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學術論著

The Role of Living Environment in Ageing and Happiness Perception among Older Adults in Taiwan*

居住環境對臺灣高齡者老化和幸福感之作用*

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ABSTRACT

The living environment plays a crucial role in the ageing and happiness perception of older adults. This study verifies the mutual influence of living environment evaluation and happiness perception in older adults living in Taiwan and discusses the heterogeneous variables involved. A total of 409 samples were used in a Bivariate Generalised Ordered Probit model. The findings demonstrate that the interactive relationship between the evaluation of the living environment of older adults and their psychological perception of happiness is significant. When the evaluated community is perceived as clean, interesting, and safe, its probability of being suitable for living increases, which highlights that interesting elements should be incorporated into the designs of living environments, while avoiding a monotonous and dull environment. Unsatisfactory quality of life and age explained the heterogeneity among older adults. Moreover, with progressing age, older adults' dependency on their existing residences increased. Therefore, to maintain consistency in older adults' daily lives, their retirement plans should include improving their current residences or moving them to better ones.

Key words: living environment, happiness perception, environmental press theory, sense of coherence

摘　要

居住環境對高齡者的老化與幸福感起著至關重要的作用。本研究驗證臺灣高齡者對居住環境的評價和幸福感間的相互影響關係，並討論異質性。本研究採用雙變量一般化依序Probit模型及409個樣本。研究發現，高齡者對居住環境的評價及幸福感知存在顯著的交互影響關係。當社區被認知為清潔、有趣、安全時，其適居的機率會增加，凸顯居住環境設計應該融入有趣的元素，避免單調與沉悶。不滿意的生活品質和年齡解釋了高齡者的異質性。隨著年齡增長，高齡者愈趨依賴既有之生活環境，為了維持日常生活的一致性感知，高齡者的退休計劃應納入改善或搬遷規劃。

關鍵詞：居住環境、幸福感知、環境壓力理論、一致性感知

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1. Introduction

Older adults are a group of individuals whose physical and mental condition changes rapidly. They are extremely vulnerable to permanent disabilities that result from accidents caused by the environment, which leads to them becoming bedridden and weakens them psychologically. Additionally, they are also a highly heterogeneous group, with various physical, mental, and social experiences. The interaction between humans and the environment is closely related (Lawton & Nahemow, 1973), and the health outcomes and quality of life brought about by the environment greatly affect the perception of happiness [see note at the end] among older adults, highlighting the need to focus on the interactive effects between the living environment and happiness among older adults (Chang, 2013; Lawton & Nahemow, 1973; Sivertsen et al., 2015). According to the WHO (2008), depression will become the first leading cause of disability worldwide by 2030, which strongly highlights the fact that attention to psychological health remains an urgent issue. Accordingly, this study explores the interactive impact between one's living environment and one's perception of happiness. The purpose is to propose strategies for older adults to be independent and active in their lives, as pictured by the WHO (2020).

The living environment significantly affects the life course and lifestyle coherence of an individual (Fernández-Ballesteros, 2001; Kaplan et al., 2015; Lawton & Nahemow, 1973; Wahl & Oswald, 2010). A safe, stable, and familiar living environment allows older adults to maintain their 'life habitus' (Bourdieu, 1990) and promotes 'home attachment' (Jirovec et al., 1985; Oswald & Wahl, 2005), making it more likely to be evaluated as suitable for long-term habitation by older adults.

The WHO (2020) advocates that every person should have the opportunity to live a long and healthy life. Environments have a significant influence on our behaviour, exposure to health risks (e.g., air pollution or violence), access to quality health and social care, and opportunities that come with aging (WHO, 2020). As the physical, functional, and psychological health of older adults declines over time (Hwang & Sim, 2021; Iwarsson et al., 2004; Sixsmith & Sixsmith, 2008), the range of activities and social support available to them may be limited, thereby affecting their quality of life. Thus, a high-quality living environment plays a crucial role in determining the active ageing opportunities and happiness perception of older adults (Iwarsson et al., 2007; Stephens et al., 2019; Zaheed et al., 2019).

A high-quality living environment instils confidence in older adults to engage in everyday activities, such as walking, going out, participating in sports, and relaxing (Figueiredo et al., 2023). Conversely, a poor and dangerous environment not only restricts older adults from going outside but also increases the likelihood of accidents that can impair their physical, functional, and mental health, ultimately reducing their happiness (De Mello et al., 2013; Gerber & Puehse, 2009; Ohrnberger et al., 2017). Thus, the design of the built environment plays a critical role in either enhancing or hindering the happiness of older adults. Indeed, a high-quality living environment is a positive preventative strategy for active ageing.

Happiness perception is complex and can be influenced by various personal factors, social interactions, and engagement with the physical environment. Prior studies have identified several determinants of happiness and their correlation with the quality of living environments. A poor living environment that lacks resources and is polluted can cause anxiety and a low quality of life, leading to the social isolation of older adults and the deterioration of their mental health (Ali & Khoja, 2019; Herbert & Molinsky, 2019). Mental frailty is considered the main risk factor for increasing mortality rates among older adults (Bruce et al., 1994).

The perception of the neighbourhood environment is the result of experiences gathered from engaging in various activities. Different neighbourhood environmental features and conditions, such as access to outdoor activities, may influence cognition through various mechanisms, thereby affecting happiness (Spence, 2020). Engaging in physically demanding activities, such as exercise, has been positively associated with greater happiness (McAuley et al., 2005). Thus, the living environment affects physical health and reduces anxiety and depression.

However, living environments consist of multiple dimensions. Most studies have focused on dimensions such as landscaping, available facilities, streets, and sidewalks. In addition, from the user's perspective, the evaluation of comprehensive neighbourhood environmental conditions and understanding of residential feelings by older adults cannot be overlooked. A previous study has used the term macro (neighbourhood) environmental conditions, including neighbourhood beauty, safety, interest level, and quietness, to discuss the impact of residential satisfaction of older urbanites (Jirovec et al., 1985). Nevertheless, perceptions of macro environmental conditions by older adults have not yet been fully explored. This is because evaluating a living environment involves personal emotions, experiences, feelings, and perceptions that must be simultaneously considered in the decision-making process to capture real behaviour and avoid biased model calibrations.

Additionally, older adults are not cognitively or physically homogeneous, and their heterogeneous features must be considered. Therefore, this study attempts to explore the mutual relationship between the living environment and happiness of older adults by considering the joint influence of endogeneity and heterogeneity using the bivariate generalised ordered probit (BGOP) model. The findings are expected to bridge the gap in the literature regarding the living neighbourhood environment and happiness perception of older adults.

The remainder of the paper is organised as follows. Section 2 reviews existing literature and presents the research framework. Section 3 describes the methods and variables used in the study. Section 4 presents the study findings, and Section 5 discusses the results. Section 6 presents the limitations, directions for future research, implications, and conclusions.

2. Literature Review

A report about Age-friendly Environments in Europe by the WHO (2018) mentions the need for building age-friendly environments that encourage a participatory approach to community engagement for older people and introduces bottom-up initiatives of gathering and sharing information that allow

older people to remain active and engaged in their communities so that they can continue important activities. In addition, the WHO (2022) advocates for the role of physical and social environments, apart from genes and personal characteristics, in determining lifelong health and well-being of individuals. Thus, it is vital to consider older adults' engagement in the assessment of their living environment.

The physical environment has been identified as a significant factor influencing the health and happiness of older adults in developed countries (Gobbens & Van Assen, 2018; van Hoof et al., 2021; Yen et al., 2009). Lower-quality environments are associated with a loss of physical function and disability, poorer self-reported health, reduced health-related quality of life, increased incidence of degenerative disease and incidence of falls, cardiovascular mortality, and reduced longevity (Bowling et al., 2006; Merkin et al., 2007; Zeng et al., 2010). Iwarsson et al. (2007) and Rubinstein & De Medeiros (2003) presented evidence to support the interrelationship between living environment and happiness. However, they argued that the available evidence, which was limited by the perceived conditions of the housing environment, was insufficient for the in-depth elucidation of this mutual relationship. Based on the environmental press theory by Lawton & Nahemow (1973), places should be designed to facilitate the maintenance of a dynamic and balanced interaction between a person's competencies and environmental press (Iwarsson et al., 2004; Iwarsson et al., 2007; Lawton & Nahemow, 1973). If the environmental pressure is too low, psychosocial and physical abilities may be impaired and prevent individuals from being inspired and meaningfully engaged with their living environment. These studies emphasise that all older adults are not frail and that designs for their residential environments should not be boring and uniform. Older adults need a diverse living environment that supports their life.

Familiar surroundings and place attachment allow people to easily determine how to gauge or resist risks and gain resources (Quinn et al., 2018; Scannell & Gifford, 2014). By staying in the same place, older adults can continue their habitus, maintain a sense of coherence, and reduce life pressures. Ageing at home and in the same neighbourhood facilitates a strong sense of attachment, identity, and familiarity (Burns et al., 2012; Kaplan et al., 2015), ultimately leading to positive perceptions, such as better mental happiness and increased quality of life (Iwarsson et al., 2004; Sixsmith & Sixsmith, 2008).

Happiness is an important indicator of physical health (Chiang & Lee, 2018; Hwang & Sim, 2021). For some people, low and deteriorating health and daily functions can lead to the development of unpleasant perceptions. A positive attitude towards ageing is related to increased quality of life in older adults (Zielińska-Więczkowska & Sas, 2020). There is also a substantial association between housing quality and health-related well-being (Evans, 1999; Evans et al., 2002; Krekel & MacKerron, 2020). The controllable environment represents a major source of happiness among older people, especially those who are frail or living alone (Rubinstein et al., 1992). Swenson (1998) mentioned that staying in one's home reduced the vulnerability of older adults, such as those who were widowed.

Figure 1 presents this paper's research framework and model. The right-hand side of the

figure displays both endogeneity variables. It is essential to consider the joint decisions and the corresponding factors in a super-ageing society to obtain the needs of older adults from effective modelling, and to simultaneously propose suitable living environmental suggestions to promote the mental health of older adults. Generally, only considering either living environments or happiness perception as a dependent variable may result in a loss of valuable information, as observed or unobserved factors are usually correlated to some degree. Moreover, not considering endogeneity may result in parameter overestimation problems. Additionally, the threshold functions of the BGOP model are calibrated during the model estimation process to condense model heterogeneity and provide more real insights into the living environment and happiness perception classification, which is one of the contributions of this study to the literature. The BGOP model is described in the Methods section given below.

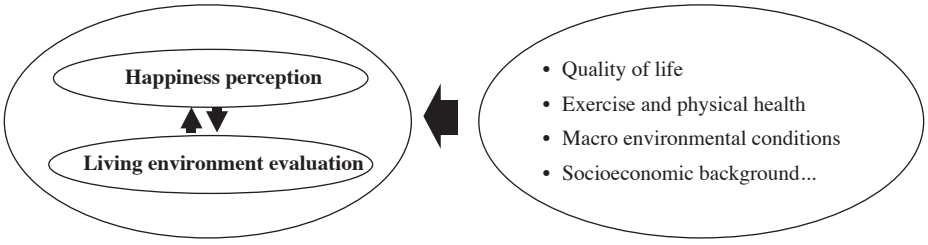

Figure 1. Subjective perceptions of older adults on living environment and happiness

Data Source: Author's own illustration

3. Materials and Methods

3.1 Hypotheses

Hypothesis 1

Based on the environmental press theory, the perception and physical aspects of the built environment influence the accessibility and willingness of older adults to venture outdoors, potentially impeding their ability and opportunities to engage in outdoor activities and, consequently, affecting their subjective happiness. Therefore, the first hypothesis of this study aims to examine the correlation between both indicators, highlighting the importance of well-designed built environments for ageing care.

Hypothesis 2

The lifestyle coherence of older adults highly affects their subjective happiness. Disorganization can significantly challenge their mental health. Thus, the second hypothesis of this study aims to examine the correlation between the quality of life and these factors in older adults.

Hypothesis 3

The third hypothesis of this study aims to examine the effects of age on living environmental preference. Older adults do not prefer to change their living environment owing to the high opportunity costs and slow adjustment (Helson, 1964; Lowe et al., 2022).

Hypothesis 4

The final hypothesis of this study aims to examine the effects of inspiring physical and supportive environments. An unsafe and unstimulating outdoor environment with low accessibility can adversely affect older adult's physical health. Well-designed residential environments play a crucial role in promoting their interaction with the external environment and enhancing their happiness.

3.2 Data

The data used in this analysis were taken from those published by Wu (2022). This survey was conducted nationally, in a face-to-face manner, with the interviewer visiting respondents' homes. It employed a stratified survey design using the multi-stage probability sampling method. The in-person survey approach was chosen to assist respondents with lower levels of education in completing the questionnaires. A total of 1,839 completed questionnaires were returned, generating a 50% completion rate. As this study focuses on the subjective indicator evaluation of living environment and happiness of older adults aged over 65 years, only samples over the age of 65 by the end of 2020 were used. A total of 409 samples were used for the subsequent BGOP model, after excluding those with incomplete responses.

3.3 Methods

In social sciences, decision-making is often not a singular process and is conducted through the combined effects of related factors, such as emotional perceptions. In particular, when evaluating whether the current living environment is suitable for lifelong residence, the decision is influenced by the happiness perception generated by long-term living experiences, leading to joint decision-making. Therefore, the BGOP model is highly suitable for explaining the decision-making process and endogeneity issues, as emphasis is placed on the fact that seemingly unrelated phenomena are, in essence, interconnected and should not be neglected (Chen, 2018; Chiou et al., 2013). In particular, it is important to pay attention to the quality of the residential environment in Taiwan, given its high-density population and housing prices, which result in a huge dilemma for improving living environments. Therefore, to avoid mental health problems caused by poor living conditions, focus should be placed on the above-mentioned decision-making process and endogeneity issues.

The BGOP model is specialised to address two joint-ordered dependent variables. A subjective indicator analysis at the individual level can be explained by the econometric structure of the BGOP model, which recognises the ordinal nature of the categories wherein subjective indicators are recorded (Chiou et al., 2013; Greene et al., 2008), facilitates flexibility in capturing the effects of explanatory variables on each ordinal category (Chiou et al., 2013), and allows for heterogeneity in the effects of contributing factors because of the moderating influence of unobserved factors (Chiou et al., 2013; Greene et al., 2008; Yamamoto & Shankar, 2004). As the model establishes a threshold function and contains a flexible threshold estimation (Chiou et al., 2013; Eluru et al., 2008), it assumes the error variations of the variable to be unknown and unequal (Chiou et al., 2013; Eluru et al., 2008;

Greene et al., 2008). Thus, the empirical results can illustrate the varying thresholds of both subjective indicators.

A feature of this method is that each individual is allowed to observe each category and cumulative probability density area separately. For example, the status of 'not being suitable to live in', 'neutral', and 'suitable to live in' depend on the life experiences and socioeconomic factors of older adults (Greene & Hensher, 2009). Thus, the BGOP model is a powerful tool to explain and explore heterogeneous behaviour (Chiou et al., 2013). The equations and calibrated coefficients of the BGOP model are described as follows.

The BGOP model is extended from the bivariate ordered probit (BOP) model and the mixed generalised ordered response logit model (Eluru et al., 2008). The equations of the BOP model, that is, Equations (1)–(4), are as follows:

$$environment^{*}_{i,j} = e, if\ \mu_{j,e-1} < Y^{*}_{i,j} \leq \mu_{j,e}, \quad (1)$$

$$happiness^{*}_{i,k} = h, if\ \mu_{k,h-1} < Y^{*}_{i,h} \leq \mu_{k,h}, \quad (2)$$

$$environment^{*}_{i,j} = \alpha'_{j} X_{i,j} + \varepsilon_{i,j}, \quad (3)$$

$$happiness^{*}_{i,k} = \alpha'_{k} X_{i,k} + \varepsilon_{i,k}, \quad (4)$$

where $environment^{*}_{i,j}$ and $happiness^{*}_{i,k}$ are the two order indicators of the unobservable i and k of an individual i;

k and j are the two ordinal category indicators, separately 1, 2, and 3;

α'_{j} and α'_{k} are the parameter vectors calibrated by $X_{i,j}$ and $X_{i,k}$;

$X_{i,j}$ and $X_{i,k}$ are the explanatory variable vectors of indicators j and k; and

$\varepsilon_{i,j}$ and $\varepsilon_{i,k}$ are the random error terms that capture all unobserved factors.

Equations (5)–(8) describe the functions of the BGOP model. As the thresholds are determined by an individual's preference/discrepancy, the approach is to assign subscript i to functions (1) and (2) and let $\mu_{j,e}$ and $\mu_{k,h}$ be $\tilde{\mu}_{i,j,e}$ and $\tilde{\mu}_{i,k,h}$ (Chen, 2022; Chiou et al., 2013; Savolainen et al., 2011); therefore, given the observed satisfaction characteristics, these cut-offs can change individually.

$$environment^{*}_{i,j} = e, if\ \tilde{\mu}_{i,j,e-1} < Y^{*}_{i,j} \leq \tilde{\mu}_{i,j,e}, \quad (5)$$

$$happy^{*}_{k,h} = h, if\ \tilde{\mu}_{i,k,h-1} < Y^{*}_{i,k} \leq \tilde{\mu}_{i,k,h}, \quad (6)$$

This study adopts a specific parametric function for each threshold to satisfy the following two ordering conditions: $\left(-\infty < \tilde{\mu}_{i,j,1} < \tilde{\mu}_{i,j,2} \ldots < \tilde{\mu}_{i,j,e-1} < \infty\right)$ and $\left(-\infty < \tilde{\mu}_{i,k,1} < \tilde{\mu}_{i,k,2} \ldots < \tilde{\mu}_{i,k,e-1} < \infty\right)$ for individual i. Thus, this study specifies them as

$$environment \text{ threshold: } \tilde{\mu}_{i,j,e} = \tilde{\mu}_{i,j,e-1} + exp(\beta_{i,e} + \zeta'_{i,e}\varphi_{i,e}), \quad (7)$$

happy threshold: $\tilde{\mu}_{i,k,h} = \tilde{\mu}_{i,k,h-1} + exp(\gamma_{i,h} + \xi'_{i,h}\varphi_{i,h})$, ... (8)

where $\varphi_{i,e}$ are $\varphi_{i,h}$ the variable vectors of the two indicators correlated with their thresholds $\tilde{\mu}_{i,j,e}$ and $\tilde{\mu}_{i,k,h}$, respectively;

$\zeta'_{i,e}$ are $\xi'_{i,h}$ the two endogenous variables' coefficients of correlation; $\beta_{i,e}$ and $\gamma_{i,h}$ are the parameters of the indicators' specific perception levels.

$$LL = \sum_i Ln\left\{\Phi_2\left(\tilde{\mu}_{i,j,e} - \alpha'_j X_{i,j}, \tilde{\mu}_{i,k,h} - \alpha'_k X_{i,k}; \rho\right) - \Phi_2\left(\tilde{\mu}_{i,j,e-1} - \alpha'_j X_{i,j}, \tilde{\mu}_{i.k,h} - \alpha'_k X_{i.k}; \rho\right)\right.$$
$$\left. - \Phi_2\left(\tilde{\mu}_{u,j,e} - \alpha'_j X_{i,j}, \tilde{\mu}_{i,k,h-1} - \alpha'_k X_{i,k}; \rho\right) + \Phi_2\left(\tilde{\mu}_{i,j,e-1} - \alpha'_j X_{i,j}, \tilde{\mu}_{i,k,h-1} - \alpha'_k X_{i,k}; \rho\right)\right\} \quad \text{.....(9)}$$

where $\Phi_2(\cdot)$ is the standard bivariate normal cumulative distribution function.

The maximum likelihood method was employed to estimate parameters $\alpha'_j, \alpha'_k, \tilde{\mu}_{i,j,e}$ $(\beta_{i,e}, \zeta'_{i,e})$ and $\tilde{\mu}_{i,k,h}$ $(\gamma_{i,h}, \xi'_{i,h})$, as well as the correlation coefficient ρ. The increase or decrease in the probability distribution of the two dependent variables depends on the positive and negative signs of the coefficients of α'_j and α'_k (Greene, 2003).

The calibrated coefficients of threshold variables $\tilde{\mu}_{i,j,e}$ $(\beta_{i,e}, \zeta'_{i,e})$ and $\tilde{\mu}_{i,k,h}$ $(\gamma_{i,h}, \xi'_{i,h})$ substitute into threshold functions (7) and (8), respectively, for re-evaluation. Leftward and rightward variations in the cut-off point can determine the increase or decrease in the probability areas of variables to compare with the original thresholds of the BOP model.

3.4 Variables and descriptive statistics

The dependent variables of this study include two ordered probit variables, namely, 'Do you think the environment around your home is suitable for a long-term stay?' and 'Are you happy at present?' A five-point ordinal scale was used for responding to each variable. For the first variable, answers ranged from 'I want to live in this place for a lifetime' (1 point) to 'This place is unsuitable for long stays' (5 points). Meanwhile, answers to the second variable ranged from 'very happy' (1 point) to 'deeply unhappy' (5 points).

The higher-order model, being limited in its ability to calibrate coefficients, is prone to failure in convergence. Therefore, this study combined the choices of 'I really want to live in this place for a lifetime' and 'I want to live in this place for a lifetime' into a single category, as the substantive significance of 'being very suitable to live in for a lifetime' is similar to that of 'being suitable to live in for a lifetime'. 'Neutral' was retained as 'neutral', whereas 'very unsuitable for long stays' and 'unsuitable for long stays' were combined into a single category. The same was true for happiness perception. After the combination, the three-point scores maintained the sequential characteristics of the original five-point score ordered probit for further verification of the interaction between the two variables. The probability area of suitability for a lifetime/happiness and unsuitable for a lifetime/unhappiness perception could still be analysed by calculating the probability area. Table 1 presents the descriptive statistics for the two dependent variables.

Table 1. Descriptive statistics for the dependent variables

Variable	Suitable to live in/ Happiness (%)	Neutral (%)	Unsuitable to live in/ Unhappiness (%)	Total samples (%)	P value
Living environment evaluation	331 (80.9)	67 (16.4)	11 (2.7)	409 (100)	<.0001
Happiness perception	153 (37.4)	231 (56.5)	25 (6.1)		

Data Source: Author's own compilation

Table 2 lists the results of the confirmatory factor analysis of the macro environmental conditions. The composite reliability (CR) was 0.728, the average variance extracted (AVE) was greater than 0.583, and the Cronbach's α was 0.776, thus confirming the validity and intrinsic consistency of the macro environmental condition variables.

Table 2. Reliability and validity of the indicators of the macro environmental conditions

Macro environmental conditions	SFL	S.E.	CR	AVE	Cronbach's α
Quiet to noisy	0.305	0.052	N/A		
Dirty to neat	0.613	0.041			
Boring to interesting	0.526	0.045			
Dangerous to safe	0.761	0.037			
Indifferent to warm	0.709	0.038			
			0.728	0.583	0.776

Note: SFL, Statistical Fault Localisation; S.E., Standard Error; CR, Composite Reliability; AVE, Average Variance Extracted; N/A, Not Estimated.

Data Source: Author's own compilation

The independent variables explain the factors that affect the evaluation of community living. This questionnaire included five conditions for the respondents to assess their living environments: quiet to noisy, dirty to neat, boring to interesting, dangerous to safe, and indifferent to warm. Taking the quiet to noisy consideration as an example, the description consisted of five points: very quiet, quiet, ordinary, noisy, and very noisy. The older adults could then choose their answers to describe their community most appropriately. This study focussed on the kinds of living environmental conditions that are more attractive to older adults. Therefore, the level of each option is ignored, and each group of evaluations of environmental perception is combined into categories, such as quiet, neutral, and

noisy, using categorical variables in the model and setting n-1 dummy variable into calibration.

Table 3 presents the operational definitions and descriptive statistics of the continuing explanatory variables used in this study. In the sample, 37.2% were men, and 62.8% were women. The average years of education were approximately 7.76, with approximately 37% having only 6 years of education and approximately 13% having no formal education. The average age was approximately 72.62 years, with age transformed using the natural logarithm in the model.

Table 3. Symbol and descriptive statistics of continuing independent variables

Variable	Symbol	Maximum	Minimum	Average (variation)
Education (years)	Ufifty	24	0	7.76 (5.07)
Age (years)	Iother	93	65	72.62 (6.28)

Data Source: Author's own compilation

Table 4 presents the operational definitions and descriptive statistics of the categorical explanatory variables used in this study. Categorical variables, such as marital status, are represented by four dummy variables in the model: single, married (living together), married (not living together), and widowed, with 'other status' being designated as the reference group. The same approach is applied to other categorical variables, where n-1 dummy variables are created based on the number of categories they possess, with the reference group being designated as the base. In terms of marital status, more than 50% of the older adults were married and living with their spouse, while over 30% were widowed. In addition, the questionnaire inquired about the residential area with the question: 'Do you consider the place where you currently live to be urban or rural?' The response options included (i) major urban areas, (ii) suburbs near major cities, (iii) small cities or towns, (iv) rural areas, and (v) independent farms. The variable 'suburban' in the dataset refers to suburbs near major cities, while 'Village' encompasses rural areas and independent farms. Regarding the living area, 18.33% of older adults resided in suburban areas, while approximately 24.69% lived in villages. 56.96% of older adults lived in major urban areas, small cities, or towns.

4. Empirical Results

Table 5 presents the results of the empirical model for BGOP. The evaluation of the living environment was significantly correlated with older adults' perception of happiness ($\rho = 0.248$). In other words, older adults who evaluated their living environment as more suitable for living a lifetime experienced greater happiness. This shows that the interactive relationship between the evaluation of the living environment of older adults and their psychological perception of happiness is significant.

Table 4. Symbol and descriptive statistics of categorical independent variables

Variable	Symbol	Descriptive statistic (%)	Operational definition
Marital status			**409 (100)**
Single	Single	12 (2.93)	Single=1; otherwise=0
Married and live together	Marry	220 (53.79)	Married and live together=1; otherwise=0
Married and do not live together	Smarry	22 (5.38)	Married and do not live together=1; otherwise=0
Widowed	Widow	125 (30.56)	Widowed=1; otherwise=0
Other status	Omarry	30 (7.33)	Reference group
Living area			**409 (100)**
Suburban	Subur	75 (18.33)	Suburban=1; otherwise=0
Village	Villa	101 (24.69)	Village=1; otherwise=0
Other areas	Rother	233 (56.96)	Reference group
Indicators of the macro environmental conditions			**409(100)**
Quiet	Quiet	310 (75.79)	Quiet=1; otherwise=0
Noisy	Noisy	55 (13.45)	Noisy=1; otherwise=0
Neutral	Neu1	44 (10.76)	Reference group
Dirty	Dirty	15 (3.67)	Dirty=1; otherwise=0
Neat	Neat	246 (60.15)	Neat=1; otherwise=0
Neutral	Neu2	148 (36.19)	Reference group
Boring	Boring	31 (7.58)	Boring=1; otherwise=0
Interesting	Interes	186 (45.48)	Interes=1; otherwise=0
Neutral	Neu3	192 (2.13)	Reference group
Dangerous	Danger	17 (4.16)	Dangerous=1; otherwise=0
Safe	Safe	306 (74.82)	Safe=1; otherwise =0
Neutral	Neu4	86 (21.03)	Reference group
Indifferent	Indiff	23 (5.62)	Indifferent=1; otherwise=0
Warm	Warm	290 (71.39)	Warm=1; otherwise=0
Neutral	Neu5	96 (23.47)	Reference group
Self-reported quality of life			**409 (100)**
Satisfied	Quality	127 (31.05)	Satisfied=1; otherwise=0
Unsatisfied	Uquality	20 (4.89)	Unsatisfied=1; otherwise=0
Neutral	Qneu	262 (64.06)	Reference group
Self-reported condition of health			**409 (100)**
Satisfied	Health	90 (22.00)	Satisfied=1; otherwise=0
Unsatisfied	Uhealth	74 (18.09)	Unsatisfied=1; otherwise=0
Neutral	Hneu	245 (59.90)	Reference group
Outdoor leisure and exercise			**409 (100)**
Frequently	Fsport	131 (32.03)	Frequently=1; otherwise=0
Other	Sother	278 (67.97)	Reference group
Individual income per month (Taiwan dollars)			**409 (100)**
More than fifty thousand	Ufifty	36 (8.80)	More than fifty thousand=1; otherwise=0
Less than fifty thousand	Iother	373 (91.20)	Reference group

Note: NT$50,000 is approximately US$1,785 based on the conversion rate of NT$28 to approximately US$1.

Data Source: Author's own compilation

Table 5. Bivariate generalised ordered probit (BGOP) model results

Variable	Environment		Happiness		$\tilde{\mu}_{j,e}$	$\tilde{\mu}_{k,h}$	
	^ *coeff.* (T value)		^ *coeff.* (T value)		^ *coeff.* (T value)	^ *coeff.* (T value)	
Const.	0.484 (1.786)		0.804 (5.122)	***	-4.943 (-1.830)	0.935 (15.485)	***
Quality	N/A		-0.971 (-6.266)	***	N/A	N/A	
Uquality	N/A		N/A		N/A	-0.487 (-4.419)	***
Qneu			*Reference*				
Health	N/A		-1.179 (-6.200)	***	N/A	N/A	
Uhealth	N/A		0.773 (4.419)	***	N/A	N/A	
Hneu			*Reference*				
Fsport	N/A		-0.306 (-2.104)	***	N/A	N/A	
Sother			*Reference*				
Macro environmental conditions							
Quiet	-0.199 (-0.825)		N/A		N/A	N/A	
Noisy	-0.030 (-0.102)		N/A		N/A	N/A	
Neu1			*Reference*				
Dirty	0.676 (1.921)		N/A		N/A	N/A	
Neat	-0.591 (-3.079)	***	N/A		N/A	N/A	
Neu2			*Reference*				
Boring	0.419 (1.442)		N/A		N/A	N/A	
Interes	-0.584 (-2.582)	***	N/A		N/A	N/A	
Neu3			*Reference*				
Danger	-0.433 (-1.123)		N/A		N/A	N/A	
Safe	-0.724 (-3.489)	***	N/A		N/A	N/A	
Neu4			*Reference*				
Indiff	0.075 (0.219)		N/A		N/A	N/A	

Table 5. Bivariate generalised ordered probit (BGOP) model results (continued)

Variable	Environment		Happiness		$\tilde{\mu}_{j,e}$		$\tilde{\mu}_{k,h}$
	^ *coeff.* (T value)		^ *coeff.* (T value)		^ *coeff.* (T value)		^ *coeff.* (T value)
Warm	-0.075 (0.365)		N/A		N/A		N/A
Neu5	*Reference*						
Living areas							
Subur	-0.101 (-0.488)		N/A		N/A		N/A
Villa	-3.324 (-3.325)	***	N/A		N/A		N/A
Urban/town/Rother	*Reference*						
Marital status							
Widow	-0.449 (-2.301)	***			N/A		N/A
Smarry	N/A		0.675 (2.232)	*	N/A		N/A
Single	N/A		-0.176 (-0.435)		N/A		N/A
Marry	N/A		-0.052 (-0.368)		N/A		N/A
Omarry	*Reference*						
Age	N/A		N/A		2.702 (1.961)	*	N/A
Socioeconomic status							
Edu	N/A		0.120 (0.869)		N/A		N/A
Income	-0.321 (-0.933)		N/A		N/A		N/A
Iother	*Reference*						
Sample sizes	409						
Statistics	ρ	0.248 (2.360)*					
	LL(O)	-575.336					
	LL(β)	-424.589					
	ρ^2	0.262					
	AIC	907.179					
	BIC	1023.576					
	CAIC	1,052.576					

Note 1. *, **, and *** indicate that the two-tailed test results are significant below the 5%, 1%, and 0.1% levels, respectively.

Note 2. 'NA' indicates that the variable is not included in the model

Data Source: Author's own compilation

4.1 Variables affecting living environments

The parameters for ‘environment’ and ‘happiness’ in Table 5 are the calibrated results of Equations (3) and (4), respectively, while the parameters for and are the calibrated results of equations (7) and (8), respectively. Additionally, the negative symbols of the parameters indicate a leftward shift in the ordered probit distribution, implying an expansion of the probability area of suitable living environments and a contraction of the probability area of unsuitable living environments. However, the actual area of the ordered probability is unknown; this was calculated further and presented in Table 6.

The empirical results of evaluations of living environments are presented as follows. With respect to the parameters that were important for assessing a community environment for older adults, significant variables were found to include perceptions of cleanliness (-0.591), interest (-0.584), and safety (-0.724). This indicates that when the community is evaluated as clean, interesting, and safe by older adults, the ordered probit distribution shifts to the left. The probability of being suitable for living a lifetime therein increases. These findings showed that clean, interesting, and safe designs were preferred by older adults, emphasising that an attractive and interesting neighbourhood environment was needed by older adults. An engaging living environment can encourage physical activity and improve psychological health among older adults.

Table 6. The probability of variables of the latent function

Variable	**Suitable to live in**	**Neutral**	**Unsuitable to live in**
Original living environment valuations	0.815	0.158	0.027
Neat	0.819	0.162	0.019
Interes	0.858	0.129	0.013
Safe	0.871	0.116	0.012
Widow	0.848	0.134	0.018
Villa	0.889	0.100	0.011
Variable	**Happiness**	**Neutral**	**Unhappiness**
Original happiness perceptions	0.375	0.565	0.060
Quality	0.497	0.480	0.023
Health	0.594	0.394	0.012
Unhealth	0.245	0.653	0.102
Fsport	0.404	0.549	0.048
Smarry	0.234	0.628	0.138

Data Source: Author’s own compilation

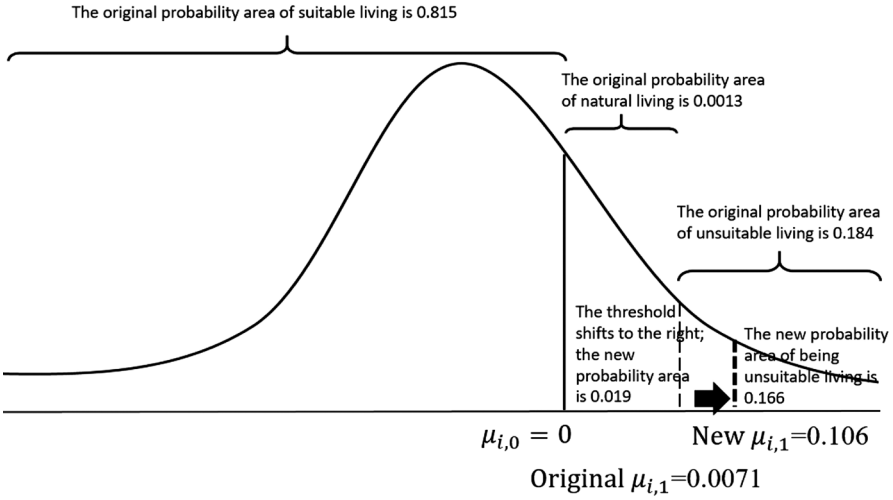

Figure 2. The concept of the heterogeneity of age

Data Source: Author's own illustration

Age was included in the threshold function (7) and yielded a significantly positive coefficient (2.702), which measures heterogeneity. This indicates that as the second threshold of the ordered probit model shifts to the right, the probability area for unsuitable living environments decreases (Figure 2). This result suggests that individuals have varying probabilities of unsuitable living environments based on their age, which is called heterogeneity. Furthermore, with progressing age, older adults' dependency on their existing residences increases and the probability of these living environments being unsuitable for living decreases, possibly due to the solidification of their life behaviour and habits, particularly with regards to residential inertia.

4.2 Variables affecting the perception of happiness

The primary factors affecting the perception of happiness among older adults were found to include 'satisfaction with the quality of life' (-0.971), 'satisfaction with physical health' (-1.179), and 'frequent outdoor leisure activities' (-0.306). These factors were found to significantly improve older adults' evaluation of the perceptions of their happiness. Unhealthiness was a significantly positive variable (0.773), implying that when the ordered probit distribution shifted to the right, the probability area of unhappiness increased and the probability area of happiness decreased. Hence, health is a crucial factor in assessing older adults' perceptions of happiness.

Furthermore, dissatisfaction with quality of life was included in the threshold function (8) and yielded a significantly negative coefficient (-0.487), which measures heterogeneity, indicating that when the second threshold of the ordered probit shifted to the left, the probability area of unhappiness increased (see Figure 3). This shows that the quality of life of older adults affects their perception of happiness, and dissatisfaction with quality of life is the main heterogeneous source of difference in their perception of happiness. Therefore, maintaining the quality of daily life of older adults is an important part of eldercare.

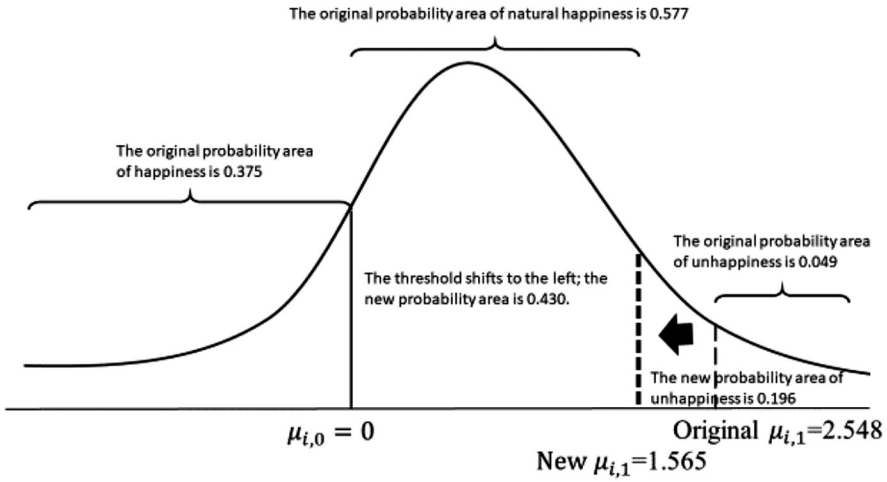

Figure 3. The heterogeneity of dissatisfaction with quality of life.

Data Source: Author's own illustration

4.3 Living areas and marital status

Living in rural areas was found to be a significantly negative variable (-3.324), indicating that the ordered probit distribution moved to the left. This means that compared with older adults living in large cities and small towns, those living in rural areas considered their area as suitable for long-term living. Widowed older adults (-0.449) had the highest probability of evaluating their living environment as being suitable for a lifetime, thereby decreasing the probability of the environment being unsuitable for living. In other words, the living environment is an extremely important source of support for widowed older adults. Compared with older adults belonging to other marital status, widowed older adults had a significantly higher probability of evaluating their neighbourhood environment as being suitable for living a lifetime, which is consistent with the findings of Swenson (1998).

4.4 Socioeconomic status

Education level was included as a factor affecting happiness perception based on previous studies which found a significant relationship between educational levels and happiness (Blanchflower & Oswald, 2004; Ferrer-iCarbonell, 2005; Frey & Stutzer, 2002). However, the results of this study showed that education level did not affect the happiness perception of older adults. Some studies have found a negative or no statistically significant relationship between happiness and education (Helliwell, 2003; Veenhoven, 2010). These findings confirm that the empirical relationship is not stable between education and happiness, probably due to factors such as data quality, age stages, and economic development level of countries.

Income was included as a factor to determine whether the present living environment was suitable for lifelong residence, but the result was not significant in this empirical model. Newman (2003) showed that the number of unmet needs for dwelling modification increased as income decreased, but the regression-adjusted result was not statistically significant, which is consistent with our finding.

4.5 Probability

Table 6 presents the probability of significant variables in latent functions. It demonstrates that a neighbourhood's atmosphere that provides cleanliness, interest, and safety leads older adults to have a higher probability of evaluating their living environment as being suitable for living for a lifetime. Both being widowed and living in rural areas increased older adults' probability of evaluating their present living place as being suitable for living for a lifetime, compared with the original probability. Satisfaction with quality of life, physical health, and frequent outdoor leisure activities among older adults demonstrated a high probability area, with the perception of happiness being higher than that in the original. Conversely, unhealthiness and being married but living separately showed a high probability area, with the perception of happiness being lower than that in the original high probability area with the perception of happiness.

5. Discussion

This section discusses the critical determinants of living environment in ageing and happiness perceptions of older adults based on the empirical results, including the implications of the significant heterogeneity variables.

Cleanliness, interest, and safety characteristics were verified by the empirical results, which highlight that the residential environment of older adults should not be boring and uniform. Creating inspiring physical environments and supporting older adults to access these environments are vital considerations for designing the living environment. In particular, as some older adults have declined functional capacities, residential environment designs are important for their sensory comfort and to encourage them to access the external environment (Yen et al., 2009). Even if older adults have a luxurious and comfortable indoor residential environment, an unsafe and dirty outdoor environment with low accessibility can harm their physical health and cause psychological problems.

Sharifian et al. (2020) demonstrated that neighbourhood characteristics could be targeted for intervention in improving the mental and cognitive health outcomes in older adults. Unfriendly living environments lead to older adults being nervous about going outside and losing their intention to do so. The health risks of environmental exposure, such as air pollution (Krieger & Higgins, 2002; Manisalidis et al., 2020), also result in older adults not wanting to go outside. The macro-environment conditions must address the aesthetics, interest level, maintenance, safety, and tidiness of the neighbourhood. A safe environment is a basic necessity for humans, particularly for older adults. A clean, interesting, and safe environment is conducive to the maintenance of high environmental

evaluation and psychological happiness for older adults. The neighbourhood designs of residential communities for older adults lacked diversity and flexibility in the past, resulting in monotonous designs. However, our finding shows that when older adults evaluate communities as being interesting, the probability of these communities being suitable for long-term living increases significantly, indicating that an attractive and interesting neighbourhood environment is needed for ageing people. Interesting and pleasant features attract and gain a high positive evaluation among older adults, highlighting that soft fascination elements (Kaplan & Kaplan, 1989) are required in neighbourhood environments.

Outdoor activities play a prominent role in maintaining the health of older adults (Zheng & Yang, 2019). Recreational activities, sports, and exercise are correlated with more happiness and meaningfulness than with passive leisure, such as screen time (Yamashita et al., 2018). Frequent outdoor activities promote positive social interactions and reduce stress, depression, and loneliness (Gardiner et al., 2018; Kim et al., 2014; Paggi et al., 2016), as well as improve older adults' overall health and happiness. However, the present housing design often consists of thresholds and many stairs. This makes them unsuitable for individuals with impaired mobility (Pynoos et al., 2010), which leads to a deterioration in their health, quality of life, and happiness because they are excluded from these environments. The findings of this study highlight that outdoor activities support the happiness perceptions of older adults; however, they need a supporting neighbourhood environment to remain happy. This result confirms that well-designed neighbourhood environments are important for active ageing.

More importantly, the empirical model shows that age is a source of heterogeneity in the older adults' evaluation of their living environments. As shown in Figure 2, the probability that older adults consider a living environment to be suitable for living for a lifetime is 0.815, while the probability that they consider a living environment to be unsuitable is 0.184. The older the age (coefficient positive, let the second threshold shift to the right), the more likely it is that older adults' evaluations of unsuitability significantly decrease to 0.106. This heterogeneity further confirms that older adults are dependent on their existing environment and have a high preference for ageing in the same place. Clearly, their retirement plans should include consideration for their living environments, which can either be moved or improved, all of which should be considered as early as possible to maintain a perception of consistent daily life and happiness among older adults.

Quality of life is a subjective indicator determined by an individual's life experiences and other factors, which is often used to assess their subjective happiness (Degges-White & Stoltz, 2015; Rondón García & Ramírez Navarrro, 2018; Sabbah et al., 2003). This study's findings demonstrate that individuals who frequently participate in outdoor activities, have good physical health, and are satisfied with their quality of life have a significantly positive perception of happiness.

A crucial finding in this research is that 'dissatisfied quality of life' is a main factor in the heterogeneity that affects the happiness perception of older adults (Figure 3). When older adults reported dissatisfaction with their quality of life, the original probability field of their unhappiness

increased from 0.049 to 0.196, indicating that 'dissatisfied quality of life' leads to a high probability of perceived unpleasantness (second threshold shifts to the left).

These findings imply that quality of life is a critical factor influencing the happiness perception of older adults, and a good neighbourhood environment that excludes the possibility of shifting from familiar surroundings is necessary to maintain their quality of life. This can help reduce negative health issues and prevent the breakdown of social networks, ultimately preventing mental frailty.

Padeiro et al. (2022) studied the relationship between neighbourhood characteristics and the well-being of older adults living in urban areas. Their findings indicated that the presence and availability of natural areas, adequate street furniture (physical environment), a good transit system, and local services (service environment) significantly affected older adults' happiness. A sense of community (social environment) was found to compensate for adverse living conditions and regional social deprivation. Krishnappa et al. (2021) found that primary care that provides essential services can bridge this urban–rural divide and improve quality of life of older individuals in rural areas of south India. Baernholdt et al. (2012) suggested that rural older adults might be socially isolated. In rural areas, they may need interventions to maintain physical and mental health, strengthen social relationships, and increase their participation in the community. Even though many studies indicate that urban older adults have a better quality of life than rural older adults, this study's findings show that older adults who live in rural areas evaluated their living environments as suitable for lifelong habitation. Rural older adults in Taiwan often have a long-term living and family history in the same area because of their jobs. This explains why older adults are attached to their living environment in these areas.

Furthermore, Murgaš and Klobučník (2016) indicated that people living in rural areas had a higher quality of life. More green spaces in one's living environment are associated with better health (Hajrasoulih et al., 2018; Ulrich, 1983). People's exposure to nature is found to reduce stress (Chang et al., 2020; Kaplan & Kaplan, 1989; Ulrich, 1983). In summary, older adults living in rural areas can enjoy more green space, nature, and lower pollution morbidity rates, despite shortages of other resources. This finding shows that nature-related factors improve the quality of life for older adults living in rural areas compared with those living in other areas.

5.1 Practical Strategies

1. Empirical findings indicate a strong correlation between older adults' preference for their current living environment and their subjective well-being. It is recommended that future retirement planning for the upcoming older population should not only consider financial planning and living arrangements but also focus on the quality of the living environment and available resources. If the living environment is extremely unfavourable, relocation should be considered as early as possible to prevent unforeseen incidents and maintain good physical and mental health. Therefore, the ongoing government initiatives for housing exchanges among older adults appears to be necessary.

2. Older adults attach great importance to the safety and appeal of their living environment. Existing residential settings should use resources more efficiently to make them more senior-friendly and attractive. Currently, government policies offer subsidies to senior citizens for retrofitting their older homes with senior-friendly facilities. It is recommended that government policies increase subsidies for communities to establish senior-friendly facilities, thus promptly improving the macro environmental conditions and making living environments more senior-friendly, especially concerning community activities.
3. Older adults often face limitations in physical activity and may experience a decline in sensory abilities, making it challenging for them to respond effectively to environmental hazards, such as accidents; dangerous situations, like robberies; and uneven sidewalks. The high cost associated with relocating or improving their immediate surroundings poses a significant barrier for most older adults. Therefore, public spaces in residential communities or semi-public areas within communities may require government subsidies and collaboration with property management companies to apply for grants aimed at enhancing safety and the overall quality of residential environments. This provides substantial assistance in ensuring a safe and conducive living environment for all community residents while simultaneously increasing their happiness, which is beneficial for fostering their independence and ability to lead active lives.

The empirical data in this study did not cover the housing component. The interior of the residence has clear private domain characteristics, and its design is highly related to personal preferences, which cannot be easily accessed with public resources. However, as Taiwan is a country with high homeownership rates, the interior of residences cannot be overlooked. Thus, the empirical results of the macro environment conditions were used as a reference for the interior design of residences, providing a general direction for housing design recommendations. The highly attractive characteristics for older adults include safety, cleanliness, and interesting elements. Therefore, equal attention should be paid to the safety design of the interior environment for older adults, which includes activity space safety and anti-theft measures (Kaplan et al., 2015; Krieger & Higgins, 2002; Lawton, 1980; Mulliner et al., 2020). Cleanliness includes avoiding complex traffic flows or cable leakage that may cause falling accidents (Howell, 1980). Interesting elements include the introduction of captivating designs to the indoor space, such as plants and fascinating elements. Therefore, the healing concept has been recommended to be introduced into housing design in recent years, with the aim of improving the monotonous indoor living environment (Wahl & Weisman, 2003).

6. Conclusions and Limitations

This study has made a significant contribution to the existing literature by focussing on how older adults' living environments significantly influence their perception of happiness. It is important to emphasise that the planning of elderly care environments should be given priority and incorporated

into retirement plans. This is because it will have a crucial impact on the mobility, disability, and even the perception of happiness of older adults, and is an important public health policy for promoting the health of the super-aging population. In particular, happiness is significantly affected by quality of life. Additionally, the frequency of outdoor activities significantly affects older adults' perception of happiness, namely, maintaining physical bodily functions, perceiving the surrounding greenery, and fatigue recovery, which is indispensable in well-building environments. Moreover, neighbourhood environmental factors, including cleanliness, interest, and safety, significantly affect older adults' evaluations of their living environment. Thus, meaningful, inspiring designs are beneficial for practicing ageing in place.

This study also fills the research gap in terms of heterogeneity among older adults. Dissatisfaction with quality of life is the main heterogeneous factor affecting older adults' happiness perceptions and living environment evaluations. This result highlights the fact that quality of life is an important factor in maintaining older adults' perception of happiness and that happiness perception can prevent the deterioration of psychological health. This is the main reason that ageing in place in a high-quality environment is both desirable for older adults and an important intervention for maintaining their overall well-being.

Age is another notable heterogeneous variable, as older adults show a decreasing willingness to move from their present living environment over time because they tend to protect their habits and sense of coherence to these environments. Based on the model's results and person–environment fit theory (Lawton & Nahemow, 1973), uninteresting, monotonous, and inflexible environmental designs are unsuitable for older adults. Living environments should support human psychological health and inspire human activity.

Residential environment plays an important role in successful and active ageing during old age. Taiwan stands on the threshold of becoming a super-aged society. Older adults in Taiwan are highly inclined to live in their own residences, and better neighbourhood surroundings will promote their health and reduce the overall cost of care. However, as Taiwan constitutes a highly dense population contained within a small island, high housing prices and low retirement pensions are indeed major obstacles to improving the living environment. This dilemma emphasises once more the importance of planning the living environment.

However, this study had a few limitations. All indicators of living environments were not included in the questionnaire. More detailed surveys in the future regarding living environments could include aspects such as micro-substantive environmental barriers, environmental design atmosphere, and internal residential conditions for a comprehensive understanding of the quality of older adult living environments.

Continual improvements can be made to the computation program of BGOP to improve its operational efficiency, allowing for the calculation of 5-point ordered or even 7-point ordered responses. Finally, questionnaire designs in the future should avoid using ordinary options to address non-response issues or the addition of percentage level notes. For environmental-related questions,

specific aspects should be designated more clearly to obtain more specific answers. Moreover, in the future, questionnaire survey designs should incorporate measures to proactively prevent common method variance issues, thereby enhancing the analytical value of survey data.

To conclude, the above improvements, if implemented, would greatly benefit care plans, and consequently, would result in the improved implementation of care plans under a super-aged society.

Note

The definitions of happiness and well-being are indeed highly correlated; both concepts are similar and are derived from psychology. They refer to positive mental states, emotions, and feelings of satisfaction; it is not easy to distinguish between just feeling better emotionally or feeling better overall. Therefore, this study maintains the use of the term 'happiness', which aligns with the dependent variable of happiness perception most of the time. Occasionally, the term 'well-being' may be used as an alternative.

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