their mental health by participating in light- and moderate-level intensity PA through proactive use of environments with urban greenness, diverse land use, and sports-related facilities (Cerin, Lee et al., 2013; Li et al., 2005). Participation in SA, such as volunteering and interest groups, promotes a sense of meaning and purpose in life and facilitates social support and social interactions, known to promote better mental health (Dawson-Townsend, 2019; Filges et al., 2020; Zhao et al., 2020). A small number of studies have also revealed that neighborhood facilities' availability facilitates older adults' SA (Levasseur et al., 2011).

Few studies explored *compensatory process* in relationships between BEs and older adults' mental health. Compensatory processes reflect the supportive environments to preserve functional ability (FA), health-related attributes that enable older people to do what they value to do (World Health Organization, 2015). For older adults, the essential FA is related to their ability to live independently in a community (World Health Organization, 2015). Low FA or dependence on others often has consequences for low self-esteem and the onset and chronicity of depressive symptoms (Chen et al., 2012). With the help of supportive BEs (e.g., accessible shops), people can still enjoy the greatest opportunity to maintain their mental health through preserving their FA in the face of age-related declines in their capacity (Lawton & Nahemow, 1973). Some studies have revealed that neighborhoods with few leisure areas are associated with reduced functional independence in daily living (Danielewicz et al., 2018). Although FA is a protective factor for mental health, no study has examined how FA mediates the effects of BEs on late-life depression.

Although both *enabling* and *compensatory processes* are conceptualized as major intermediate points in the ecological model of aging, no study has used an integrative framework to investigate both processes in relationships between BEs and late-life depression. Examining both processes simultaneously can better understand intricate relationships between BEs and mental health and advance our knowledge of how neighborhood- and individual-level factors jointly influence late-life depression.

Understanding pathways between BEs and late-life depression may help optimize a large-scale late-life depression prevention strategy, especially for high-density Asian cities experiencing rapid population aging. Like other Asian societies, Hong Kong is undergoing rapid population aging: The share of the older adult population will double from 16% to 34% between 2016 and 2066 (Hong Kong Census and Statistics Department, 2017). Compared to relatively low-density urban areas in Western cities, Hong Kong, a high-density city with scattered and limited urban greenness, limited land supply, and an efficient public transportation system, presents unique environmental features that may influence older adults' enabling and compensatory processes (Cerin, Macfarlane et al., 2013; Guo et al., 2020; Huang et al., 2020).

This study addresses the following research questions: (a) How are BEs associated with late-life depression? (b) Do enabling and compensatory processes mediate the effects of BEs on late-life depression? We included population density, urban greenness, land-use diversity, and facilities in our model, relevant to depression and purposively modified. Based on the ecological model of aging, we conceptualize capacity-enhancing behaviors and FA as mediators. The conceptual framework is presented in Figure 1.

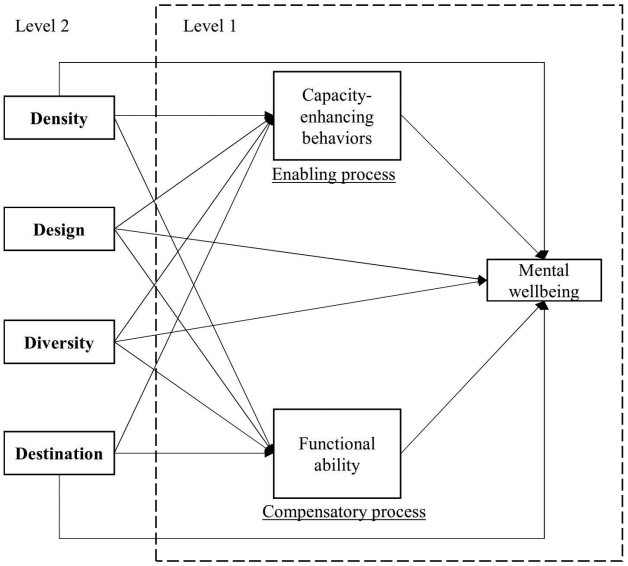

Figure 1. Conceptual framework.

Method

Sample

We conducted a cross-sectional study of the BEs, PA and SA, FA, and mental health of older adults in Hong Kong. Residents were eligible to participate if they were aged 65 years or older, without any known dementia or other psychiatric disorder, able to speak Cantonese, and living in 12 public rental estates for lower-income households. Random sampling was applied to recruit eligible participants in three age strata (65–74 years, 75–84 years, 85 years and older). A total of 2,081 participants comprised 591 (28.4%), 741 (35.6%), and 749 (36.0%) in these three age groups, respectively. Trained researchers conducted all assessments during home visits in 2014. The study was approved by the Human Research Ethics Committee, The University of Hong Kong. All participants provided written informed consent.

Neighborhood BEs

We geocoded participants' residential addresses based on their building blocks within 12 public rental estates, with a tally of 82 building blocks identified. These 82 buildings were built between 23 years and 60 years ago. They are all high-rise buildings with 30–40 stories. On average, the number of units in each building is 326. We used road-network-based service area buffers adjusted by terrain and slope from each building block to define the scope of neighborhoods. A road-network-based service area buffer encompasses all accessible streets tracing a given distance from a home address, as applied in the previous studies (Sun et al., 2018). ArcGIS 10.5 was used to perform geocoding and spatial buffering analysis. All BEs measures were derived using a satellite image from Satellite Pour l'Observation de la Terre, multiple data sources of Hong Kong Lands Department, and the census data.

We created the 200- and 500-m buffers to extract urban greenness, land-use diversity, and neighborhood facilities. The 500-m buffer was used because it was regarded as the maximum comfortable walking distance from older adults' residences to basic services (Burton & Mitchell, 2006). Hong Kong older adults usually walked at a self-paced speed of 2.8 km/h in urban environments (Cerin, Lee et al., 2013). The 200-m buffer was used to capture the availability of resources within a short walking distance (less than 5 min) for low-income older adults with different levels of functioning limitations in our sample.

The Density domain included population density, defined as the residential population per unit of land area (square kilometer) in District Council Constituency Areas (DCCAs) in Hong Kong, the smallest district administration units with publicly available census-level data. The average size of DCCAs in Hong Kong is 2.62 km^2.

The Design domain included urban greenness, which was assessed by the mean normalized difference vegetation index (NDVI) based on a determination of photosynthesis-related activities through the red band and infrared band of a multispectral image within selected buffers, ranging from −1 to 1, with a higher score indicating higher greenness (de Bie et al., 2011). We extracted data for BEs based on the street connectivity of the road-network-based service area buffers. Therefore, street connectivity was not included to avoid multicollinearity.

The Diversity domain included land-use diversity, measured by land-use mix based on the evenness of distribution of five land-use types: residential, commercial/industrial, institution, open space, and others within observed areas (Frank et al., 2006). Values ranged from near 0, reflecting the single-use environment, to near 1, reflecting maximal mixed usage.

The Destination included six facilities and was calculated by its number of each type of facility within two buffers using the GeoCommunity Database. Commercial facilities refer to supermarkets, shopping centers, markets, bazaars, and convenience stores. Community facilities refer to community centers, welfare centers, and family service centers. Cultural facilities refer to civic centers and libraries. Active leisure facilities refer to indoor sports venues and sports grounds. Passive leisure facilities refer to parks, pavilions, and minor open spaces. Public transportation refers to the bus terminus and railway stations. These facilities were selected because of their relevance to older people's enabling and compensating processes (Barnett et al., 2017). Health service facilities were not included because, given their nature, their pathway via these processes is less relevant to depression. The number of each of these types of facilities within selected scales was calculated.

Depressive Symptoms

Depressive symptoms were assessed using the 15-item Geriatric Depression Scale (GDS), validated in local

Chinese populations (Wong et al., 2002). Scores on the scale ranged from 0 to 15, with higher scores indicating greater severity of symptoms. The internal reliability coefficient (Cronbach's α) was 0.85.

Capacity-Enhancing Behaviors

Capacity-enhancing behaviors were measured by the frequency of moderate-intensity PA and SA. For PA, participants were asked: "How many days in a typical week do you do 30 minutes of moderately intensive PA?" Examples included fast walking, housework requiring strength or endurance. For SA, participants were asked: "How many days in a typical week are you engaged in activities that keep you socially and productively engaged?" The possible responses for these two questions were "0–2 days a week" (1), "3–4 days a week" (2), and "5 days or more" (3).

Functional Ability

FA was measured by the Chinese Lawton Instrumental Activities of Daily Living scale (IADL), which has been validated in Hong Kong (Tong & Man, 2002). IADL consists of nine self-care items required for independent community living. The possible responses included "not capable of doing it" (0), "need some help" (1), and "fully capable and require no help" (2). The IADL ranges from 0 to 18, with higher scores indicating better FA. The internal reliability coefficient (Cronbach's α) was 0.89.

Covariates

Control variables included age, gender, marital status, education, chronic diseases (none, only one, and two and more), and cognition, measured by the Cantonese Chinese Montreal Cognitive Assessment (MOCA) version (Chu et al., 2015). Including chronic diseases and cognition as covariates helps to increase power to detect environment–depression relationships due to reduced residual variance in mediators and the outcome (Barnett et al., 2018).

Analytical Procedure

To answer research questions, we used multilevel structural equation modeling (MSEM) to test the multilevel path model as the data had a clustered structure with individuals nested within buildings (Preacher et al., 2011). The model used a maximum likelihood estimation algorithm to accommodate missing data and unbalanced cluster sizes (Preacher et al., 2011). We created a 2-1-1 multilevel mediation model, meaning that BEs were assessed at Level 2, whereas all mediators (PA, SA, and FA) and depressive symptoms were measured at Level 1. Our statistical model included direct and indirect paths from all BEs to depressive symptoms via three mediators. Correlated terms among three mediators were included. All control variables were regressed on the dependent variable and mediators. A mean-variance inflation factor of less than 2 indicates no evidence of multicollinearity. A range of measures, the χ^2 statistic greater than 0.05, comparative fit index and Tucker–Lewis Index greater than 0.90, the root-mean-square error of approximation less than 0.06, and a standardized root-mean-square residual less than 0.08, were used to assess model fit (Hu & Bentler, 1999). We reported unstandardized estimates for direct, indirect, and total effects. Estimates with a p value of less than .05 were interpreted as statistically significant. Noting the tendency of the skewed distribution of indirect effects, we determined a 95% confidence interval of indirect effects with 10,000 bootstrap samples. We used Mplus 8 software (Muthén & Muthén, 2017) for MSEM, STATA (version 15.0) for descriptive analysis, and R (version 4.0) for bootstrapping.

Little's test indicated that data were missing completely at random (Li, 2013). We included 1,946 cases (93.5%) with no missing data on GDS as our final sample size, in which missing data on PA, SA, FA, marital status, and education were less than 1.0%, while 9.7% of data on MOCA was missing. We performed a sensitivity analysis to examine the effects of missing data on model outcomes.

Results

Sample Description

Participants' characteristics and BEs are presented in Table 1. The majority were female (56.1%), with a mean age of 79.6 years (SD = 8.0), without formal education (48.2%), married (59.7%), and with two or more chronic diseases (64.5%). They were capable of self-care with a mean IADL score of 14.9 (SD = 4.2). Less than half (46.5%) engaged in PA for 5 days or more per week. A total of 77.6% of participants engaged in SA for 2 or fewer days each week. MOCA and GDS scores were 19.7 (SD = 5.8) and 2.9 (SD = 3.3), respectively. The average population density was around 91,790 people/km^2. In a 500-m buffer, NDVI was 0.31 (SD = 0.10). The land-use mix was 0.69 (SD = 0.08), indicating that 12 sampled estates are located in urbanized areas either surrounded by greenness of lawn area or with a mixture of urban greenery and high-rise building. On average, commercial facilities comprised the greatest number of facilities (500-m buffer; mean = 9.7, SD = 6.1) and cultural facilities the smallest (mean = 0.9, SD = 0.7). Similar patterns of BEs measures were found within a 200-m buffer.

Table 2 displays that PA (r = −0.16, p < .001), SA (r = −0.13, p < .001), and FA (r = −0.36, p < .001) were negatively correlated with depressive symptoms. These three mediators were correlated with each other. No correlation was found between population

Table 1. Sample Description

Individual-level variables (n = 1,946)		**Mean (*SD*)/%**
Female		56.06
Age, years (range = 65–101)		79.62 (7.98)
Education level		
No formal education		48.17
Primary		30.28
Secondary		19.54
Postsecondary		2.01
Marital status		
Married		59.69
Divorced/widowed/single		40.31
Number of chronic diseases		
None		13.67
One		21.79
Two or more		64.54
IADL (range = 0–18)		14.91 (4.15)
Physical activities (range = 1–3)[a]		2.01 (0.96)
0–2 days a week		45.07
3–4 days a week		8.46
5 days or more a week		46.47
Social activities (range = 1–3)[a]		1.36 (0.71)
0–2 days a week		77.56
3–4 days a week		8.58
5 days or more a week		13.86
MOCA (range = 3–30)		19.68 (5.79)
GDS (range = 0–15)		2.93 (3.34)
Built environment characteristics		**Mean (*SD*)**
Population density (1,000 people/km^2; range = 18.28–218.24)		91.79 (64.35)
500-m buffer	Urban greenness (range = 0.15–0.51)	0.31 (0.10)
	Land-use mix (range = 0.06–0.57)	0.69 (0.08)
	Commercial facility (range = 1–25)	9.66 (6.10)
	Community facility (range = 1–5)	2.59 (1.28)
	Cultural facility (range = 0–2)	0.88 (0.67)
	Leisure facility (active; range = 0–7)	1.94 (1.51)
	Leisure facility (passive; range = 2–16)	7.04 (3.65)
	Transportation (range = 0–9)	2.67 (2.29)
200-m buffer	Urban greenness (range = 0.15–0.4)	0.25 (0.06)
	Land-use mix (range = 0.24–0.98)	0.71 (0.17)
	Commercial facility (range = 0–6)	1.54 (1.45)
	Community facility (range = 0–3)	0.50 (0.71)
	Cultural facility (range = 0–1)	0.15 (0.36)
	Leisure facility (active; range = 0–3)	0.37 (0.60)
	Leisure facility (passive; range = 0–7)	1.35 (1.54)
	Transportation (range = 0–4)	0.41 (0.77)

Note: MOCA = Montreal Cognitive Assessment; GDS = 15-item Geriatric Depression Scale; IADL = instrumental activities of daily living.
[a]Three-point scale: 1 = *0–2 days per week*, 2 = *3–4 days per week*, and to 3 = *5 days and over per week*.

density and depression/mediators. In a 500-m buffer, urban greenness was negatively correlated with depressive symptoms, while passive leisure facilities were positively correlated with depressive symptoms. Urban greenness was positively correlated with SA and FA. Land-use diversity was negatively correlated with SA. The numbers of community and cultural facilities were negatively correlated with PA. The number of passive leisure facilities was positively correlated with PA but negatively with FA. The number of transportation terminals was negatively correlated with PA. Similar patterns were found in a 200-m buffer, yet with fewer significant correlations than those in a 500-m buffer.

Table 2. Pearson Correlations Between Built Environments, Physical and Social Activities, Functional Ability, and Depressive Symptoms

Variables	1	2	3	4	5							
1. GDS	1.00											
2. PA[a]	−0.16***	1.00										
3. SA[a]	−0.13***	0.14***	1.00									
4. FA	−0.36***	0.18***	0.08***	1.00								
5. Population density	−0.004	−0.002	0.01	0.02	1.00							
500-m buffer	1	2	3	4	5	6	7	8	9	10	11	12
6. Urban greenness	−0.06*	−0.03	0.06**	0.07**	−0.06**	1.00						
7. Land-use diversity	−0.01	0.04	−0.06*	0.02	0.29***	−0.06*	1.00					
8. Commercial facility[b]	0.01	−0.02	−0.00	−0.04	0.10***	−0.58***	−0.43***	1.00				
9. Community facility[b]	0.02	−0.05*	0.01	−0.02	−0.02	−0.21***	−0.08***	0.32***	1.00			
10. Cultural facility[b]	−0.01	−0.05*	−0.02	−0.04	−0.19***	0.01	−0.29***	0.41***	0.08***	1.00		
11. Leisure facility (A)[b]	−0.03	−0.00	0.03	0.01	−0.22***	−0.12***	−0.49***	0.45***	0.05*	0.27***	1.00	
12. Leisure facility (P)[b]	0.04*	0.05*	0.04	−0.04*	−0.11***	−0.24***	−0.29***	0.45***	−0.09***	−0.02	0.32***	1.00
13. Transportation[b]	0.01	−0.05*	−0.02	−0.02	0.27***	−0.13***	−0.22***	0.46***	0.33***	0.52***	0.30***	−0.30***
200-m buffer	1	2	3	4	5	14	15	16	17	18	19	20
14. Urban greenness	−0.08***	−0.03	0.04	0.06**	0.02	1.00						
15. Land-use diversity	−0.03	−0.04	0.01	−0.00	0.02	0.26***	1.00				–	
16. Commercial facility[b]	0.03	−0.01	−0.04	−0.06*	0.12***	−0.52***	0.02	1.00			–	
17. Community facility[b]	0.06*	0.01	0.07**	−0.05*	−0.22***	−0.26***	−0.19***	0.13***	1.00			
18. Cultural facility[b]	0.01	0.02	−0.00	0.01	−0.39***	−0.08***	−0.29***	−0.03	0.02	1.00		
19. Leisure facility (A)[b]	−0.00	−0.05*	0.04	−0.03	−0.08***	0.48***	0.47***	−0.06**	0.01	−0.03	1.00	
20. Leisure facility (P)[b]	0.01	0.04	0.02	−0.04	−0.17***	0.01	−0.32***	0.35***	0.21***	0.14***	0.14***	1.00
21. Transportation[b]	0.04	−0.05*	−0.04	−0.05*	−0.10***	−0.04	0.21***	0.50***	0.14***	0.11***	0.32***	0.22***

Note: GDS = 15-item Geriatric Depression Scale; FA = funtional ability; PA = physical activities; SA = social activities.

[a]Three-point scale: 1 = *0–2 days per week*, 2 = *3–4 days per week*, and to 3 = *5 days and over per week*.

[b]Neighborhood service facilities are measured by the number of facilities. A = active, P = passive.

***$p < .001$, **$p < .01$, *$p < .05$.

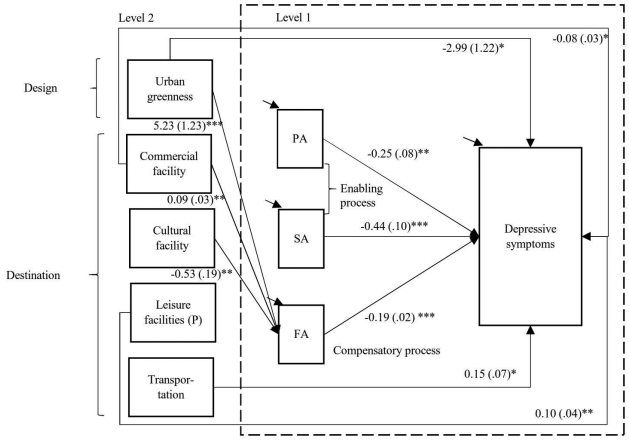

Figure 2. Unstandardized estimates of multilevel path analysis with adjustment (500-m buffer). *Notes:* Model fit indices: $\chi^2(6) = 8.389$, $p = .211$, root mean square error of approximation = 0.015, comparative fit index = 0.998, Tucker–Lewis index = 0.970, standardized root-mean-square residual (SRMR) within = 0.002, SRMR between = 0.077. PA = physical activities; SA = social activities; FA = functional ability; leisure facilities (P) = passive leisure facilities. Results are controlled for age, gender, marital status, education, cognitive function, and number of chronic diseases. Only statistically significant paths are shown (unstandardized estimates) and standard errors are displayed in parentheses. Correlated error values among the three mediators are not shown but are available upon request. ***$p < .001$, **$p < .01$, *$p < .05$.

Direct Associations Between BEs and Depressive Symptoms

Figure 2 shows the results of MSEM analysis (500-m buffer). Unstandardized coefficients for statistically significant pathways are presented. The MSEM path model fits the data well. In Level 1 analysis, PA ($\beta = -0.25$, $p < .01$), SA ($\beta = -0.44$, $p < .001$), and FA ($\beta = -0.19$, $p < .001$) were negatively and directly associated with depressive symptoms. In Level 2 analysis, urban greenness was directly associated with fewer depressive symptoms ($\beta = -2.99$, $p < .05$). The number of commercial facilities was directly associated with fewer depressive symptoms ($\beta = -0.08$, $p < .05$), while passive leisure facilities ($\beta = 0.10$, $p < .01$) and transportation ($\beta = 0.15$, $p < .05$) were directly associated with more depressive symptoms. Regarding the associations between BEs and mediators, no significant association was found between BEs and PA/SA. Urban greenness was positively associated with FA ($\beta = 5.23$, $p < .001$). The number of commercial facilities was associated with better FA ($\beta = 0.09$, $p < .01$), while more cultural facilities were related with lower FA ($\beta = -0.53$, $p < .01$). Population density and land-use diversity had no significant associations with depressive symptoms/mediators.

The MSEM analysis for the 200-m buffer also fits our data, yet with fewer significant associations (Supplementary Figure 1). Consistent with a 500-m buffer, urban greenness and transportation were significantly associated with depressive symptoms. In addition, more community facilities ($\beta = 0.08$, $p < .01$) were associated with more SA while transportation ($\beta = -0.09$, $p < .05$) was associated with fewer SA.

Indirect and Total Associations Between BEs and Depressive Symptoms

Table 3 summarizes indirect and total effects of BEs on depressive symptoms measured in a 500-m buffer. Total indirect effects were equal to the sum of the indirect effects of BEs through PA, SA, and FA. The total indirect effect ($\beta = -1.15$, $p < .01$) and total effect ($\beta = -4.15$, $p < .01$) of urban greenness on depressive symptoms were significant. FA significantly mediated the association between urban greenness and depressive symptoms ($\beta = -1.02$, $p < .001$) by 24.6%. For destinations, the total indirect effect ($\beta = -0.02$, $p < .05$) and total effect ($\beta = -0.10$, $p < .01$) of the number of commercial facilities on depressive symptoms were significant. The total effect between the number of commercial facilities was mainly mediated by FA ($\beta = -0.02$, $p < .01$; 20%). In contrast, the total indirect effect of cultural facilities on depressive symptoms ($\beta = 0.13$, $p < .01$) was significant although its total effect was nonsignificant and mediated by FA ($\beta = 0.10$, $p < .05$). Passive leisure facilities and transportation had no significant indirect associations on depressive symptoms, although their total effects were significant.

Fewer significant pathways were found within a 200-m buffer (Supplementary Table 1). In the sensitivity analysis, MSEM path analysis was reanalyzed using completed-case data (no missing data on any variable: $n = 1{,}722$), showing no difference than model outcomes using full data.

Discussion

This study aimed to examine the mediating effects of PA, SA, and FA in relationships between BEs and late-life depression. To the best of our knowledge, this is the first study to apply an integrative framework to examine both enabling and compensatory processes in relationships between BEs and late-life depression. This study adds knowledge to the existing literature by lending support to both enabling and compensatory processes as pathways. This study generates several additional insights.

In terms of individual-level factors, more PA and SA and better FA were directly associated with fewer depressive symptoms, consistent with previous research (Chen et al., 2012). In terms of neighborhood-level factors, we found that urban greenness and service facilities were directly associated with depressive symptoms.

First, we found neighborhood urban greenness was directly associated with fewer depressive symptoms in 200- and 500-m buffers. Prior studies suggested that neighborhood urban greenness provides a restorative stress-relieving environment and mitigates the urban heats that directly instill a positive psychological state (Astell-Burt

Table 3. Unstandardized Estimates of Indirect and Total Effects of the Built Environment on Depressive Symptoms

		500-m buffer	
		Indirect effect	Total effect
Pathways		Estimates (bootstrapped 95% CI)	Estimates (bootstrapped 95% CI)
Design			
Urban greenness		**−1.15**** (−1.81, −0.49)	**−4.15**** (−6.61, −1.69)
Enabling process	PA	0.10 (−0.10, 0.31)	
	SA	−0.24 (−0.51, 0.04)	
Compensatory process	FA	**−1.02***** (−1.54, −0.50)	
Destination			
Commercial facility		**−0.02*** (−0.03, −0.01)	**−0.10**** (−0.16, −0.03)
Enabling process	PA	0.00 (−0.004, 0.01)	
	SA	0.00 (−0.01, 0.01)	
Compensatory process	FA	**−0.02**** (−0.03, −0.01)	
Cultural facility		**0.13**** (0.04, 0.24)	−0.07 (−0.44, 0.30)
Enabling process	PA	0.02 (−0.01, 0.05)	
	SA	0.02 (−0.02, 0.06)	
Compensatory process	FA	**0.10*** (0.02, 0.17)	
Leisure facility (P)		0.00 (−0.02, 0.02)	**0.10**** (0.03, 0.18)
Enabling process	PA	0.00 (−0.01, 0.00)	
	SA	0.00 (−0.01, 0.00)	
Compensatory process	FA	0.01 (−0.01, 0.02)	
Transportation		−0.01 (−0.04, 0.03)	**0.14*** (0.04, 0.28)
Enabling process	PA	0.00 (−0.01, 0.01)	
	SA	0.00 (−0.01, 0.02)	
Compensatory process	FA	0.00 (−0.03, 0.02)	

Notes: PA = physical activities; SA = social activities; FA = functional ability; leisure facilities (P) = passive leisure facilities; estimates = unstandardized estimates; CI = confidence interval. Only statistically significant paths are shown. The bold values indicate the significant estimates.
***$p < .001$, **$p < .01$, *$p < .05$.

et al., 2019; Sarkar et al., 2018). Our finding was consistent with evidence from Western and Eastern countries (de Keijzer et al., 2020), highlighting the importance of urban greenness for older adults' mental well-being (World Health Organization, 2007).

Second, although we found direct relationships between facilities and depressive symptoms, they varied by facility types. Specifically, more commercial facilities within a 500-m buffer were directly associated with fewer depressive symptoms, consistent with previous studies (Saarloos et al., 2011). The inside/outside noise and crowding may stress older adults living within neighborhoods with many commercial facilities. However, these effects may be offset by benefits from commercial facilities' availability within a close distance. Prior studies have found that older people use commercial facilities in various ways, including sitting and doing nothing, bringing the simple pleasures (White et al., 2015).

However, more passive leisure facilities (500-m buffer) and transportation terminals (both two buffers) were directly associated with more depressive symptoms, a finding that contrasts with previous studies in Western cities (Baranyi et al., 2019). Such inconsistency may be due to the features of high-density Asian cities. With high population density and a dearth of land resources, the quantity and quality of open space for leisure activities are far from satisfactory. A recent qualitative study revealed Hong Kong older adults' dissatisfaction with small yet crowded parks (Chui et al., 2019). It is possible that many passive leisure facilities, such as parks, can exist within a 500-m buffer if they are small, and some of them may not be large enough to support many visitors. Hence, a greater number of passive leisure facilities may remind older adults of their unmet needs for outdoor space, thus leading to adverse mental health outcomes. Future studies can consider the size of passive leisure facilities when exploring their relationships with depressive symptoms as a prior study has suggested that one hectare is proposed as a minimum for a neighborhood park (Van Herzele & Wiedemann, 2003).

Relatedly, in contrast to Western countries with a high degree of automobile dependence, most Hong Kong residents rely on public transportation, which is designed for maximum efficiency, mainly prioritizing the working population's demands and downplaying the needs of older adults who travel during off-peak hours (Chui et al., 2019). Neighborhoods with denser transport terminals exhibit increased crowding and noise (de Sa & Ardern, 2014). As

such, more transport transits may increase older adults' stress, adversely affecting their mental health.

Third, we found no significant direct association between population density and depressive symptoms, which is inconsistent with existing literature about the beneficial effects of population density on mental health (Sarkar et al., 2018). This is likely because Hong Kong is a very crowded urban city, particularly in our study sites of the 12 public housing estates. In addition, we did not find a significant direct association between land-use diversity and depressive symptoms. Previous studies on the effects of land-use diversity and mental health have been inconclusive (Saarloos et al., 2011). Several studies have shown that areas with more land-use diversity indicate better access to local services, potentially promoting mental health (Rosso et al., 2013). However, areas with mixed commercial and residential land use are often situated in the inner-urban core. Senior residents may be exposed to greater common urban stresses and reported poor mental health (Saarloos et al., 2011). Future research can incorporate urban stress as the potential underlying mechanism to better understand the BE's contribution to residents' mental health.

In terms of pathways between BEs and depressive symptoms, this study provides evidence of both enabling and compensatory processes, echoing similarities with the Healthy Aging Framework by highlighting the roles of environments as promoting capacity-enhancing behaviors and maintaining FA (World Health Organization, 2015, p. 33).

Regarding the enabling process, we found evidence to support mediating effects of SA for associations between BEs and depressive symptoms. Specifically, the number of community facilities within a 200-m buffer was indirectly associated with fewer depressive symptoms through more SA, reinforcing existing literature (Levasseur et al., 2011). Community facilities support older adults' participation in SA and maintaining social contacts, which help lower risks of depression (Levasseur et al., 2011). However, our study revealed that older adults living in neighborhoods with more transportation terminals participated in fewer SA, consequently associated with more depressive symptoms, contrasting with a previous study showing that inadequate access for older adults to transportation is a barrier to social participation (Dahan-Oliel et al., 2010). As we mentioned above, a public transportation system designed for a working population may be an environmental barrier rather than a facilitator for older adults' social participation. As social participation is a key modifiable factor for lowering the risk of late-life depression and promoting other favorable health outcomes (Chen et al., 2012), the need to build a supportive neighborhood environment with more community facilities should be highlighted (World Health Organization, 2007).

Moderate-level PA had no mediating effects on relationships between any BEs and depressive symptoms, in contrast with previous literature (Li et al., 2005). One possible explanation for this is that neighborhood BEs are not appropriately designed for moderate-level PA among older adults (Cerin, Macfarlane et al., 2013). Many public housing sites are situated on hilly terrain (The Government of the Hong Kong Special Administrative Region, 2017). Even though these neighborhoods contain a greater amount of active and passive leisure facilities, the hilliness may deter older adults from going out for moderate-level PA (Meeder et al., 2017). Another possible reason is that the single-item measurement of PA did not comprehensively capture older adults' PA patterns. Previous studies have shown that moderate-level PA decreased and light-intensity or leisure PA, such as walking, increased with age (Ayabe et al., 2009). Future studies should explore mediating effects of types, intensity, and duration of PA in relationships between BEs and late-life depression. The distribution of PA in our study could be another potential reason for not detecting any significant association as more than 45% of participants doing PA for 2 days or fewer per week and 5 days or more, respectively.

Regarding the compensatory process, we found that FA was a significant mediator for associations between BEs and depressive symptoms in a 500-m buffer, adding new knowledge to existing literature. This study found that the urban greenness–depression relationship was mediated by FA. More urban greenness helps older adults better maintain FA, which further helps them reduce depressive symptoms. Perhaps more urban greenness may encourage older adults to spend more time walking outdoors for pleasure (Barnett et al., 2018). However, it could also be possible that people living in neighborhoods with more urban greenness have better mental health, maintaining their FA. Future research should use longitudinal studies combined with the real-time assessment to identify time sequences of outcomes to determine causation further. We also found that the number of commercial facilities was indirectly associated with fewer depressive symptoms through maintaining better FA. Living in neighborhoods with denser commercial facilities is important for older adults to perform activities and meet their daily needs, which help compensate for the potential loss of age-related capacities, leading to better mental health (Remigio-Baker et al., 2014).

Meanwhile, we found the number of cultural facilities within a 500-m buffer was indirectly associated with more depressive symptoms through FA. Perhaps cultural facilities could be purposively located at convenient transport hubs, which increases crowding and noise (Barnett et al., 2018) and presents environmental challenges for older people to venture outside for daily activities. Therefore, determining the relationship between this type of facility and older adults' mental health requires more systematic research.

In addition to direct and indirect associations between BEs and depression, we observed discrepancies between two observed areas. For instance, the mediating effect of FA on the association between commercial facilities and late-life depression was only found within a 500-m buffer. More commercial facilities were found within a 500-m buffer

than a 200-m buffer (9.70 vs. 1.54). A greater number of commercial facilities located beyond a 200-m buffer may provide diverse choices for daily shopping and other activities. Future studies can further explore how the distance, quantity, and diversity of facilities influence older adults' FA and depression.

Our study has several strengths, including a large sample size in a large urban and high-density Asian city, using probability sampling, applying objective BEs, estimating the pathways using two buffers, applying MSEM analysis to adjust the nested data structure, and estimate multilevel pathways for BEs–depressive symptoms associations, and sensitivity check to estimate the effects of missing data on the model outcomes. Additionally, the assignment of public housing units in Hong Kong is based on flat availability and family size (Zang et al., 2019), thus, to a large extent minimizing the potential impact of self-selection bias on our findings.

Our study also has some limitations. First, the cross-sectional nature of the data does not allow us to conclude the association between BEs and depressive symptoms. Second, the study sample was limited to low-socioeconomic status older adults living in public rental housing. Thus, our findings may not be generalizable to other aging populations or other developed cities with different public housing modes. Third, PA and SA were each self-reported using a single-item question and thus prone to recall error. Future studies that apply validated measurements to capture comprehensive PA and SA profiles, ecological momentary assessment, and real-time sensory devices to objectively assess capacity-enhancing behaviors are needed better to understand the effects of BEs on mental health. Fourth, we did not have data on the crowding within/outside the buildings, which could be a confounding variable. Finally, the use of population density of DCCAs may lead to inconsistent boundaries across BE indicators.

Conclusions

Our study applied an integrative framework to examine the mediating effects of PA, SA, and FA in relationships between BEs and late-life depression. Both enabling and compensatory processes were key pathways between BEs and late-life depression that SA and FA are mediators for the effects of the BE on depressive symptoms, substantiating the ecological model of aging, thus providing evidence of the importance of promoting an active social lifestyle and maintaining FA among older adults. This study also found that capacity-enhancing behaviors and FA at the individual level, urban greenness within 200- and 500-m buffers, and the number of commercial facilities within a 500-m buffer were directly associated with better mental health. Governments can use our findings to optimize policy efforts to build age-friendly communities. In Asian societies with a rapidly aging population, there is an imperative to provide more urban greenness, ensure the availability of commercial facilities and community centers, and further optimize large-scale depression prevention strategies.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Conflict of Interest

None declared.

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Author Contributions

T. Y. Lum designed the study, supervised the data collection, and supported data analysis. S. Lu contributed to the conceptual framework, performed data analysis, wrote the manuscript and finalized the manuscript based on reviewers' comments. Y. Liu, Y. Guo, and O. F. Chan supported data analysis and merged built environment variables into individual-level survey databases. H. C. Ho, Y. Song, and W. Cheng derived built environment variables based on existing databases. C. Chui, C. Webster, and R. L. H. Chiu critically revised the manuscript.

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