



23 **Keywords:** neighborhood environment; quality of life; the elderly; multiple mediation effects; aging in  
24 place; influence relationship.

## 25 **1. Introduction**

26 According to the newest population report from the United Nations, one person in eleven persons is over  
27 65 years old in 2019, and by 2050, this proportion will reach one person in six persons, meaning the whole  
28 population of the elderly over 65 will double from 0.703 billion to 1.500 billion from 2019 to 2050. United  
29 Nations points out that the worldwide population will keep aging, and the population group over 65 will  
30 increase the fastest among all population groups (United Nations, 2019a). The aging problem becomes  
31 increasingly severe, particularly in China. In 2019, Chinese older adults over 65 reached to 0.164 billion,  
32 accounting for around 25% of worldwide older adults, and this proportion will continue to grow (United  
33 Nations, 2019b). Government is under tremendous pressure to improve the quality of life (QoL) of a  
34 considerable number of older adults and support them aging successfully (Li, Xu, & Chi, 2016).

35 Because of physical disability, mature social network and a sense of belonging towards their communities,  
36 the majority of the elderly choose to age in place (Hui, Wong, Chung, & Lau, 2014). They wish to remain  
37 as autonomous, active, and independent as long as possible (Iecovich, 2014). Unfortunately, traditional co-  
38 habitation of parents and children is waning, especially in urban areas (Chiu & Ho, 2006), the proportion  
39 of family support keeps decreasing. In light of this trend, functional impairment and competence decline of  
40 older adults must result in the extreme shrinkage of the range of movement of the elderly in daily life  
41 (Chaudhury, Mahmood, Michael, Campo, & Hay, 2012). Additionally, older adults no longer need to  
42 commute daily, neighborhood environment becomes their main outdoor environment in their lives (B. P. Y.  
43 Loo, Mahendran, Katagiri, & Lam, 2017). The interaction between individuals and their living environment  
44 is considered as a continuous process with complex interrelationship (J. M. Cramm, van Dijk, & Nieboer,  
45 2018; Leung & Liang, 2019). Different from the environment of professional institutions for the elderly,  
46 neighborhood environment of general communities comprises more elements under complex operation

47 mechanisms, since general communities need to meet requirements of all generations, rather than only the  
48 group of the elderly. General renewals of neighborhood environment are not sufficiently valid to improve  
49 QoL of the elderly. In order to determine targeted renewal schemes of neighborhood environment, this study  
50 aims to figure out deeper influence relationships between neighborhood environment and QoL of the elderly,  
51 rather than existing simple direct relationships.

### 52 *1.1. Neighborhood environment for the elderly*

53 The living environment for the elderly can be divided into three levels geographically: indoor environment,  
54 neighborhood environment, and urban environment (B. P. Loo, Lam, Mahendran, & Katagiri, 2017).  
55 Generally, neighborhood environment means the outdoor environment within areas of neighborhoods and  
56 communities, or areas 500 meters around homes. Comparing with the young, the elderly spend more time  
57 in their neighborhood environment (Nicklett, Lohman, & Smith, 2017). Since neighborhood environment  
58 is regarded as a complex system containing sub-systems with different functions, several classifications of  
59 elements of neighborhood environment have been proposed and adopted by researchers. For instance,  
60 Cramm et al. (2018) used age-friendly cities guideline developed by World Health Organization (WHO)  
61 (WHO, 2007). For eliminating elements of neighborhood environment unrelated with QoL of the elderly,  
62 this study adopts neighborhood environmental elements which are proved to significantly affect QoL of the  
63 elderly in previous literature review (Zhang, Li, Ahrentzen, & Feng, 2020).

64 *Physical neighborhood environment* is the artificial built environment within the neighborhood, such as  
65 streets, planning, design, and infrastructure within the neighborhood. Related studies have verified that  
66 physical neighborhood environment influences self-related health in the later life of older adults (Krause,  
67 1996). The street connectivity (Engel et al., 2016), street noise level (Krause, 1996; Parra et al., 2010),  
68 placement of sidewalk (Koehn, Mahmood, & Stott-Eveneshen, 2016) and crosswalk, neighborhood  
69 walkability (Alidoust, Bosman, & Holden, 2017) have close relations with capability wellbeing and QoL  
70 of the elderly. The planning-related factors, like land-use mix, are determinations of the physical function

71 of the elderly (Cerin et al., 2012; Soma et al., 2017). Moreover, the barrier-free or age-friendly design  
72 provides a more comfortable and safe physical environment for the elderly's daily life, helps to reduce  
73 physical injuries (Yan, Gao, & Lyon, 2014), and enhances mental health (Y. Zhao & Chung, 2017) and  
74 social relationship (Yu, Ma, & Jiang, 2017).

75 *Natural neighborhood environment* is the natural aspect of the environment within the neighborhood, such  
76 as climate, weather, environmental pollution, etc. Natural environmental problems play an important role  
77 in the life satisfaction of the elderly (Braubach, 2007; Fernández-Carro, Módenes, & Spijker, 2015).  
78 Especially, air pollution has been confirmed to have actual effects on individual morbidity (Zock et al.,  
79 2018) and mental health (Tian, Chen, Zhu, & Liu, 2015). Climate changes, like extreme or changeable  
80 weather, are harmful to older adults' activity participation and QoL (Annear et al., 2012; Braubach, 2007).

81 *Social neighborhood environment* is regarded as the interpersonal communication, social structure,  
82 sociodemographic characteristics, and socioeconomic status of the neighborhood or community. In  
83 individual level, high-quality social network, neighbors support and concentration of older adults offer more  
84 opportunities to enhance physical activities of the elderly (Chaudhury et al., 2012), lower depressive  
85 symptoms (Chen et al., 2016), improve QoL (Dennis, 2003; Levasseur, Desrosiers, & Noreau, 2004;  
86 Stephens, Szabo, Allen, & Alpass, 2019), then help them living independently (Choi, Kwon, & Kim, 2018).  
87 Furthermore, as main social characteristics of the neighborhood, social cohesion is associated with older  
88 adults' capability wellbeing (Engel et al., 2016) and QoL (Friedman, Parikh, Giunta, Fahs, & Gallo, 2012;  
89 Tiraphat et al., 2017); lower population density has a negative influence on physical functions (Soma et al.,  
90 2017); lower percent poverty, residential stability, concentration of the elderly, and neighborhood  
91 socioeconomic status are helpful to their self-rated health (Mooney et al., 2017; Subramanian, Kubzansky,  
92 Berkman, Fay, & Kawachi, 2006).

93 *Facilities and services within the neighborhood* are the facilities and services which are provided within  
94 neighborhood for supporting the elderly's daily life, containing transportation infrastructures, outdoor

95 public spaces, entertainment & exercise facilities, commercial facilities, medical & professional facilities,  
96 etc. Researchers have proved potent effects of facilities or services within the neighborhood on older adults,  
97 such as effects of sitting facilities (Cerin et al., 2012), public space (Clarke, Weuve, Barnes, Evans, &  
98 Mendes de Leon, 2015), facilities related to physical exercise (Ruengtam, 2017), medical facilities (Soma  
99 et al., 2017), public transportation (White et al., 2010), retail, churches and recreational services (Sarkar,  
100 Gallacher, & Webster, 2013). Likewise, accessibility to these facilities or services is also quite critical to  
101 the elderly's physical activities (Wu, Li, & Sung, 2016; Yoo & Kim, 2017) and life satisfaction (Fernández-  
102 Carro et al., 2015; Iwarsson, Horstmann, & Slaug, 2007).

103 *Safety and security* are also essential components of neighborhood environment. Security of neighborhood  
104 is a psychological perception of security within the neighborhood, while safety is physical protection with  
105 the neighborhood (Chaudhury et al., 2012). Typically, the elderly's safety and security within neighborhoods  
106 are caused by the status of design, crime and traffic. The most common unsafety and insecurity results from  
107 the paucity of age-friendly design and appropriate physical layout. For example, physical barriers (like  
108 uneven road surface, too steep steps and crossing design) are quite harmful to the elderly (Rantakokko,  
109 Iwarsson, Portegijs, Viljanen, & Rantanen, 2015). Furthermore, safety and security are also related to the  
110 prevalence of criminal activities within the neighborhood, like mugging, attack, stealing, or drug dealing.  
111 These illegal acts that are harmful to QoL of the elderly (Friedman et al., 2012). Besides, traffic hazards  
112 have been reported in many neighborhoods, especially high-density neighborhoods (Parra et al., 2010).  
113 Because the travel of the elderly within the neighborhood relies more on walking, terrible traffic lowers the  
114 safety and security of the elderly by resulting in several issues, such as high-speed cars/non-motor vehicles  
115 on roads and less time to cross intersections (Chaudhury et al., 2012).

## 116 *1.2. QoL of the elderly*

117 QoL is a worldwide-used official index to measure the life of an individual. The concept of QoL is clarified  
118 by WHO as "*individuals' perception of their position in life in the context of the culture and value systems*

119 *in which they live and in relation to their goals, expectations, standards and concerns"* (WHOQOL Group,  
120 1995). Based on the official definition, WHOQOL-BREF, a standard measurement of QoL, is proposed by  
121 WHOQOL Group (Harper, Power, & Grp, 1998; WHO, 1996), then widely adopted by worldwide  
122 researchers (Al-Shibani & Al-Kattan, 2019; Hernández-Ledesma et al., 2018; Tiraphat, Peltzer, Thamma-  
123 Aphiphol, & Suthisukon, 2017). WHOQOL-BREF provides specific items to calculate the score of the  
124 overall QoL and four domains - living environment (LE), physical health (Phy-H), psychological health  
125 (Psy-H), and social relationship (SR) (WHO, 1996). Since the aim of this study is to explore the influence  
126 of neighborhood environment on QoL of the elderly, this study considers Phy-H, Psy-H and SR as three  
127 main domains of the elderly for avoiding redundant analyses.

128 Phy-H refers to individuals' perception of their physical state and fitness, containing individuals' mobility,  
129 sleep, work capacity, pain, energy, activities of daily living, etc. (WHOQOL Group, 1995). As individuals  
130 get older, their organ functions and physical health keep declining. Despite sudden illness, older adults are  
131 more like to get several chronic diseases, like arthritis, heart disease, respiratory diseases, Alzheimer's  
132 disease, osteoporosis, and diabetes<sup>1</sup>. Psy-H reflects individuals' perception of their cognitive and affective  
133 state, such as negative/positive feeling, self-esteem, concentration, bodily appearance, personal beliefs, etc.  
134 (WHOQOL Group, 1995). The elderly's mental outlook, attitudes and personality characteristics usually  
135 influence their lives and actions, and contribute to their overall QoL (Gabriel & Bowling, 2004). Keeping  
136 optimistic and positive feelings in daily life benefit Psy-H of the elderly definitely. SR is individuals'  
137 perception of interpersonal relationships and social roles in their life (WHOQOL Group, 1995). The private  
138 SR of the elderly is crucial sources offering them emotional communication and actual support (Dong, Beck,  
139 & Simon, 2010). Unfortunately, their social networks shrink heavily after retirement. Developing new SR  
140 within the neighborhood is quite essential to the elderly.

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<sup>1</sup> <https://www.everydayhealth.com/news/most-common-health-concerns-seniors/>

141 How different components of neighborhood environment influence the elderly's life has caused broad  
142 concern of researchers. However, most existing studies paid attention to direct impacts of neighborhood  
143 environment on QoL of older adults, with the paucity of exploration of other kinds of impacts, like  
144 mediation effects. In terms of studies on contributions of domains of QoL on the overall QoL (Arnold et al.,  
145 2004), it is quite possible that elements of neighborhood environment influence the overall QoL through  
146 influencing certain domains, such as Phy-H, Psy-H or SR. That is to say, Phy-H, Psy-H or SR may be  
147 mediators between certain elements of neighborhood environment and the overall QoL of the elderly.  
148 Mediation effects would be great supplements to complex relationship networks among neighborhood  
149 environment and QoL. Consequently, this study aims to explore more in-depth roles of Phy-H, Psy-H and  
150 SR as multiple mediators existing between neighborhood environment and the overall QoL of the elderly,  
151 then develop multiple mediation models for community-dwelling older adults. Ultimately, according to  
152 diverse mediation models, this study is able to propose targeted retrofit suggestions for specific components  
153 of neighborhood environment by taking advantage of contributions of multiple mediators. These valuable  
154 suggestions guide renewals of neighborhood environment for supporting aging in place more efficiently.

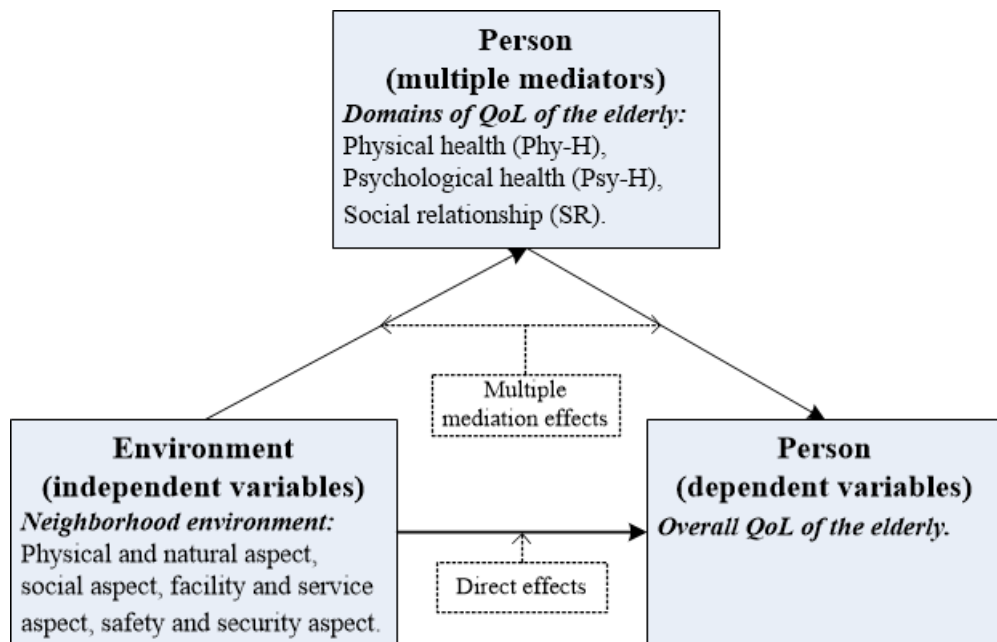
## 155 **2. Conceptual Model**

156 According to contributive literature, a conceptual model is proposed reasonably to describe diverse kinds  
157 of relations between QoL of the elderly and their surrounding neighborhood environment, as shown in  
158 Figure 1.

159 Based on the person-environment fit (P-E fit) theory (Leung, Famakin, & Kwok, 2017), Lawton proposed  
160 the ecological theory of aging to point out that the performance and comfort of the elderly can be better  
161 when the environment has an appropriate match with them (Lawton, Windley, & Byerts, 1982; Lien,  
162 Steggell, & Iwarsson, 2015). Hereafter, a series of studies have confirmed the strong influence of the  
163 environment on the elderly (Gobbens & Van Assen, 2018; Leung & Liang, 2019; Zhang & Li, 2019b).

164 Consequently, it is reasonable to suppose neighborhood environment can affect QoL of the elderly, as the  
165 direct effects in Figure 1.

166 Furthermore, as elaboration in the review, whether the overall QoL or domains of QoL are affected by  
167 neighborhood environment. Also, domains of QoL, Phy-H, Psy-H and SR are confirmed to contribute to  
168 the overall QoL differently (Al-Shibani & Al-Kattan, 2019; Hernández-Ledesma et al., 2018; Gabriel &  
169 Bowling, 2004; Arnold et al., 2004). Thus, it is entirely rational to set multiple mediation effects in Figure  
170 1, consisting of relations between neighborhood environment and Phy-H, Psy-H, SR, and relations between  
171 Phy-H, Psy-H, SR and the overall QoL of the elderly. Phy-H, Psy-H, SR are assumed as three mediators in  
172 the conceptual model for the elderly. The combination of direct effects and mediation effects is regarded as  
173 the conceptual models of this study.



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Figure 1 The conceptual model of this study



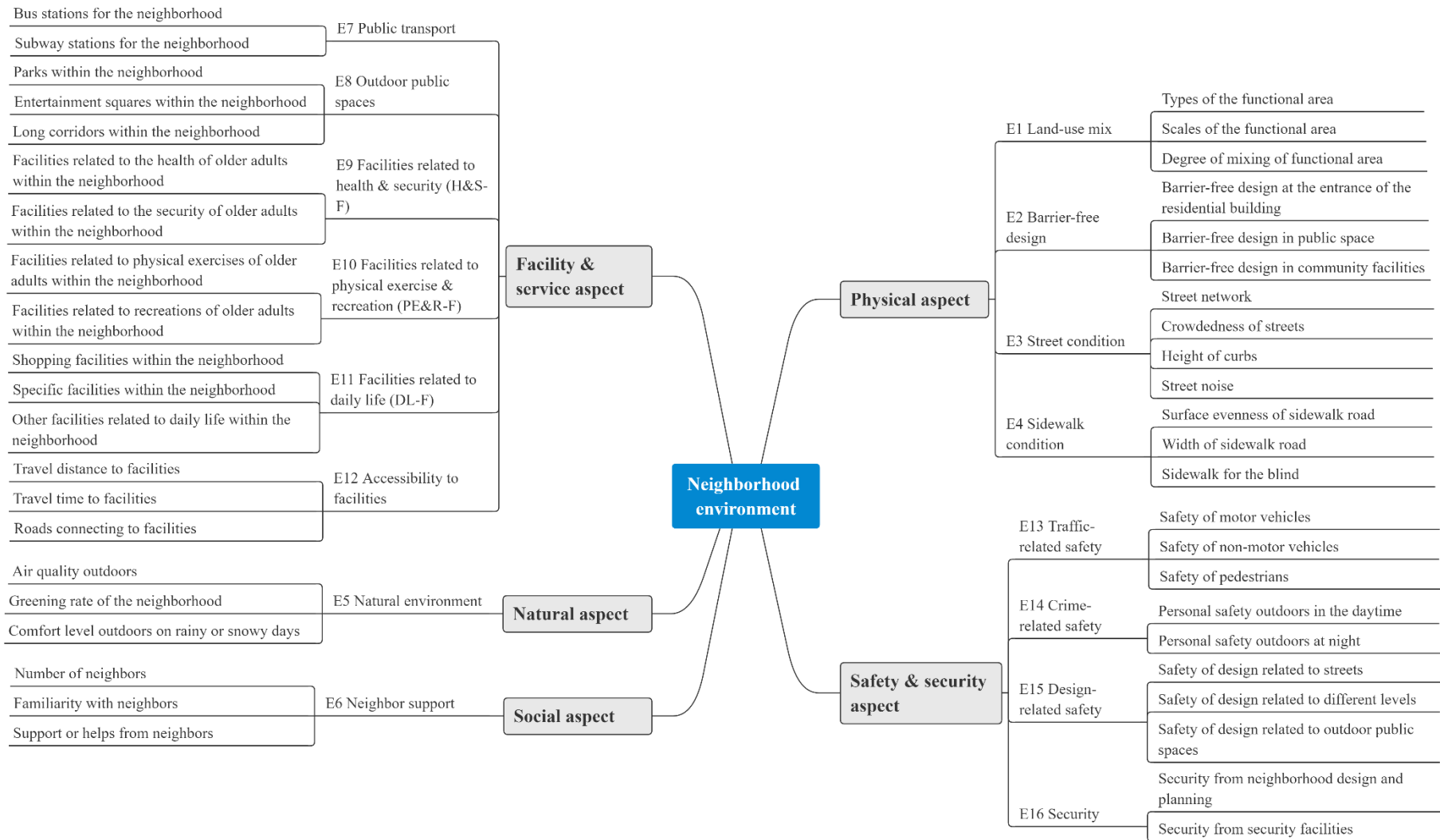
176 **3. Research Methodology**

177 *3.1. Questionnaire Design*

178 All data of independent variables, multiple mediators and dependent variables in the conceptual model  
179 should be collected from the elderly. The questionnaire survey is an appropriate way to collect perception  
180 data from the elderly directly. The questionnaire is designed to obtain three parts of data, including the  
181 general information of respondents, their perception of surrounding neighborhood environment, their  
182 perception of domains of QoL and the overall QoL.

183 First of all, the general information should be included in this questionnaire. These data help to ensure all  
184 respondents are qualified (detail sampling criteria are described in 3.2). The quality of sampling can be  
185 checked briefly. The basic information is collected from respondents, containing their age, gender, type of  
186 residence, whom they live with, and how long they have lived.

187 Secondly, the questionnaire should be designed to obtain the elderly's perception of their neighborhood  
188 environment. Typically, the latent variable refers to the variable that cannot be observed directly, and need  
189 to be inferred from other observed variables. The elderly's perception of neighborhood environment is  
190 exactly latent variable. So, other measurable items should be set as observed variables to capture accurate  
191 perception from respondents scientifically. According to detailed elements of neighborhood environment,  
192 which are identified as significant factors of QoL of the elderly (Zhang, Li, Ahrentzen, & Feng, 2020),  
193 questionnaire adopts the measurable items that have been proposed and validated in previous studies,  
194 (Zhang & Li, 2019a). All factors of the neighborhood environment and their measurable items are shown  
195 in Figure 2. Questions of measurable items are set with five-point Likert scales, like the question of "surface  
196 evenness of sidewalk road" should be "how do you satisfy with surface evenness of sidewalk road in your  
197 neighborhood environment?" The elderly are required to grade each question from 1 (very unsatisfied) to 5  
198 (very satisfied). In total, there are 44 measurable items in the part of neighborhood environment.



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Figure 2 The measurement of perceived neighborhood environment

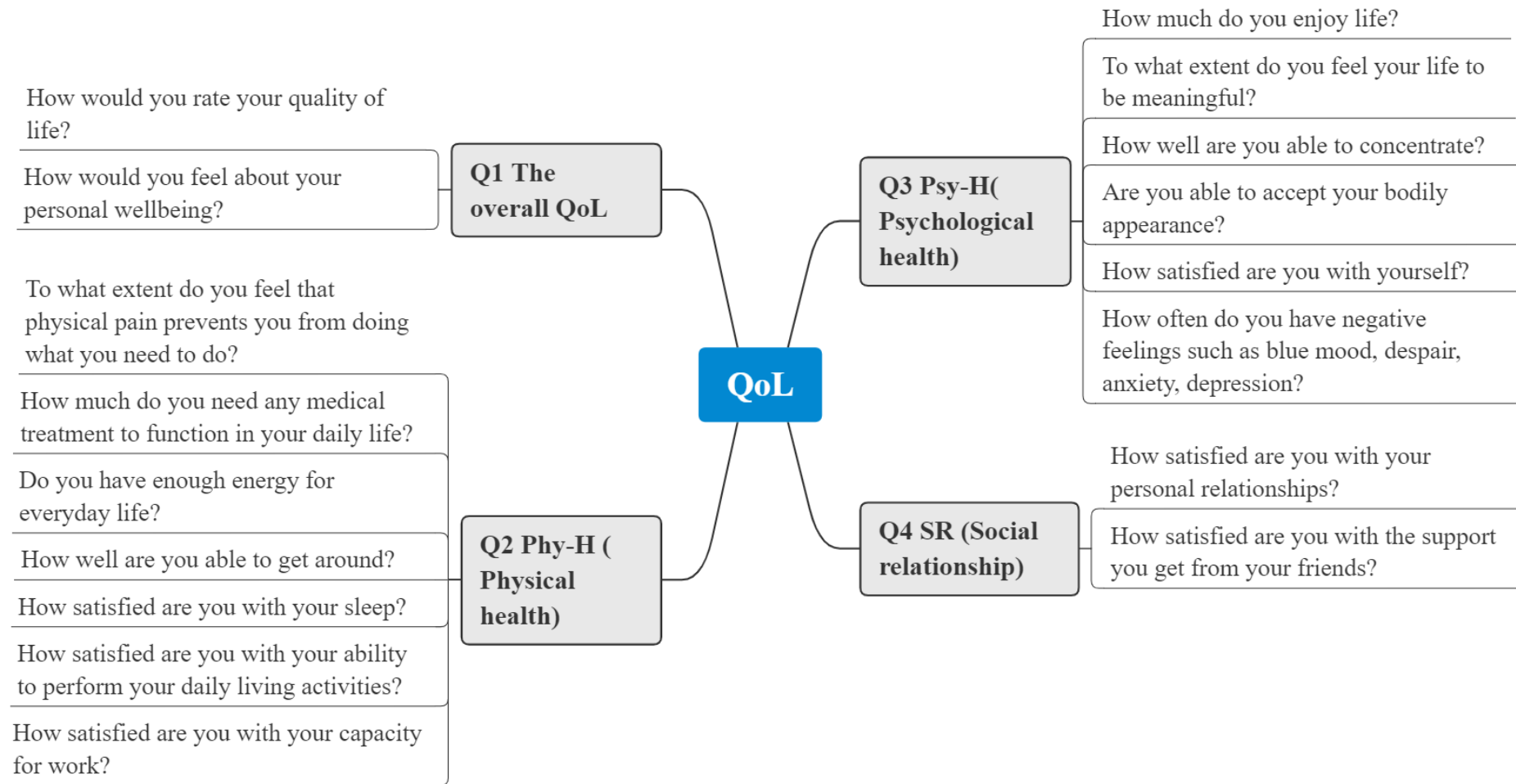


Figure 3 The assessment of QoL of the elderly

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203 The final part of questionnaire quantifies the elderly's perception of QoL. The questionnaire retrieves  
204 corresponding measurable items of the overall QoL, Phy-H, Psy-H, and SR from WHOQOL-BREF. In  
205 total, 17 measurable items derived from WHOQOL-BREF are adopted, as shown in Figure 3.

### 206 *3.2. Data Collection Approaches*

207 Based on the well-designed questionnaire, the perception data can be collected from respondents.  
208 According to the objectives of this study, sampling criteria of respondents are set as age needs over 60,  
209 residences should be original habitat, and the ability of communication should be good enough to  
210 express their feelings. The elderly who meet these criteria can be chosen as eligible respondents of this  
211 study.

212 The questionnaire survey was conducted in September-October 2018 in Nanjing. The whole population-  
213 scale determines the size of random sampling. Generally, if the whole population is limited, the  
214 sampling size should be more than 5 percent of the whole population; while the whole population is  
215 vast enough that can be regarded as infinite size, the sampling size should be more than 173 under 5  
216 percent error. Older people in Nanjing have reached 1.45 million, accounting for more than 20% of the  
217 whole population of Nanjing. Due to the enormous population of the elderly in Nanjing, 204 qualified  
218 respondents were chosen to participate in this survey. Eventually, 194 valid data were collected with  
219 the response rate of 94.12%. There are 94 female respondents and 98 male respondents. The number of  
220 respondents aged between 60 and 69 is 125, aged between 70 and 79 is 29, and aged over 80 years old  
221 is 38. 110 of 194 respondents live with their spouses, 49 respondents with their children, and 16  
222 respondents live alone, and the other 8 respondents live with other people, like friends or relatives.  
223 Among these respondents, 116 older adults live in commercial housing, 8 in affordable housing, 55 in  
224 self-built housing and 13 in other types of residences. Regarding their current residences, 47  
225 respondents have moved in within 5 years, 99 respondents have lived for more than 10 years, and the  
226 other 46 respondents have lived for 5-10 years.

227 Besides the questionnaire survey, the interview with 30 respondents was conducted to collect  
228 supplemental qualitative data, which implies more perceptual feelings of the elderly.

### 229 *3.3. Data Analysis Procedures*

230 Main objectives of data analysis are to check the quality of collected data, then detect multiple mediation  
231 effects. Based on this logic, procedures of data analysis are set as three steps: reliability test to the  
232 quality of data, multiple linear regression analysis to obtain the significant relations and propose  
233 hypotheses for multiple mediation effect tests, and multiple mediation effect tests to verify the  
234 mediation effects of Phy-H, Psy-H and SR. Three steps of data analysis procedures are elaborated as  
235 follows.

#### 236 Step 1: Reliability test

237 The first step of data analysis should be reliability test and validation test to decide if this questionnaire  
238 is qualified for the following data analysis. The neighborhood environment part of the questionnaire is  
239 derived from the peer-reviewed study (Zhang et al., 2020), this part has already been validated (Zhang  
240 & Li, 2019a); the QoL part of the questionnaire is based on the worldwide-used WHOQOL-BREF  
241 which has already validated by WHO (WHO, 1996). Thus, it is unnecessary to conduct the validation  
242 test again. However, due to different respondents, the reliability test is still essential. The leading  
243 indicator of the reliability test is Cronbach's  $\alpha$ -value. If the Cronbach's  $\alpha$ -value of a variable is greater  
244 than 0.8, it indicates measurable items of this variable are with good reliability and the questionnaire  
245 does not need any modification. If the Cronbach's  $\alpha$ -value of a variable is between 0.6 and 0.8, it  
246 indicates measurable items are with acceptable reliability and the questionnaire can accept the waiver  
247 of modification. If the Cronbach's  $\alpha$ -value of a variable is lower than 0.6, it indicates the reliability of  
248 measurable items is terrible and the questionnaire must be modified to improve the Cronbach's  $\alpha$ -value  
249 more than 0.6 (Hair, Black, Babin, & Anderson, 2010; Ott & Longnecker, 2008; Leung, Famakin, &  
250 Kwok, 2017). Consequently, 0.6 is a baseline to decide whether to revise the questionnaire. Regarding

251 the item with 0.6-0.8  $\alpha$ -value, this item should be removed if its deletion causes a marked rise of original  
252  $\alpha$ -value; otherwise, it can be retained.

253 Step 2: Multiple linear regression analysis.

254 The multiple linear regression analysis is applied to analyze correlations between all factors of  
255 neighborhood environment and the overall QoL of the elderly. The mean value of measurable items is  
256 set as the value of the variable. The Statistical Package of Social Science (SPSS) is a professional  
257 software for data analysis.

258 Factors of neighborhood environment, which have significant relations with the overall QoL, are  
259 qualified to be the independent variables in the conceptual model (Figure 1). And then, multiple  
260 mediation models can be established based on the conceptual model.

261 Step 3: Multiple mediation effect test.

262 Regarding mediation effects, several controversies of standards testing approaches and methods are still  
263 existing. Almost widely used tests (like causal step regression) have limitations on the power and  
264 accuracy in the statistics. Therefore, this study adopts a series of multiple mediation effect tests for  
265 reducing errors, and detailed reasons why each test is adopted are elaborated as follows.

266 1) The first test is the causal step regression. The causal step regression proposed by Baron and Kenny  
267 is one of the most popular methods to test mediation effects (Baron & Kenny, 1986). The causal step  
268 regression model contains three steps as following: ① regressing dependent variables ( $Y$ ) on  
269 independent variables ( $X$ ), coefficient  $c$  should be significant (Equation 1); ② regressing mediators ( $M$ )  
270 on independent variables ( $X$ ), coefficient  $a$  should be significant (Equation 2); ③ regressing dependent  
271 variables ( $Y$ ) on both independent variables ( $X$ ) and mediators ( $M$ ), coefficient  $b$  should be significant,  
272 and coefficient  $c'$  should be less than  $c$  (Equation 3). However, the causal step regression has been  
273 questioned by many researchers heavily, since it shows low power in simulation studies and it is not

274 based on a quantification of the mediation effect (Hayes, 2009; Preacher & Hayes, 2004; X. Zhao,  
275 Lynch Jr, & Chen, 2010). So, additional tests are necessary for higher accuracy.

$$276 \qquad Y = i + cX + e_1 \qquad \text{(Equation 1)}$$

$$277 \qquad M = i + aX + e_2 \qquad \text{(Equation 2)}$$

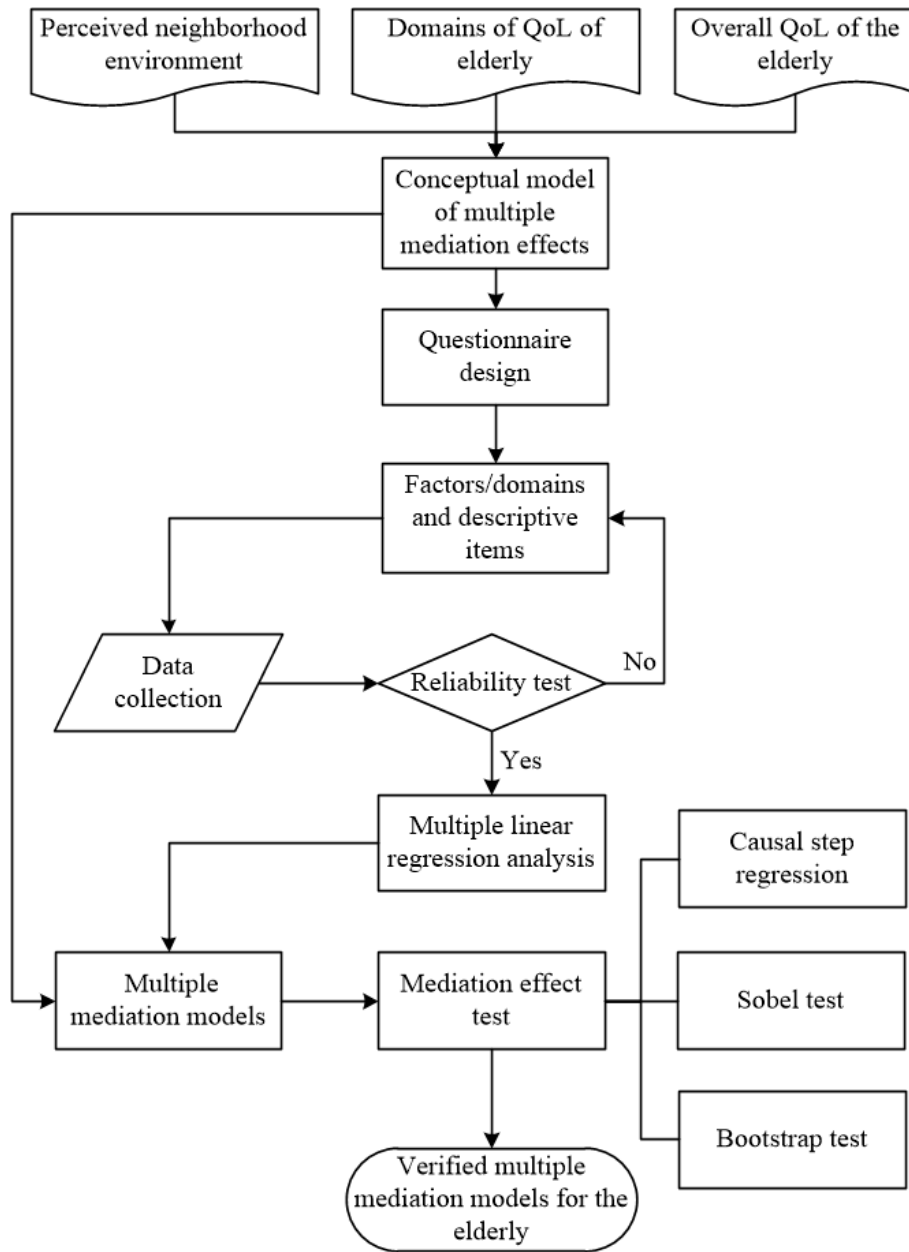
$$278 \qquad Y = i + c'X + bM + e_2 \qquad \text{(Equation 3)}$$

279 2) The second test is the Sobel test. Sobel test is proposed by Sobel in 1982, testing the null hypothesis  
280 by estimating the standard error of  $a*b$  (Sobel, 1982). According to previous simulation studies, results  
281 of the Sobel test is more accurate than causal step regression (MacKinnon, Lockwood, Hoffman, West,  
282 & Sheets, 2002). Hayes considered Sobel test should be applied as a supplement to the causal step  
283 regression rather than instead of it (Hayes, 2009). Nevertheless, Sobel test can help to improve the  
284 validity of mediation effects, it also has the main limitation that the distribution of coefficient  $a*b$  will  
285 influence the accuracy of Sobel test. Although Sobel test can help to improve the validity of mediation  
286 effects, it also has the main limitation that the distribution of coefficient  $a*b$  will influence the accuracy  
287 of Sobel test. Only when its sampling distribution is normal, the Sobel test is the most accurate. However,  
288 in reality, the sampling distribution is usually not normal, but the asymmetric distribution (Hayes, 2009;  
289 MacKinnon, Lockwood, & Williams, 2004).

290 3) The last test is the Bootstrap test. Bootstrap test is developed by Preacher and Hayes, considered as  
291 a better alternative method to cover the limitation of Sobel test by researchers nowadays (Preacher &  
292 Hayes, 2004). Bootstrap test overcomes the limitation of Sobel test by generating an empirical sampling  
293 distribution of coefficient  $a*b$  (X. Zhao et al., 2010). Its power of validation of mediation effects has  
294 been verified to be better than Sobel test (Fritz & MacKinnon, 2007; MacKinnon et al., 2004). So, five  
295 thousand times' Bootstrap test under 95% confidential level is also adopted as a supplementary test.  
296 When the interval of the mediation effect does not contain zero, the mediation effect is proved.

297 All multiple mediation tests are conducted with the PROCESS Procedure v2.16 which is developed by  
 298 Hayes (Hayes, 2017).

299 Figure 4 presents the procedures of research methodology of this study.



300

301

Figure 4 Procedures of research methodology



302 **4. Results**

303 *4.1. Results of the Reliability Test*

304 The reliability of data collected from the questionnaire survey is tested to check the internal consistency  
 305 with the indicator of Cronbach's  $\alpha$ -value. Table 1 & 2 list results of the reliability test in detail. As  
 306 mentioned in the methodology, only when the Cronbach's  $\alpha$ -value of the variable is greater than 0.6, its  
 307 measurable items are acceptable and the questionnaire meets the requirement of the internal consistency  
 308 (Hair et al., 2010). Otherwise, measurable items of this variable need to be modified.

309 Table 1 shows the Cronbach's  $\alpha$ -values of all neighborhood environmental factors are greater than 0.6,  
 310 so this part of the questionnaire meets the requirement of reliability. Nevertheless, in Table 2, the  
 311 Cronbach's  $\alpha$ -value of Phy-H (Q2) is less than 0.6, meaning that measurable items of Phy-H are not  
 312 appropriate. By checking the indicator of "Cronbach's  $\alpha$ -value if deleted", the "Cronbach's  $\alpha$ -value if  
 313 deleted" of item 3 and 4 are 0.642 and 0.597, much higher than original Cronbach's  $\alpha$ -value (0.456),  
 314 revealing that deleting item 3 and 4 from Phy-H can improve the reliability of the questionnaire  
 315 markedly. Furthermore, regarding the domain of Psy-H (Q3), the original Cronbach's  $\alpha$ -value is between  
 316 0.6 and 0.8, but "Cronbach's  $\alpha$ -value if deleted" implies that deleting item 15 can raise  $\alpha$ -value from  
 317 0.713 to 0.853. So, item 3, 4 & 15 should be eliminated for better reliability of the questionnaire.

318 Table 1 The reliability test of neighborhood environment

Factor of neighborhood environment	$\alpha$ -values	Factor of neighborhood environment	$\alpha$ -values
E1	0.931	E9	0.844
E2	0.944	E10	0.947
E3	0.930	E11	0.874
E4	0.844	E12	0.962
E5	0.883	E13	0.926
E6	0.895	E14	0.910
E7	0.815	E15	0.942
E8	0.916	E16	0.925

319 Table 2 The reliability test of neighborhood environment

Domain	Item	$\alpha$ -values	$\alpha$ -values if deleted	Domain	Item	$\alpha$ -values	$\alpha$ -values if deleted
Q1	1	0.922	-	Q3	10	0.713	0.589
overall QoL	2		-	Psy-H	11		0.573

Q2	3		0.642		12		0.638
Phy-H	4		0.597		13		0.631
	5		0.331		14		0.635
	6	0.456	0.304		15		0.853
	7		0.291	Q4	16		-
	8		0.249	SR	17	0.835	-
	9		0.287				

320 *4.2. Results of the Multiple Linear Regression Analysis*

321 The multiple regression analysis is applied to detect neighborhood environmental variables which  
 322 closely relate to the overall QoL of the elderly from 16 neighborhood environmental factors.

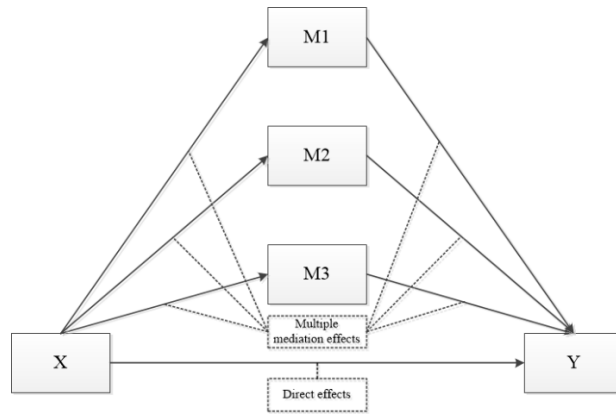
323 Results of indicators of the multiple linear regression are listed in Table 3. Results reveal that three  
 324 neighborhood environmental factors can influence the overall QoL of the elderly, containing neighbor  
 325 support (E6), PE&R-F (E10), and accessibility to facilities (E12). The F value of ANOVA is 53.743, its  
 326 significance is 0.000, meaning the whole regression equation is significant. R<sup>2</sup> is an indicator to present  
 327 goodness of fit. R<sup>2</sup> of this regression equation is 0.462, indicating 46.2% of the variance of dependent  
 328 variables can be explained by E6, E10 and E12.

329 Table 3 Results of the multiple linear regression analysis

	Model	B	S.E.	t	Sig.	R	R <sup>2</sup>	ANOVA	
								F	Sig.
Overall QoL	Constant	1.032	0.208	4.970	0.000	0.679	0.462	53.743	0.000
	E6 Neighbor support	0.384	0.073	5.244	0.000				
	E12 Accessibility to facilities	0.226	0.072	3.125	0.002				
	E10 PE&R-F	0.123	0.060	2.085	0.038				

Notes: Sig. = significance; B = unstandardized beta; S.E. = standard error.

330 Three factors of neighborhood environment - E6, E10 and E12 have been proved to affect the overall  
 331 QoL of the elderly significantly. According to the conceptual model (Figure 1), it is reasonable to  
 332 assume that domains of QoL (Phy-H, Psy-H and SR) may be mediators between E6, E10, E12 and the  
 333 overall QoL. Figure 5 shows the basic structure of multiple mediation models, X refers to neighborhood  
 334 environmental factors, MI-3 refer to Phy-H, Psy-H and SR, Y refers to the overall QoL of the elderly.  
 335 All variables of three multiple mediation models are shown in Table 4 in detail.



336

337

Figure 5 The basic structure of multiple mediation models for the elderly

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Table 4 The detail variables of multiple mediation models

	<b>Model 1</b>	<b>Model 2</b>	<b>Model 3</b>
<i>X</i>	Neighbor support (E6)	PE&R-F (E10)	accessibility to facilities (E12)
<i>M1</i>	Phy-H (Q2)	Phy-H (Q2)	Phy-H (Q2)
<i>M2</i>	Psy-H (Q3)	Psy-H (Q3)	Psy-H (Q3)
<i>M3</i>	SR (Q4)	SR (Q4)	SR (Q4)
<i>Y</i>	The overall QoL (Q1)	The overall QoL (Q1)	The overall QoL (Q1)

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#### 4.3. Results of the Multiple Mediation Effect Tests

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Multiple mediation effect tests consist of casual step test, Sobel test and Bootstrap. Only when multiple

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mediation models meet requirements of all mediation effect test, the mediation effects can be proved.

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The verification result of model 1 is shown in Table 5. According to the causal step test, F value of

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model 1-1~1-5 and coefficients of model 1-1~1-4 are significant. However, in model 1-5, only

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coefficients of neighbor support and Psy-H are significant to the overall QoL of the elderly. R<sup>2</sup> increases

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from 0.372 of model 1-1 to 0.470 of model 1-5, meaning that the mediation effect of Psy-H helps the

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neighbor support to explain more variance of the overall QoL of the elderly. Sobel test presents only

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the z-score of the indirect effect of Psy-H is significant at 0.01 level. Then, mediation effects of each

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domain of QoL are tested by Bootstrap test. The interval of the path " $X \rightarrow M2 \rightarrow Y$ " is (0.047, 0.231),

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which does not contain zero, and intervals of the other two paths contain zero. With three mediation

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effect tests, the mediation effect of Psy-H between neighbor support and the overall QoL of the elderly

351

is proved statistically.

Table 5 The verification result of Model 1

Model 1	Model 1-1		Model 1-2		Model 1-3		Model 1-4		Model 1-5		
Independent Variable	Y = Q1		M1 = Q2		M2 = Q3		M3 = Q4		Y = Q1		
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.	
X = E6	0.642***	0.060	0.301***	0.064	0.328***	0.065	0.490***	0.062	0.518***	0.065	
M1 = Q2	-	-	-	-	-	-	-	-	-0.036	0.078	
M2 = Q3	-	-	-	-	-	-	-	-	0.377***	0.084	
M3 = Q4	-	-	-	-	-	-	-	-	0.022	0.078	
F	112.395***		22.358***		25.609***		62.892***		41.507***		
R	0.610		0.324		0.345		0.499		0.686		
R <sup>2</sup>	0.372		0.105		0.119		0.249		0.470		
Sobel test	X→M1→Y		Indirect effect = -0.011				z = -0.447				
	X→M2→Y		Indirect effect = 0.124				z = 3.326***				
	X→M3→Y		Indirect effect = 0.011				z = 0.278				
Bootstrap test	Mediation effect		Indirect effect				BootLLCI		BootULCI		
	X→M1→Y		-0.011				-0.067		0.033		
	X→M2→Y		0.124				0.047		0.231		
	X→M3→Y		0.011				-0.066		0.118		
Model 1	Partially verified										
Note: B = unstandardized beta; S.E. = standard error; ***-significant at the 0.01 level (2-tailed); **-significant at 0.05 level (2-tailed); *-significant at 0.1 level (2-tailed).											

353 Table 6 lists all verification results of model 2. In results of the causal step test, F value and coefficient  
 354 of all models are significant statistically, except the coefficient (-0.013) in model 2-5 does not reach the  
 355 requirement of significance. R<sup>2</sup> of model 2-1 is 0.275, which means the direct effect of PE&R-F can  
 356 explain 27.5% variance of the overall QoL of the elderly; and R<sup>2</sup> of model 2-5 reaches 0.441, showing  
 357 multiple mediation effects of Psy-H and SR enhance the explanation for the variance of the overall QoL  
 358 of the elderly. Sobel test presents that z-score of mediation effects of Psy-H and SR is both significant  
 359 at 0.001 level and 0.05 level. Then, 5000 times' Bootstrap test confirms intervals of the path "X→M1 →  
 360 Y" and "X→M2 →Y" are (0.016, 0.130) and (0.001, 0.101), not containing zero. Consequently, model 2  
 361 is supported partially: there are multiple mediation effects of Psy-H and SR contributing to the influence  
 362 of PE&R-F on the overall QoL of the elderly.

363 Table 6 The verification result of model 2

Model 2	Model 2-1		Model 2-2		Model 2-3		Model 2-4		Model 2-5	
Independent Variable	Y = Q1		M1 = Q2		M2 = Q3		M3 = Q4		Y = Q1	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.
X = E10	0.412***	0.049	0.156***	0.049	0.180***	0.050	0.188***	0.051	0.318***	0.045
M1 = Q2	-	-	-	-	-	-	-	-	-0.013	0.080

M2 = Q3	-	-	-	-	-	-	-	-	0.333***	0.086
M3 = Q4	-	-	-	-	-	-	-	-	0.189**	0.075
F	71.899***		10.213***		13.011***		13.398***		36.860***	
R	0.524		0.226		0.253		0.257		0.664	
R <sup>2</sup>	0.275		0.051		0.064		0.066		0.441	
Sobel test	X→M1→Y		Indirect effect = -0.002				z = -0.150			
	X→M2→Y		Indirect effect = 0.060				z = 2.589***			
	X→M3→Y		Indirect effect = 0.036				z = 2.028**			
Bootstrap test	Mediation effect		Indirect effect		BootLLCI		BootULCI			
	X→M1→Y		-0.002		-0.036		0.022			
	X→M2→Y		0.060		0.016		0.130			
	X→M3→Y		0.036		0.001		0.101			
Model 2					Partially verified					
Note: B = unstandardized beta; S.E. = standard error; ***-significant at the 0.01 level (2-tailed); **-significant at 0.05 level (2-tailed); *-significant at 0.1 level (2-tailed).										

364 The last neighborhood environmental factor with the direct influence on the overall QoL of the elderly  
365 is accessibility to facilities. The multiple mediation effects existing in this influence path is tested, as  
366 shown in Table 7. All F values in causal step test are significant at 0.01 level, indicating regression  
367 equations among accessibility to facilities, domains of QoL and the overall QoL of the elderly are valid.  
368 Coefficient of Phy-H in model 3-5 is not significant, showing the mediation effect of Phy-H does not  
369 work. Since R<sup>2</sup> increases from model 3-1 to model 3-5, multiple mediation effects explain more variance  
370 of the overall QoL of the elderly. Indirect effects of Psy-H and SR have significant z-scores by applying  
371 Sobel test. And then, multiple mediation effects are confirmed by Bootstrap test with intervals of (0.015,  
372 0.163) and (0.000, 0.122). Therefore, Psy-H and SR are regarded as multiple mediators between  
373 accessibility to facilities and the overall QoL of the elderly.

374 Table 7 The verification result of model 3

Model 3	Model 3-1		Model 3-2		Model 3-3		Model 3-4		Model 3-5	
Independent Variable	Y = Q1		M1 = Q2		M2 = Q3		M3 = Q4		Y = Q1	
	B	S.E.	B	S.E.	B	S.E.	B	S.E.	B	S.E.
X = E12	0.521***	0.050	0.190***	0.054	0.273***	0.053	0.264***	0.055	0.402***	0.050
M1 = Q2	-	-	-	-	-	-	-	-	0.013	0.077
M2 = Q3	-	-	-	-	-	-	-	-	0.267***	0.085
M3 = Q4	-	-	-	-	-	-	-	-	0.166**	0.073
F	107.579***		12.601***		26.319***		22.657***		42.332***	
R	0.601		0.249		0.349		0.326		0.689	
R <sup>2</sup>	0.362		0.062		0.122		0.107		0.475	
Sobel test	X→M1→Y		Indirect effect = 0.003				z = 0.166			
	X→M2→Y		Indirect effect = 0.073				z = 2.651***			
	X→M3→Y		Indirect effect = 0.044				z = 2.019**			

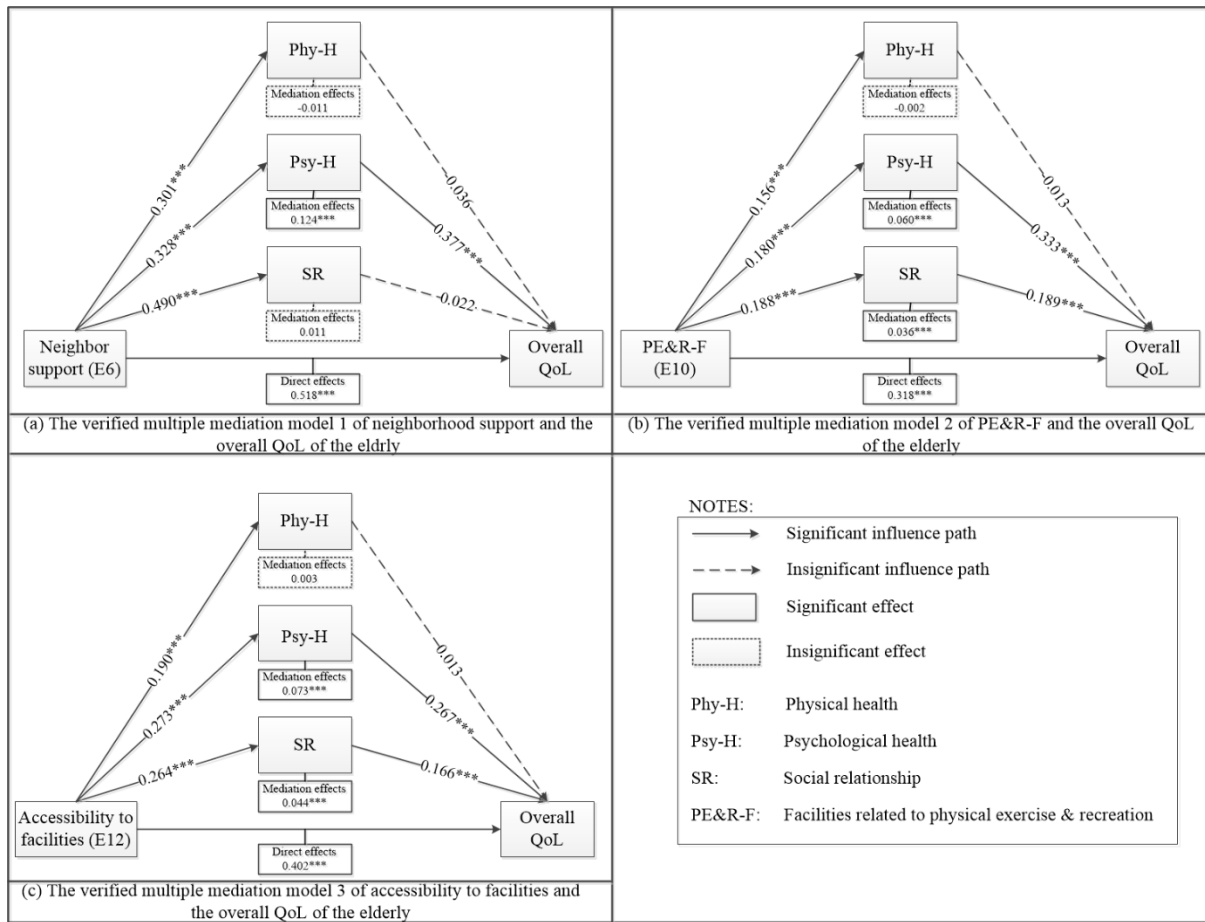
	Mediation effect	Indirect effect	BootLLCI	BootULCI
Bootstrap test	X→M1→Y	0.003	-0.033	0.034
	X→M2→Y	0.073	0.015	0.163
	X→M3→Y	0.044	0.000	0.122

Model 3 Partially verified

Note: B = unstandardized beta; S.E. = standard error; \*\*\*-significant at the 0.01 level (2-tailed); \*\*-significant at 0.05 level (2-tailed); \*-significant at 0.1 level (2-tailed).

375 **5. Discussion**

376 In terms of verification results, final multiple mediation models are summarized in Figure 6. Neighbor  
377 support, PE&R-F, and accessibility to facilities have significant impacts on the overall QoL of the  
378 elderly. As shown in Figure 6, multiple mediation effects vary with dependent factors of neighborhood  
379 environment, thus Phy-H, Psy-H and SR play different roles as mediators in influence relationships.



380

381

Figure 6 Summary of verified multiple mediation models

382 5.1. Mediation Effects between Neighbor Support and the Overall QoL of the Elderly

383 Neighbor support is a central component of social environment within the neighborhood, generally  
384 referring to the support or help that residents obtain from neighbors formally or informally (Chaudhury  
385 et al., 2012). The formal aspect of neighbor support is the support obtained from professional  
386 institutions or formal teams of neighbors regularly, such as personal care assistance (bathing, canteen,  
387 etc.), the peer-supporting group for the elderly, teams of physical activities & square dancing, etc.  
388 Besides, older adults also receive unscheduled helpfulness and assistance freely in daily life within their  
389 private social network, such as helps in an emergency or casual communication when neighbors  
390 encounter older adults (Greenfield, 2016). Figure 7 shows two examples of formal and informal support  
391 within the neighborhood. Neighbor support has been proved to remarkably impact the overall QoL of  
392 the elderly (Tiraphat et al., 2017). It is critical to enhance neighbor support of older adults for effectively  
393 improving their overall QoL.



(a) Community canteen for the elderly

Source [https://www.thepaper.cn/newsDetail\\_forward\\_8174811](https://www.thepaper.cn/newsDetail_forward_8174811)



(b) Casual chatting with neighbors

Source: shot in Fuqiangxincun, Changzhou

394

395 Figure 7 Examples of formal and informal support within the neighborhood

396 As shown in model 1 (Figure 6(a)), only the mediation effect of Psy-H works actually, indicating  
397 neighbor support can enhance the overall QoL of the elderly indirectly by affecting their Psy-H. The  
398 formal neighbor support (like interest groups or activity teams) provide suitable opportunities for older  
399 adults to participate in activities related to their hobbies, and also guarantees necessary peer supports  
400 and communications with neighbors. Moreover, the informal neighbor supports help older adults deal  
401 with issues that occasionally happened, like emergency conditions. Comparing with others, older adults

402 who can obtain neighbor support can have a higher level of Psy-H due to increment of psychological  
403 consolations, self-esteem, mutual respect and sense of safety (Jane M. Cramm, van Dijk, & Nieboer,  
404 2012). Eventually, the higher level of Psy-H of the elderly is able to cause a prominent increment of  
405 their overall QoL.

406 With enough neighbor support, older adults may avoid physical injuries and receive timely medical  
407 treatment after an outbreak of illness. And their SR with other people would be enhanced in the process  
408 of neighbor support. It is reasonable that neighbor support assists in improving Phy-H and SR of the  
409 elderly. Even so, according to the verification of multiple mediation effects, the other two assumed  
410 mediators do not contribute to the influence of neighbor support appreciably, meaning that the  
411 improvements of Psy-H and SR caused by neighbor support seem not critical to their overall QoL. In  
412 the interview with the elderly, they consider that the part of additional SR developed in processes of  
413 neighbor support only accounts for a minority of their whole SR. Hence, neighbor support is difficult  
414 to impact on their overall QoL through enhancing their SR. Similarly, the elderly think Phy-H relies  
415 more on their own physical condition and medical treatment. The enhancement of Phy-H by external  
416 support cannot provide actual changes to their perception of the overall QoL.

#### 417 *5.2. Multiple Mediation Effects between PE&R-F and the Overall QoL of the Elderly*

418 PE&R-F is the main kind of facility within the neighborhood, generally containing public facilities  
419 supporting the elderly to do physical exercises (fitness centers, swimming pools, playgrounds, etc.),  
420 facilities for recreation (activities centers, KTVs, chess rooms, community libraries, etc.) and multiple  
421 functional facilities (senior centers, community centers, etc.). Because PE&R-Fs provide various  
422 interesting activities or services, where elderly can explore more enjoyment. The close relationship  
423 between the availability of PE&R-F and overall QoL has been confirmed (Ruengtam, 2017).

424 Besides direct impacts, Figure 6(b) reveals PE&R-Fs also benefit the overall QoL of the elderly via  
425 improving their Psy-H and SR. Higher availability of PE&R-Fs provides more heterogeneous physical  
426 and recreational activities to the elderly. Psy-H can be promoted by easing depressive and negative



427 emotions, improving the quality of rest and sleep, and bringing pleasure to their life. Moreover, with  
428 higher availability of PE&R-Fs, the elderly would be more willing to spend much time in PE&R-Fs.  
429 They have more opportunities to get familiar with their neighbors and peers, and to increase social  
430 contact with other peoples. Thus, the SR of the elderly can be strengthened by the improvement of the  
431 availability of PE&R-Fs. Finally, the overall QoL of older adults benefits from the improvement of both  
432 Psy-H and SR.

433 Local availability of PE&R-Fs helps to prevent frailty of the elderly in their daily life within the  
434 neighborhood (Soma et al., 2017). Nevertheless, in the interview, older adults express their perception  
435 that PE&R-Fs are just leisure facilities rather than professional institutions for recuperation. Taking  
436 activities in PE&R-Fs only assist in enhancing their physical fitness slowly, rather than solving their  
437 physical issues fundamentally. In the opinion of the elderly, functions of PE&R-F do not mainly act on  
438 their Phy-H, consequently, it is hard to transfer the impact on Phy-H to their perception of the overall  
439 QoL.

### 440 *5.3. Multiple Mediation Effects between Accessibility to Facilities and the Overall QoL of the Elderly*

441 Accessibility to facilities is considered as a vital environmental factor to the elderly. Generally,  
442 accessibility is an essential indicator of resources to evaluate the difficulty level of assessing resources  
443 for users (Zhang, Li, Ahrentzen, & Zhang, 2019). Since the elderly have lower mobility and severer  
444 functional impairment, it is harder for the elderly to access facilities geographically than the youth.  
445 Higher accessibility to facilities usually means shorter distance, shorter travel time, and better road  
446 connectivity to arrive facilities provide more convenience and safety for the elderly in their daily life.  
447 Thus, accessibility to facilities has a positive impact on the quality of life of the elderly definitely  
448 (Fernández-Carro et al., 2015; Haugen, 2011).

449 Results of multiple mediation effects test (as shown in Figure 6(c)) reveal that both Psy-H and SR can  
450 be primary mediators to stimulate the influence of accessibility to facilities on the overall QoL.  
451 According to the elaboration of residential normalcy theory, when the elderly occupy residences where

452 their residential emotional experience, including comfort experience and mastery experience, is overall  
453 favorable or positive, the elderly can achieve residential normalcy (Golant, 2011). High accessibility to  
454 facilities brings a sense of familiarity and fair access to facilities psychologically, encouraging the  
455 elderly to obtain resources or participate in activities in facilities. Better accessibility can decrease the  
456 likelihood that older adults feel incompetent, then increases their residential mastery experience (Golant,  
457 2015). Furthermore, they can also build friendships and trust over time by sharing life experiences and  
458 stories in facilities (Yoo & Kim, 2017). As a result, accessibility can facilitate the Psy-H of the elderly  
459 by enhancing their positive feelings, and SR by activating their social contact. Then, these  
460 improvements of Psy-H and SR have a close relationship with the overall QoL.

461 Accessibility also affects the Phy-H of the elderly. The physical attribute of accessibility determines the  
462 physical burden of access to facilities on the elderly (Gao, Ahern, & Koshland, 2016). For instance,  
463 better road conditions and connectivity contribute to the reduction of bodily injuries on the elderly.  
464 Nevertheless, in fact, the elderly usually change their travel behavior under different conditions. When  
465 lower accessibility leads to worse mastery experience, more older adults will decide to reduce the  
466 frequency of facility usage. The elderly can avoid most of negative impacts of Phy-H caused by  
467 accessibility to facilities by adjusting their behavior.

#### 468 *5.4. Practical recommendations*

469 Multiple mediation effect models can offer valuable guidelines for future retrofits of age-friendly  
470 neighborhood environment. Neighbor support, PE&R-F, and accessibility to facilities should be paid  
471 more attention to retrofits of neighborhood environment. In order to maximize effects of neighborhood  
472 environmental retrofits, more actions are recommended to make multiple mediators to function.

473 Psy-H is the only mediator between neighbor support and the overall QoL of the elderly. It is very  
474 suggested to focus more on how to enhance Psy-H of the elderly by developing neighbor support. In  
475 the future, more types of formal support should be designed and provided to the elderly for upgrading

476 their psychological feelings. For instance, exciting peer groups or study classes are scheduled to  
477 encourage the elderly to pursue their hobbies and interests.

478 Moreover, retrofits of PE&R-Fs should take advantage of multiple mediation effects of Psy-H and SR.  
479 The functions of PE&R-Fs, which can facilitate Psy-H and SR rather than Phy-H, should be considered  
480 first. We suggest PE&R-F should customize its programs of physical exercise and entertainment to meet  
481 diverse requirements of older adults with interests and habits. Besides, more public spaces should be  
482 designed in PE&R-Fs for promoting social communication and relationship.

483 Similarly, accessibility to facilities also need to utilize mediators of Psy-H and SR, in order to achieve  
484 a most efficient retrofits of neighborhood environment. The land mix should be taken into consideration  
485 in the spatial allocation of various facilities with the neighborhood. Facilities with high-frequency usage  
486 of older adults should be allocated center areas of neighborhood to guarantee fair and high accessibility  
487 for most of the elderly. While facilities with relatively low-frequency usage of older adults can be  
488 located a long distance away from residences, then convenient travel modes should be provided to  
489 shorten the travel time, such as the little shuttle bus or free service of pick-up. Going to facilities with  
490 others by bus or pick-up is a good opportunity for older adults to build relationships.

## 491 **6. Conclusions**

492 Facing the severe issue of large-scale aging in place, QoL of community-dwelling older adults has raised  
493 public concerns. As the main component of living environment, the optimization of neighborhood  
494 environment is an appropriate way to improve QoL of the elderly explicitly. However, the exact  
495 influence mechanism of neighborhood environment on the QoL of the elderly is not clear enough. Based  
496 on the questionnaire survey and data analyses, multiple mediation models of neighborhood environment  
497 and QoL are established for community-dwelling older adults. The neighbor support, PE&R-F and  
498 accessibility to facilities are three critical factors of neighborhood environment, which proved to have  
499 significant impacts on the overall QoL of the elderly. This study contributes to explore diverse roles of  
500 Phy-H, Psy-H and SR in the influence mechanism. Psy-H and SR are multiple mediators through which

501 PE&R-F and accessibility to facilities influence the elderly's overall QoL indirectly. Nevertheless, only  
502 Psy-H can actually mediate the impact of neighbor support on the overall QoL of the elderly. Based on  
503 findings, useful recommendations and suggestions of retrofits of neighborhood environment have been  
504 developed for age-friendliness, by making maximum use of multiple mediation effects of Phy-H, Psy-  
505 H and SR.

506 Even though diverse roles as multiple mediators have been revealed, this study still has limitations. The  
507 literature proves that Phy-H, Psy-H and SR will have diverse contributions to the overall QoL of the  
508 elderly under different diseases. So, the multiple mediation effects for the elderly may change with  
509 different diseases. Based on the analysis of this study, future studies should consider more common  
510 geriatric diseases, such as diabetes, arthropathy, hypertension, and dementia.

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