Original scientific paper

A Preliminary Study of the Relationship Between Built Environment of Open Space and Cognitive Health of Older People

[1] Ph.D. Candidate **Ruozhu YIN** , [2]* Prof. Dr. **Mei-yung LEUNG** , [3] Ph.D. Candidate **Yueran LI**
The Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, China. [1, 2 & 3]
E-mail [1]: ruozhuyin2-c@my.cityu.edu.hk , E-mail [2]: bcmei@cityu.edu.hk, E-mail [3]: yueranli3-c@my.cityu.edu.hk

ARTICLE INFO:

ABSTRACT

Many older people are facing various risks of cognitive impairment, while outdoor activities in open spaces may be helpful for their cognitive health. However, the effect of open spaces on cognitive health is unclear. This study aims to investigate the relationships between the cognitive health of older people and the built environment of open spaces. A questionnaire survey of 60 older people aged 60 and above was conducted. Results identified three major components of the built environment of open spaces, namely, planning, supporting facilities, and building services. According to the correlation and regression analysis, it is revealed that 8 BEOS items, including green ratio, a width of the pathway, maintenance of the whole garden, the color of green space, diversity of plants, location, and font of signage, artificial light of sitting area were positively related to memory, while only the size was negatively associated with memory. Only the green ratio could positively predict the concentration. The judgment was positively influenced by the green ratio, width of pathways, maintenance of the whole garden, color of green space and diversity of plants. A BEOS – cognitive health model for older people was built in this study. The results highlighted the importance of plants for cognitive health. Several recommendations, such as not-so-large sizes and diverse plants with vivid colors and signages with big fonts, etc., were proposed to improve the built environment of the open spaces and support the declining cognitive health of older people.

Highlights:	Contribution to the field statement:
- This paper provides evidence for the effect of built environments of open spaces on cognitive health. - The built environments of open spaces - cognitive health model has been built. - The benefits of plants for cognitive health have been emphasized in this study. - Practical recommendations on built environments of open spaces have been proposed to improve the cognitive health of older people.	This study fills a gap in understanding the specific features of urban open spaces that can enhance cognitive functions such as memory, concentration, and judgment in the elderly, providing valuable insights for urban planners and policymakers to foster age-friendly urban environments.

*Corresponding Author:
The Department of Architecture and Civil Engineering, City University of Hong Kong, Hong Kong, China
Email address: bcmei@cityu.edu.hk

How to cite this article:
Yin, R., Leung, M., & Li, Y. (2023). A Preliminary Study of the Relationship Between Built Environment of Open Space and Cognitive Health of Older People. *Journal of Contemporary Urban Affairs*, 7(2), 144–155. https://doi.org/10.25034/ijcua.2023.v7n2-9

1. Introduction

Ageing is a serious problem faced by many countries and regions all over the world. By the end of 2021, the population over 60 years old in Hong Kong accounted for 28.6% of the total population (Census and Statistics Department, 2022). People will suffer from the decline of cognitive health when they are getting old. Poor cognitive health increases the risk of older people getting lost, suffering from negative emotions and higher mortality, and creating difficulty in dealing with complex housework and personal issues, which definitely increase the burden of caregivers and make older people more likely to be institutionalized (Lloyd et al., 2001). However, it is expected to improve cognitive health via outdoor activities (Linde and Alfermann, 2014).

Due to the high density in Hong Kong, indoor space is really limited for residents. Residents, especially older people, have to go to open spaces for rest or activities (Richardson et al., 2013), e.g., major parks, pocket parks, gardens, and sitting-out areas (Leisure and Cultural Services Department, 2021). Due to the limited mobility of older people, they normally prefer open spaces that are relatively near their homes (Lau et al., 2021). Unfortunately, the existing open spaces are not particularly designed for older people. Thus, older people encounter a lot of problems while visiting the open spaces. For example, they may get lost with unclear signage due to the complicated roads and the same scenery in a large open space. Although much of the research investigates the effects of green space for physical activity and stress on older people (Park et al., 2016), it remains unknown how the built environment of open spaces (BEOS) affects the cognitive health of older people. Because poor cognitive health can bring great risks and adverse effects to the daily life of older people, it is urgent to improve the cognitive health of older people by improving the BEOS. Therefore, this study aims to investigate the influence of BEOS on the cognitive health of older people by building a BEOS–cognitive health model for older people.

2. Literature Review

2.1. Cognitive health of older people

Cognitive health is the ability to think, concentrate, and memorize (Stern and Carstensen, 2000). With ageing, the brain function progressively degenerates. The rates of heart disease, diabetes, stroke, and other diseases usually increase among older people, while their sleep periods and participation in social and physical activities decrease accordingly. These factors are all considered to have negative effects on the cognitive health of older people, including memory loss, less concentration, poor judgment, etc. (Lloyd et al., 2001).

As one of the most obvious indicators of cognitive health, memory can be classified into long-term memory and short-term memory. The former is the ability to remember things that happened a long time ago, while the latter refers to the ability to remember information in a recent period (Verhaeghen, 2014). The process of memory includes encoding, storage, and retrieval. Older people with poor memory may find difficulties in all these three processes and get lost (Shiffrin and Atkinson, 1969). Older people also tend to forget their experiences and acquaintances, damaging their social relationships. Activity spaces and fitness facilities encourage older people to be physically and psychologically active, which is good for improving their memory (Feter et al., 2019). Some special facilities, such as eye-catching sculptures, may help older people better remember their location (Eichenbaum et al., 1999).

Concentration deficits can occur with only mild declines in cognitive health (Silveri et al., 2007). The declined concentration makes it difficult for older people to learn and complete tasks. In recent years, older people have relied more and more on smartphones (Zhou et al., 2014). However, checking smartphones can be a serious distraction and impair concentration (Chu et al., 2021). On the other hand, exercising, doing leisure activities, and being away of information overload normally improve concentration (Linde and Alfermann, 2014). Plants have a great potential to untense the directed attention system and recover attention (Raanaas et al., 2011). Visiting open spaces is, thus, expected to enhance attention.

Poor judgment is another early signal of impaired cognitive health. Older people with poor cognitive health have difficulty identifying danger, making financial decisions, and evaluating distance while driving (Lloyd et al., 2001). In reality, loss of judgment can be a serious handicap when older people need to decide on surgery or a new treatment for a serious illness. Poor of open spaces cause negative emotions and unsafety feelings, hindering the decision-making of older people (Menne and Whitlatch, 2007).

2.2. Built environment of open spaces
The built environment refers to the artificial surroundings for human activities (Leung et al., 2020). It is a broad concept including three components: planning, supporting facilities, and building services (Leung et al., 2021). Planning refers to the layout and landscape design of the open spaces, which consists of the size, green space, fountain, recreational courts, sitting area, etc., in the whole garden. A simple and clear layout with a loop circuit may be easier for older people to orient (Kessels et al., 2007). A high green ratio may help older people to restore their attention, benefit their concentration, and attract them to do more physical activities (Richardson et al., 2013), while the appropriate sitting area also plays a key role for older people with limited physical ability to rest in the daily life (Lau et al., 2021). Supporting facilities mean small facilities that can help older people perform well (Leung et al., 2020), such as seats, signage, recreational facilities, and colour. Seats with proper shape and height may reduce the risk of falling when standing up and protect older people's spines (Yim et al., 2020). Because of the poor eyesight, older people may not see the letters on the signage clearly. However, appropriate recreational facilities may encourage them to do exercises frequently, which is good for cognitive health (Linde and Alfermann, 2014). The diverse color of plants may benefit older people's special memory by strengthening the encoding-specificity effect, especially in natural scenes (Park et al., 2016).

Building services aim to keep a comfortable environment for visitors (Leung et al., 2021). In the open spaces, it mainly includes the artificial lighting environment in the evening. Many older people have night blindness and often cannot see obstacles clearly at night. Adequate artificial lighting of pathways may help older people distinguish obstacles and changes in height and help them identify the dark shadows or steps on the road, which may support their judgment in open spaces (Lu et al., 2019).

2.3. Theoretical Grounding
Older people are facing numerous stressors during their daily lives, such as declined physiological and psychological health, loss of independence, financial insecurity, hopelessness, pain and illness, deteriorating personal relationships, etc. These stressors further destroy psychological and mental health, especially cognitive health (Mikneviciute et al., 2022). *Stress Reduction Theory* suggests that contact with nature, such as watching green plants outside the window or movies of natural scenery, can reduce stress (Ulrich, 1984; Ulrich et al., 1991). As a convenient way for older people living in high-density cities to engage with nature, visiting open spaces is expected to reduce stress, which may have an impact on cognitive health in older people (see Figure 1).

On the other hand, daily activities involve great direct attention, causing mental fatigue. *Attention Restoration Theory* claims that natural stimulus evokes indirect attention that does not need a lot of cognitive effort and allows directed attention to rest (Kaplan, 1995). Thus, exploring natural environments, especially true natural environments, can restore cognitive resources. This further restores mental fatigue and gives people a clearer mind and focus (Ohly et al., 2016). According to this theory, older people's cognitive health is expected to be improved by visiting green spaces like open spaces (see Figure 1).
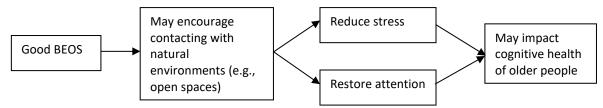
Figure 1. Theoretical framework.

3. Materials and Methods

3.1. Research Model

Based on the literature review, a conceptual BEOS–Cognitive Health model is proposed in Figure 2. It is hypothesized that the three BEOS components (planning, supporting facilities, and building services) have a significant impact on the cognitive health of older people, including memory, concentration, and judgment.
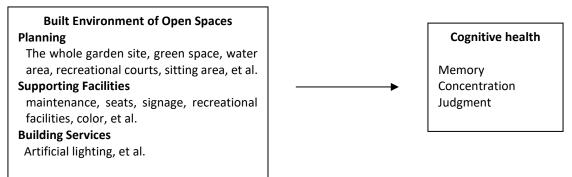

Figure 2. Conceptual BEOS – Cognitive Health Model for Older People.

3.2. Methods

To study the influence of BEOS on the cognitive health of older people, a questionnaire survey was conducted face to face among older people aged 60 and above who visit open spaces frequently. The questionnaire includes three parts: (1) the background information about older people and the open space; (2) the satisfaction degree of 17 BEOS items; and (3) the satisfaction degree of their cognitive health (see Figure 3). In the second and third sections of the questionnaire, one item included one question, namely the satisfaction evaluation of that item, ranging from 1 (very dissatisfied) to 5 (very satisfied) with a 5-point Likert scale. The items about the BEOS were selected according to previous measurement tools and research on open spaces, like Environmental Assessment of Public Recreation Spaces (EAPRS), Natural Environment Scoring Tool (NEST) and Quality of Public Open Space Tool (POST) (Broomhall et al., 2017; Gidlow et al., 2018; Saelens et al., 2016). The cognitive items were selected from the WHOQOL-BREF (Whoqol Group, 1998). To ensure the content validity of the questionnaire, the whole questionnaire was read through and verified by the expert in an age-friendly environment.

The questionnaire was distributed in three big open spaces with abundant facilities. The three open spaces are respectively located on Hong Kong Island, Kowloon Peninsula, and the New Territories. To ensure the participants understood the content, the questionnaire was translated into traditional Chinese. The survey was conducted face to face in February and March, during which period the weather was pleasant in Hong Kong. Thus, older people would go out frequently instead of staying indoors due to uncomfortable temperatures or bad weather. All the questions were asked in Cantonese or Mandarin (i.e., the participants' native languages). After the data collection, Pearson correlation analysis and multiple regression analysis were used for the data analysis.
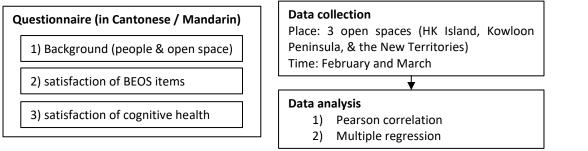
Questionnaire (in Cantonese / Mandarin)
1) Background (people & open space)
2) satisfaction of BEOS items
3) satisfaction of cognitive health

Data collection
Place: 3 open spaces (HK Island, Kowloon Peninsula, & the New Territories)
Time: February and March

Data analysis
1) Pearson correlation
2) Multiple regression

Figure 3. Research methods of the questionnaire survey.

4. Results

Sixty older people from three open spaces participated in this study, while 27 (45%) of them were male and 33 (55%) of them were female. Eighteen respondents (30%) were aged 60-69, 38 responders (63.3%) were aged 70-79, and 4 responders (6.7%) were aged 80 or above. Most of the participants (56 people, 93.3%) walked to open spaces, and others (4 people, 6.7%) went to open spaces by bus. All of them arrived in open spaces within half an hour, including 7 people (11.7%) who arrived within 5 minutes, 30 people (50%) in 5-10 minutes, and 23 (38.3%) of them in 10-30 minutes.

The results of the correlation showed that the three cognitive health items are mostly related to each other. Green ratio (P3: 0.427**), artificial light of sitting area (P17: 0.262*), location (P14: .308*) and font (P15: 0.286*) of signage, diverse plants (P11: 0.264*), and maintenance of the whole garden (P9: 0. 286*) were positively related to memory (C1). Only the green ratio (P3: 0.306*) was positively related to concentration (C2). Green ratio (P3: 0.297*), the width of the pathway (P8: 0.308*), the color of green space (P10: 0.265*), the diversity of plants (P11: 0.320*), and maintenance of the whole garden (P9: 0.420**) were significantly related to judgment (C3) (see Table 1).

Table 1. Correlation between BEOS and Cognitive Health of Older People.

	C1	C2	C3
Cognitive health			
C1 – Memory	1		
C2 – Concentration	.470**	1	
C3 – Judgment	.462**	.610**	1
Planning			
P1 – Open space size	-0.015	0.067	0.113
P2 – Green space size	0.155	0.168	0.206
P3 – Green ratio	**.427****	**.306***	**.297***
P4 – Sitting area size	-0.146	-0.031	-0.047
P5 – Water area	0.047	0.108	0.115
P6 – Recreational court size	-0.023	0.052	0.066
P7 – Connectivity of pathway	0.240	0.010	0.140
P8 – Width of pathway	0.210	0.085	**.308***
Supporting facilities			
P9 – Maintenance of whole garden	**.286***	0.077	**.420****
P10 – Color of green space	0.094	0.163	**.265***
P11 – Diversity of plants	**.264***	0.123	**.320***
P12 – Number of seats	0.127	0.036	0.000
P13 – Number of recreational facilities	-0.072	-0.054	0.034
P14 – Location of signage	**.308***	0.193	0.246
P15 – Font of signage	**.286***	0.209	0.187
Building services			
P16 – Artificial lighting of pathway	0.193	-0.029	0.000
P17 – Artificial lighting of sitting area	**.262***	0.111	0.187

Four multiple regression models were developed at the basis of the regression analysis (see Table 2). All BEOS items were put in the model as independent variables, while three cognitive health items were entered as the dependent variables. The results showed that in Model 1, memory (C1) was positively predicted by the green ratio (P3), and maintenance of the whole garden (P9), and negatively

predicted by open space size (P1) with 26.4% variance. With 7.8% of the variance, concentration (C2) was positively correlated with the green ratio (P3) in Model 2, while in Model 3, judgment has a positive relationship with the maintenance of the whole garden (P9) and green ratio (p3).

Table 2. Regression between BEOS and Cognitive Health of Older People.

Models	B	S.E.	Sig.	VIF	R	R²	Adj. R²	ANOVA F	Sig.
1 C1 – Memory ◄——— Built Environment of Open space									
(Constant)	1.012	0.559	0.076		.549	0.301	0.264	8.045	.001
P3 – Green ratio	0.456	0.113	0.000	1.100					
P9 – Maintenance of whole garden	0.301	0.109	0.007	1.143					
P1 – Open space size	-0.303	0.137	0.031	1.242					
2 C2 – Concentration◄——— Built Environment of Open space									
(Constant)	1.667	0.455	0.001		.306	0.094	0.078	6.013	.017
P3 – Green ratio	0.324	0.132	0.017	1.000					
3 C3 – Judgment ◄——— Built Environment of Open space									
(Constant)	0.873	0.517	0.097		.490	0.240	0.213	8.988	.000
P9 – Maintenance of whole garden	0.365	0.108	0.001	1.012					
P3 – Green ratio	0.251	0.115	0.033	1.012					

Note: S.E. = standard error; Sig. = significance; VIF = variance inflation factor; Adj. R^2 = Adjusted R^2
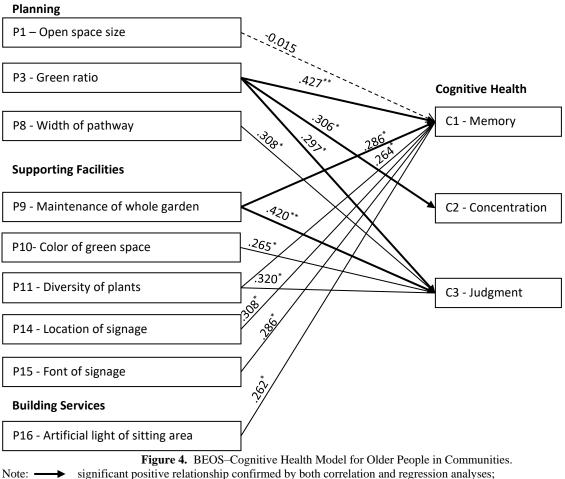
A final BEOS–Cognitive health model for older people in the community was made based on the correlation and regression result (see Figure 4). All the items confirmed by correlation or regression analysis are included in the model. It is shown that both correlation and regression verified that the green ratio has positive impacts on all three cognitive health items, while the maintenance of the whole garden can positively predict memory and judgment. Apart from that, only the correlation analysis shows the positive relationships between the diversity of plants, location, and font of signage, artificial light of sitting area, and memory, as well as the positive influences of the width of the pathway, colour of green space and diversity of plants on judgment. The only negative relationship is found by regression analysis between open space size and memory.

Figure 4. BEOS–Cognitive Health Model for Older People in Communities.

Note: ──────▶ significant positive relationship confirmed by both correlation and regression analyses;
- - - ▷ significant negative relationship confirmed by regression analyses;
────── significant positive relationship confirmed by correlation analyses.

5. Discussion

To investigate the relationship between BEOS and cognitive health, this study conducted a questionnaire survey of the elderly in 3 open spaces. Based on the descriptive statistics result, the frequency of visiting open spaces and background information of older people revealed that most of the older people who usually visit open spaces have relatively good health and eyesight. This indicates the current built environment in open spaces is extremely not suitable for those with poor health and eye conditions, which prevents them from coming to open spaces. To reveal the relationship between the BEOS and cognitive health and build a BEOS–cognitive health model for older people in communities, correlation and regression analyses were conducted. The model showed the important positive relationship of *green space* (*green ratio, colour of green space,* and *diversity of plants*) to the cognitive health of older people, especially the green ratio, which is related to all three items of cognitive health. Green space has long been recognized as an essential element of psychological and physical health (Richardson et al., 2013). This study pointed out that the cognitive health of older people also gained benefits from green spaces. The bustling city life consumes their directed attention capacity and brings difficulty for people to make judgments. Contacting with nature, like plants, can bring people four kinds of restorative experiences, namely being away, fascination, extent, and compatibility. These four kinds of restorative experiences can capture involuntary attention and restore attention fatigue in daily life (Kaplan, 1995). A higher green ratio gives older people more opportunities to contact nature and be away from the concerns of daily life, thereby restoring their attention and helping them to concentrate, remember, and judge (Strunk et al., 2019).

Interestingly, the diversity of plants was positively related to judgment and memory, and the colour of the green space positively predicted judgment. Different types of plants perform different specific experiences, e.g., brushed and trees form a "wall" around the open space to lead older people to get away from the hustle and bustle of the surrounding city area (Nordh et al., 2009). Moreover, plants with beautiful green colour stabilize the autonomic nervous system and activate alpha brainwaves so that older people enjoy the open space with physiological and psychological relaxation (Park et al., 2016). However, this cannot explain why these two items fail to predict concentration at a significant level. Other possible explanations include the presence of some outstanding plants with special characteristics as landmarks that help older people remember (Keil et al., 2020). On the other hand, the diverse vivid colours of plants can stimulate the brain, which may help with decision-making and problem-solving. For example, some studies have found that red can improve performance on detail-oriented tasks, while blue can enhance creativity (Mehta and Zhu, 2009). However, the exact reasons for these relationships still need to be studied in the future.

It showed that the location and font of signage were positively related to memory. It is not hard to understand that an open space with big, vivid, conspicuous signage with clear information can help older people remember their location. Because of impaired eyesight, if the font size is small, older people need to get very close to reading the words (Hou et al., 2018). At this time, if the signage is placed in a very high or low position, the old people must work very hard to look up or bend down to see the words clearly. This would cause great trouble for older people to read information. Hence, older people may rarely use the signage to remember the place. Some recognizable signage with special characters can also make the open space more memorable to older people (Leung et al., 2020). The size and the maintenance of the whole garden played an important role in memory and judgment. It is interesting that the satisfaction with open space size is negatively related to memory. Older people have a lower preference for large open spaces than the general adult population (Lau et al., 2021). The memory space theory supports that a complex space benefits memory through cognitive mapping (Eichenbaum et al., 1999). However, due to the declined special memory, older people can hardly use this kind of contextual memory (Kessels et al., 2007). On contrast, a big and complex space can cause barriers for them to recognize their location and memorize the event. On the other hand, a cluttered environment can distract people, making it difficult to make decisions and remember the environment (Peelen and Kastner, 2014). A well-maintained open space removes the chaotic elements (e.g., garbage and graffiti) that confuse older people and then helps them to judge and remember the situation.

The width of the pathway positively predicted the judgment. Older people often have difficulty moving around (Yim et al., 2020). If the width of the pathway is too narrow, they need to pay more attention to staying safe while walking than to make other judgments. Pathways with the proper width will occupy less attention of older people, leaving them more cognitive space to make decisions. It was shown in the result that there was a positive relationship between artificial light in sitting areas and memory. Sedentary is the most popular activity in open spaces during the night-time. More and more older people like to check their mobile phones when sitting in the open space (Zhou et al., 2014). Bright light in the evening has a positive impact on working memory while using smart devices (Kretschmer et al., 2012). Thus, it is important to provide enough artificial lighting in the sitting area.

6. Recommendation

Green space plays an important role in older people's cognitive health. A large proportion of green space should be provided in the open space. In addition to the number of plants, the species and colour of plants should also be considered. A diversity of plants with vivid and a variety of colours should be planted in the open spaces to enhance the memory, concentration, and judgment of older people. Signs must have clear, big fonts, preferably icons with text. Clear and precise directions should be given to highlight important places such as toilets and entrances. The signage with a big font size should be placed slightly lower than the height of human eyes, about 1.2-1.5m (Launer et al., 1996), and in an easily accessible place. In this way, ordinary, hunchbacked, and wheelchair-bound older

people can all easily read. An open space for old people does not need a large area, but the gardens should be well maintained, keep cleaning, remove obstacles, and repair broken facilities.

As for the limitations, only 60 older people participated in this study. However, the gender distribution of the elderly is consistent with the existing gender distribution of older people in Hong Kong. Besides, the subjects came from three main regions of Hong Kong, namely Hong Kong Island, Kowloon, and the New Territories. Thus, it can be said that the samples were representative. However, this study only asked the older people in three big open spaces, while mini-open spaces, pocket open spaces, and sitting zones were excluded from this study. Open spaces with different sizes may have diverse built environments and different types and numbers of facilities. The range of populations they serve varies at the same time. Visitors may behave differently as a result (Lau et al., 2021). Thus, further study is suggested to explore the relationships between built environments in small open spaces and the cognitive health of older people.

7. Conclusions

Cognitive health plays an important role in older people's daily life. The BEOS can impact the cognitive health of older people. To improve the cognitive health of older people by enhancing the BEOS, this study investigated the relationship between BEOS and the cognitive health of older people by building a BEOS–cognitive health model. The results revealed that memory was positively associated with green ratio, the width of pathways, maintenance of the whole garden, the color of green space, diversity of plants, location, and font of signage, and artificial light of sitting area, while only the open space size negatively influenced memory. One BEOS item, namely the green ratio, could positively predict the concentration. The judgment was positively influenced by the green ratio, width of the pathway, maintenance of the whole garden, the color of the green space, and the diversity of plants. The benefits of plants for cognitive health have been emphasized in this study. To improve their memory, concentration and judgment, practical recommendations have been proposed. Larger green spaces with diverse and colorful plants, signage with proper location and fonts, and good maintenance of the open space were suggested in this study. However, this study only collected data in big open spaces and lacked data in small open spaces. Thus, the built environment of small open spaces should be further studied in the future.

Conflicts of Interest
The author(s) declare(s) no conflicts of interest.

Data availability statement
Due to the nature of this research, participants of this study did not agree for their data to be shared publicly, so supporting data is not available.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
Studies involving human subjects: No human studies are presented in this manuscript.

Institutional Review Board Statement
Not applicable.

CRediT author statement:
Ruozhu YIN: Formal analysis; validation; visualization; writing - original draft; writing - review.Mei-yung LEUNG: Funding acquisition; conceptualization; project administration; resources; supervision; methodology; data curation; investigation; writing - review & editing. Yueran LI: Writing - review. All authors have read and agreed to the published version of the manuscript.

References
Broomhall, M., Giles-Corti, B., & Lange, A. (2004). Quality of public open space tool (POST). *Perth, Western Australia: School of Population Health, The University of Western Australia*.

Census and Statistic Department. (2022, February 28). Population by Sex and Age Group. *The Government of the Hong Kong Special Administrative Region*. Retrieved May 26, 2022, from https://www.censtatd.gov.hk/en/web_table.html?id=1A

Chu, J., Qaisar, S., Shah, Z., & Jalil, A. (2021). Attention or Distraction? The Impact of Mobile Phone on Users' Psychological Well-Being. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.612127

Eichenbaum, H., Dudchenko, P., Wood, E., Shapiro, M., & Tanila, H. (1999). The hippocampus, memory, and place cells: is it spatial memory or a memory space?. *Neuron*, *23*(2), 209-226. https://doi.org/10.1016/S0896-6273(00)80773-4

Feter, N., Spanevello, R. M., Soares, M. S. P., Spohr, L., Pedra, N. S., Bona, N. P., ... & Rombaldi, A. J. (2019). How does physical activity and different models of exercise training affect oxidative parameters and memory?. *Physiology & behavior*, *201*, 42-52. https://doi.org/10.1016/j.physbeh.2018.12.002

Gidlow, C., van Kempen, E., Smith, G., Triguero-Mas, M., Kruize, H., Gražulevičienė, R., ... & Nieuwenhuijsen, M. J. (2018). Development of the natural environment scoring tool (NEST). *Urban Forestry & Urban Greening*, *29*, 322-333. https://doi.org/10.1016/j.ufug.2017.12.007

Hou, G., Dong, H., Ning, W., & Han, L. (2018). Larger Chinese text spacing and size: effects on older users' experience. *Ageing and Society*, *40*(2), 389–411. https://doi.org/10.1017/s0144686x18001022

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*(3), 169–182. https://doi.org/10.1016/0272-4944(95)90001-2

Keil, J., Edler, D., Reichert, K., Dickmann, F., & Kuchinke, L. (2020). Structural salience of landmark pictograms in maps as a predictor for object location memory performance. *Journal of Environmental Psychology*, *72*, 101497.

Kessels, R. P., Hobbel, D., & Postma, A. (2007). Aging, context memory and binding: A comparison of "what, where and when" in young and older adults. *International Journal of Neuroscience*, *117*(6), 795-810. https://doi.org/10.1080/00207450600910218

Kretschmer, V., Schmidt, K. H., & Griefahn, B. (2011). Bright light effects on working memory, sustained attention and concentration of elderly night shift workers. *Lighting Research &Amp; Technology*, *44*(3), 316–333. https://doi.org/10.1177/1477153511418769

Lau, K. K. L., Yung, C. C. Y., & Tan, Z. (2021). Usage and perception of urban green space of older adults in the high-density city of Hong Kong. *Urban Forestry &Amp; Urban Greening*, *64*, 127251. https://doi.org/10.1016/j.ufug.2021.127251

LAUNER, L. J., & HARRIS, T. (1996). Weight, Height and Body Mass Index Distributions in Geographically and Ethnically Diverse Samples of Older Persons. *Age And Ageing*, *25*(4), 300–306. https://doi.org/10.1093/ageing/25.4.300

Leisure and Cultural Services Department. (2021). Statistics report - Leisure services. Retrieved November 10, 2021, from: http://www.lcsd.gov.hk/en/aboutlcsd/ppr/statistics/leisure.html

Leung, M. Y., Wang, C., & Famakin, I. O. (2021). Integrated model for indoor built environment and cognitive functional ability of older residents with dementia in care and attention homes. *Building and Environment*, *195*, 107734. https://doi.org/10.1016/j.buildenv.2021.107734

Leung, M. Y., Wang, C., & Wei, X. (2020). Structural model for the relationships between indoor built environment and behaviors of residents with dementia in care and attention homes. *Building and Environment*, *169*, 106532. https://doi.org/10.1016/j.buildenv.2019.106532

Linde, K., & Alfermann, D. (2014). Single Versus Combined Cognitive and Physical Activity Effects on Fluid Cognitive Abilities of Healthy Older Adults: A 4-Month Randomized Controlled Trial With Follow-Up. *Journal of Aging and Physical Activity*, *22*(3), 302–313. https://doi.org/10.1123/japa.2012-0149

Lloyd, S., Cormack, C. N., Blais, K., Messeri, G., McCallum, M. A., Spicer, K., & Morgan, S. (2001). Driving and dementia: a review of the literature. *Canadian journal of occupational therapy*, *68*(3), 149-156. https://doi.org/10.1177/000841740106800303

Lu, X., Park, N. K., & Ahrentzen, S. (2019). Lighting Effects on Older Adults' Visual and Nonvisual Performance: A Systematic Review. Journal of Housing for the Elderly, 33(3), 298–324. https://doi.org/10.1080/02763893.2018.1562407

Mehta, R., & Zhu, R. (2009). Blue or red? Exploring the effect of color on cognitive task performances. *Science*, *323*(5918), 1226-1229. https://doi.org/10.1126/science.1169144

Menne, H. L., & Whitlatch, C. J. (2007). Decision-Making Involvement of Individuals With Dementia. *The Gerontologist*, *47*(6), 810–819. https://doi.org/10.1093/geront/47.6.810

Mikneviciute, G., Ballhausen, N., Rimmele, U., & Kliegel, M. (2022). Does older adults' cognition particularly suffer from stress? A systematic review of acute stress effects on cognition in older age. *Neuroscience & Biobehavioral Reviews*, *132*, 583-602.

Nordh, H., Hartig, T., Hagerhall, C., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry &Amp; Urban Greening*, *8*(4), 225–235. https://doi.org/10.1016/j.ufug.2009.06.003

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, *19*(7), 305-343. https://doi.org/10.1080/10937404.2016.1196155

Park, S. A., Song, C., Choi, J. Y., Son, K. C., & Miyazaki, Y. (2016). Foliage Plants Cause Physiological and Psychological Relaxation as Evidenced by Measurements of Prefrontal Cortex Activity and Profile of Mood States. *HortScience*, *51*(10), 1308–1312. https://doi.org/10.21273/hortsci11104-16

Peelen, M. V., & Kastner, S. (2014). Attention in the real world: toward understanding its neural basis. *Trends in cognitive sciences*, *18*(5), 242-250. https://doi.org/10.1016/j.tics.2014.02.004

Raanaas, R. K., Evensen, K. H., Rich, D., Sjøstrøm, G., & Patil, G. (2011). Benefits of indoor plants on attention capacity in an office setting. *Journal of Environmental Psychology*, *31*(1), 99-105. https://doi.org/10.1016/j.jenvp.2010.11.005

Richardson, E., Pearce, J., Mitchell, R., & Kingham, S. (2013). Role of physical activity in the relationship between urban green space and health. *Public Health*, *127*(4), 318–324. https://doi.org/10.1016/j.puhe.2013.01.004

Saelens, B. E., Frank, L. D., Auffrey, C., Whitaker, R. C., Burdette, H. L., & Colabianchi, N. (2006). Measuring physical environments of parks and playgrounds: EAPRS instrument development and inter-rater reliability. *Journal of Physical Activity and Health*, 3(s1), S190-S207. https://doi.org/10.1123/jpah.3.s1.s190

Shiffrin, R. M., & Atkinson, R. C. (1969). Storage and retrieval processes in long-term memory. *Psychological Review*, *76*(2), 179–193. https://doi.org/10.1037/h0027277

Silveri, M. C., Reali, G., Jenner, C., & Puopolo, M. (2007). Attention and Memory in the Preclinical Stage of Dementia. *Journal of Geriatric Psychiatry and Neurology*, *20*(2), 67–75. https://doi.org/10.1177/0891988706297469

Stern, P. C., & Carstensen, L. L. (2000). The aging mind: Opportunities in cognitive research.

Strunk, J., Morgan, L., Reaves, S., Verhaeghen, P., & Duarte, A. (2018). Retrospective Attention in Short-Term Memory Has a Lasting Effect on Long-Term Memory Across Age. *The Journals of Gerontology: Series B*, *74*(8), 1317–1325. https://doi.org/10.1093/geronb/gby045

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *science*, *224*(4647), 420-421. https://doi.org/10.1126/science.6143402

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of environmental psychology*, *11*(3), 201-230. https://doi.org/10.1016/S0272-4944(05)80184-7

Verhaeghen, P. (2014). *The elements of cognitive aging: Meta-analyses of age-related differences in processing speed and their consequences*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195368697.001.0001

Whoqol Group. (1998). Development of the World Health Organization WHOQOL-BREF quality of life assessment. *Psychological medicine*, *28*(3), 551-558. https://doi.org/10.1017/S0033291798006667

Yim, J., Park, J., Lohman, E., & Do, K. (2020). Comparison of cervical muscle activity and spinal curvatures in the sitting position with 3 different sloping seats. *Medicine*, *99*(28), e21178. https://doi.org/10.1097/md.0000000000021178

Zhou, J., Rau, P. L. P., & Salvendy, G. (2013). Older adults' use of smart phones: an investigation of the factors influencing the acceptance of new functions. *Behaviour &Amp; Information Technology*, *33*(6), 552–560. https://doi.org/10.1080/0144929x.2013.780637