Physical Environment of Residential Aged Care Facilities in Northeast China

by

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ABSTRACT

The increasing number of "empty-nest elderly" has attracted much attention to the living environment of care facilities for, the elderly. For this reason, this research mainly studies and analyzes the living environments of elderly care facilities in China. With the increasing number of China's aging and self-care elderly people, the demand of residential aged care facilities (RACFs) is also growing in this country.

This study compares elderly care facilities in China and UK, with focus on the merits of some RACFs in the United Kingdom. In addition, this study also selected 305 elderly people in a city, and summarized the elements that encouragement the elderly residents' quality of life (QoL). Through the method of hierarchical coding associated with grounded theory, the relevant factors of the elderly resident's QoL and the living environment are summarized.

Yet, the RACFs are in short supply in China, and attention to this situation is insufficient. There are also problems regarding resource allocation. The system of elderly care facilities in UK is more rational organized with better caring facilities, which provides lessons for China. Drawing on the experience of the UK's provision of aged care facilities helps to explore and develop facilities that meet the needs of China's elderly care.

Three main elements that have influence on the elderly's QoL are: "What do they need; Why do they needed; and What choices are available for them" which can be approached through grounded theoretical research and analysis. The three factors play an central part in the QoL of the elderly and affect their choice behavior. In addition, the physical environment is one of the important influencing factors. The health of the elderly is poor, and any surrounding factors will affect the feeling of the elderly. Therefore, the elderly have higher requirements for RACFs.

The physical environments of the RACFs were found to be highly correlated with the indoor environmental quality (IEQ) rating, which includes acoustic, lighting, and thermal environment, and indoor air quality (IAQ). The survey found that IEQ ratings are affected by seasonality, with rating of bedrooms higher than that of activity rooms. Among them, the satisfaction threshold related to sound is higher in summer than in winter, while the satisfaction threshold related to lighting is less affected by the season.

The study of architectural composition, indoor building environment and residential satisfaction on the QoL of the elderly in the RACFs in the northeast China shows that IEQ and residential satisfaction RS as intermediary variables indirectly affect the effect

of AC building component on QoL. Meanwhile，the influences of building types, seasonal distribution and RACFs scale on IEQ were analyzed in the 34 RACFs of northeast China. The results have shown that despite the reconstruction of RACFs and seasonal distribution, the satisfaction of the participants have changed, while the scale of RACFs has less influence on the satisfaction.

Research into elderly residents' rating of acoustic comfort in an activity hall in a residential aged care facility in Harbin, China, showed that the elderly had a low satisfaction with the acoustic environment of the activity hall. As the sound pressure level (SPL) raised, the elderly's rating of their satisfaction with the acoustic environment declined. The elderly's satisfaction and preference for music sounds were higher than other sound types, such as chatting or machine noises. The satisfaction towards music can also decline due to certain factors, but was slower than other sound types.

Although the pension system has been established in China for a long time, improving the living environments of the elderly has not attracted attention, and the psychological factors of the elderly people are normally ignored due to the immature architectural understanding of the elderly. The devise of the living environment for the elderly people in China is not adequately sophisticated. The design of housing suitable for the elderly should attract social attention. In short, the investigation and analysis of this study have significance for the living environment of the elderly in China.

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LIST OF ACRONYMS

AC	Architectural Composition
AQ	Air Quality
Ave	Average Variation Extraction
CFA	Confirmatory Factor Analysis
CNCDs	Chronic Non-communicable Diseases
CR	Composition Reliability
IAQ	Indoor Air Quality
IE	Indoor Environment
IEQ	Indoor Environmental Quality
ITE	Indoor Thermal Environment
LAeq	A-weighted Equivalent Sound Pressure Level
MD	Macular Degeneration
NM	No Music
QoL	Quality of Life
RACFs	Residential Aged Care Facilities
RH	Relative Humidity
RS	Residential Satisfaction
RT	Reverberation Time
SPL	Sound Pressure Level
TC	Thermal Comfort
TE	Thermal Environment

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1. Introduction

1.1. Research Background

1.1.1. The Ageing Issues in China

Currently, the most significant social problem faced by China is the increasing proportion of the aging population, which may have profound impacts across all socioeconomic sectors. According to the criteria set up by the U.N., a person at the age of 65 or over is aged. When the aged population proportion rises to 7% or more of the total population of a nation, the society is defined as an ageing society, and this produces a series of new challenges to be faced by the public (He et al., 2016). In China, because of the shrinking family size and a growing number of people leaving home to big cities for employment, the elderly people are not able to receive traditional family care from their children (Peng & Wu, 2015). China is experiencing a rapid population aging period. While the demand for residential aged caring facilities is rising, the supply is deficient, and there are a lot of experiences that we can refer to and learn from other countries. The study regarding the requirement of elderly people in different areas in China is also inadequate. With the miniaturization decreasing size of households and the disintegration of multi-generation families, the pension resources have also changed accordingly (Wu et al., 2010).

At the same time, population aging shows significant regional imbalances in China. In the north part of China, where the temperature in winter can be considerably low, the residents suffer significant aging issues. Especially in Liaoning Province, where I am particularly interested in as the elderly residents living in these areas demand more due to the severe weather issues. According to the 6th National Population Census (2010), the proportion of the population over 65 was 14.08% of the total population. By the end of 2015, the residential population of the Province was 42.708 million, while the population of the elderly aged 60 or older was 8.79 million or 20.6% of the population, while 53.8% of the elderly lived in urban areas. It was estimated that the elder population would increase to 483 million in 2050 (Industry, 2019), making up 34.1% of the total population (as shown in Figure 1-1).

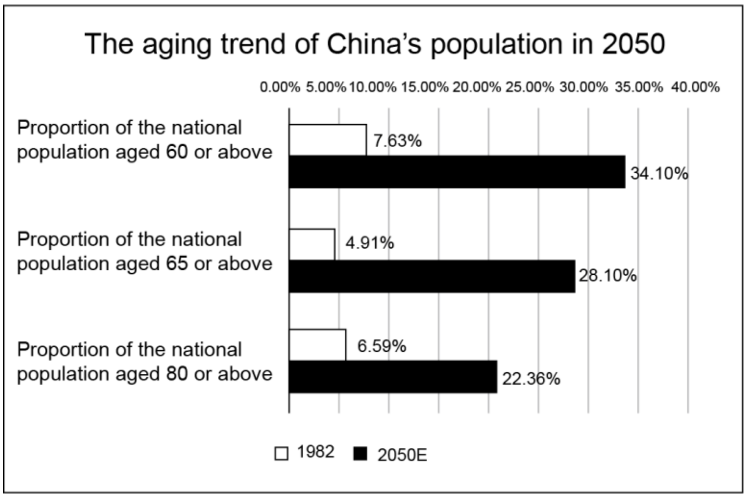


Figure 1-1. The aging trend of China's population in 2050 (sourced from Blue Book of Big Health)

According to the reports of the Sixth Census, the figure of the elderly who are aged over 60 in Jilin Province is 3.759 million, occupying 13.8% of the whole population. Based on the reports of the National Population Sample Survey of 2015, Changchun City, the capital of Jilin Province, has 828,200 people aged over 65, making up 11% of the total population. Heilongjiang's proportion of aging is similar, with 13.10% of people over the age of 60: the 2015 Census shows that the population of Heilongjiang's capital city Harbin is over 1.0420 million, making up 11% of the total population, and we will particularly conduct research in a Residential aged care facilities (RACF), which provide meals, accommodation, laundry, activity rooms, and medical services for the elderly in Harbin.

In RACFs, the mental and physical wellbeing of the elderly differs based on their different living environment. A study of the mental well-being of the elderly in the US showed that the percentage of the elderly with depression who live in the RACFs for the first year rose from 32.8% to 54.4% (Hoover et al., 2010). The elderly who live in the regular community normally have higher life contentment than those who live in RACFs. Generally speaking, a positive life orientation refers to selective and purposeful attention to positive aspects under any situation. However, this positive life orientation is not pervasive among the elderly living in RACFs, and even shows an exponential decline with aging (Eloranta et al., 2012), with a long-term impact on the length of life prognosis. A positive life orientation can solve a good survival prognosis, which is achieved by being independent of subjective health. Therefore, the increasing focus ought to be paid to the quality of life (QoL) for RACF residents. However, the lack of elderly care resources, including elderly professionals (aged care managers, nurses and physicians), and the lack of home care resources, make this a serious defiance to society.

China has a rapid-growing population of the elderly, which generates and will continue to generate various socioeconomic defiance to the existing health care system. Although it is incredible to systematically describe the many aging defiances that are emerging in China, more and more evidence shows that Chronic non-communicable diseases (CNCD), aged care and other issues mentioned above are China’s priorities for responding to various aging issues. The establishment of an atmosphere-oriented elderly care system and home care is considered to be one of the priorities of China's elderly healthcare reform. Practitioners must not only provide reasonable elderly care services to solve their life problems, but also focus on the psychological problems of modern elderly people to improve their quality of life. As mentioned earlier, the psychological problems of the elderly in RACFs have become more serious than before. Therefore, nowadays, the responsibilities of RACFs are not limited to protecting the lives of the elderly, and improving their happiness has also become a problem that needs to be solved.

1.1.2. Development of Pension Systems

In 1994, 10 government Ministries and Commissions, including the former State Planning Commission, made it clear that aging is an imperative aspect of China’s socialist cause, and put forward the principle of combining family pensions with social pensions (the family pension means the elderly people are supported by their children or family members, while the social pension refers to be supported by the governments) to expand social aged care services (Chen & Xing, 2016).

At the end of 1999, China’s elderly who aged over 60 made up more than 10% of the whole population and started an aging society, but before this, the state started to focus more on the issue of the aging population. The concept of "senior care" was first proposed in 1993, and has become pervasive among the public. In 2001, China included an aging clause for the first time in the national five-year plan, and the outline of the aging clause plan also entered the five-year normalization process. In 2006, eleven departments, such as the National Commission on Aging, clearly defined the concept of "senior service industry" for the first time, and proposed to " Establish family and community-based elderly care services and gradually improve services.” (Yang & Cheng, 2016).

In 2016, China incorporated the integration of medical and nursing care directly into the old-age care service system, and formed three types of old-age care methods: "home", "community" and "institution", with a social old-age care service system having an imperative content of "integrated medical care and care". In 2017, China added the content of " Establish a social environment and policy system to care for, filial and respect the elderly, and promoting the corporation of nursing and medical", and the policy system was further improved (S. C. o., 2017). In 2018, China clearly stated that it would no longer implement licensing for the establishment of institutions that collect, manage and allocate pension funds, which mean that the country has fully liberalized private business to enter the field of pension services. In November 2019, the State Council further adjusted their statements on the elderly care service system (ECSS), and made it clear that they should "complete a multi-level ECSS based on home and community-based, and fully developed institutions, and integrate the medical and nursing care." (G. O. o. t. S. C. o., 2019)

Therefore, modern elderly people, including elderly people living alone, should attract more attention from the state and society. Since 2001, the Chinese government has formulated various policies to improve the old-age service system and pension system. This reflects the national government’s attention to the aging of society and the care of the elderly’s lives, and to a certain extent. Certain related issues. However, some aspects still need to be improved. Active Aging

The idea of ‘active aging’ was proposed by the World Health Organization in 2002 and it has become a dominant theory and method to solve the problem of the worlds’ aging population. "Health, participation and security" is the main content of the positive aging concept, emphasizing the social participation, psychological health, and intergenerational support of the elderly as imperative guides to the social participation and management of the elderly (Rocío et al., 2013).

The concept of active aging emphasizes that the elderly are both beneficiaries of social development and contributors to, and participants in the society, affirming the social status of the elderly. Active aging has rich connotations, and applies to elderly individuals, as well as elderly groups and society. At the individual level, active aging not only requires the elderly to maintain psychological and physical health throughout their life cycle, but also to actively face their own elderly lives; The group level of active aging means that as a group, elderly people are the main resources of the family and society, and should make use of their continuing health to contribute to society. At the social level, active aging means that society can attend to the negative effects of aging, maintain sustainable, healthy and stable development, and adopt more positive attitudes, and positive policies towards the elderly (Rocío et al., 2013). These actions see the elderly as positive forces for social and economic development, and facilitate the protection, health, participation, and development of the elderly.

To implement active aging, it is indispensable to consider adaptability design. Adaptability design refers to the process of combining "adaptive" design with "humanized" design and realizing it in the process of space design. Aging is a common topic faced by many countries around the world. With the increasing age of populations, the needs of the elderly in terms of physiology, psychology and activities differ between age groups Indoor Environmental Quality (IEQ).

It is well established that a high quality of IEQ (including acoustic, lighting, thermal, and indoor air quality (IAQ)) inside a building is closely linked to the well-being of occupants or residents (Bluyssen & Cox, 2002). Keeping individuals fit and healthy, improving their living standards, and releasing pressure from life or work and the likelihood of injuries help achieve the benefits of a better IEQ. However, the links between IEQ and outcomes can be considerably complicated. There have been numerous studies reporting the issues caused by IEQ of buildings. Many studies have shown that occupants in senior residential care facilities can be affected physically and psychologically by a variety of indoor environmental parameters, such as humidity, temperature, ventilation, light level, and noise, etc. (Chiang et al., 2001). For example, if facilities and facility services were not adequately designed, they may not meet the thermal comfort (TC) needs of older people (Bluyssen & Cox, 2002); relative humidity (RH) can results in a negative impact on an indoor environment (IE) of the elderly (Chiang et al., 2001); Apart from outdoor air pollution, children and the elderly are more susceptible to indoor air pollution, and ventilation was found to reduce the impacts of pollutions on those people (Wargocki et al., 2000); excessive unwanted noise can be detrimental to senior health and impede recovering hearing loss of seniors in care facilities. Therefore, investigating the qualities of IEQ has always been of paramount importance and significance.

IEQ is seen as an imperative aspect of evaluating building performance. Overall, these ratings are based on four aspects, namely: noise, lighting, temperature, and IAQ. In the past, the ratings of indoor environmental conditions have been primarily based on objective technical criteria (Kang, 2007). However, the current IEQ tesmeasurements include both subjective and objective factors to enable comprehensive ratings

(Altomonte et al., 2013). Moreover, the importance of residential environmental satisfaction by discussing the effects on the overall resident satisfaction levels was emphasized. TC may be considered the most imperative and easiest parameter of IEQ. However, TC is on the basis of the individual thermal adaptation of occupants, which is known to be related to such factors as , time of the year, gender, age, race, climate, and geographic locations (Yang & Kang, 2005). A study (2017a) in a previous study on the acoustic comfort of underground commercial areas demonstrated that the sound pressure level (SPL) of background noise can affect the assessment of subjective acoustic comfort. In particular, thermal environment and indoor air quality (IAQ) are considered to be imperative factors for the health and comfort of elderly people.

The temperature levels during summers may be high, whereas the temperatures during the long winter season can be extremely low. The transitional seasons of spring and autumn are relatively short, with large differences between day- and night-time temperatures. Previous studies have reported that extreme cold or hot weather conditions have detrimental influences on public health (Curtis et al., 2017). This is particularly true for a vulnerable population like the elderly, who are more alive to extreme fluctuations in temperature. GB/T 50785–2012 (Li et al., 2013), which provides effective guidelines for the rating of indoor heat and humidity environments of civil buildings. These national standards for regulating the field of civil building construction were implemented on October 1, 2012. It was expected that these regulations would assist in providing comfortable indoor living environments for elderly residents, regardless of any extreme outdoor weather conditions, especially during the colder seasons in northeastern China.

In addition, it is broadly believed that climate change could potentially influence human health conditions in a diversity of ways in the future. As the number of thrilling weather events improved because of climate change, and as mentioned before, extreme weathers have a crucial impact on people's health. For example, the increased number and strength of heatwaves could reduce cold weather mortalities and alter the spread of virus-borne diseases (Kang & Zhang, 2010). In addition to weather issues, a previous study has revealed that some specific ambient environment factors, such as SPL, temperature rates, and lighting conditions, were correlated with the residents' standards of living (Yamazaki et al., 1998). In particular, high bedroom temperatures, low bedroom lighting conditions, and high SPL in general living areas were found to be linked to dissatisfaction and poor QoL of residents and noticeable effects on the residents' spirits (Barron & America, 1994). This indicates that the same IEQ criteria may result in fluctuations in residents' satisfaction levels with regard to different room types, space forms, or locations where the measurements were conduct on them, which would make spatial form another imperative aspect of residential care facilities.

Overall, the majority of the studies suggested that small-scale facilities (small RACFs are defined as facilities with less than 150 bed; medium RACFs are defined as facilities with between 151 and 300 beds; large RACFs are defined as facilities with between 301 and 500 beds; and super-large RACFs are defined as facilities with over 500 beds (50867-2013, 2013)). could provide better living standards, which would indirectly result in postponing the onset of self-care disabilities when compared with large-scale units (Zahorik & America, 2002). Meanwhile, another study illustrated that large-scale facilities were associated with increased incidence rates of hospitalization owing to mental health problems among elderly residents (Kang, 2007). To summarize, the presently available scales of RACFs should be considered as influential factors of the IEQ of RACFs.

1.2. Research Objectives

Based on the analysis of the Quality of Life (QoL) of the elderly and the current condition, I have the following objectives and research questions:

Research question 1: Compared with developed countries, China's facilities for the elderly are still relatively backward. What improvements are needed in China's facilities for the elderly?

Research question 2: What do Chinese seniors need in life? How will the surrounding environment affect its demand?

Research question 3: What is the indoor air quality of China's RACFs?

Research question 4: What will satisfy the elderly? What do they do?

Research question 5: Acoustic environment and its impact in public places.

Based on the five research questions，the five objectives were listed below：

Objective 1: To analyse possible planning and architectural strategies for the Chinese situation, by comparing facilities for the elderly in UK and China (Chapter4).

Objective 2: To understand the demand of senior citizens in China on the living environment and the role of the physical environment in satisfying the demands (Chapter 5).

Objective 3: To review IEQ of Residential Aged Care Facilities (RACFs) in Northern

China (Chapter6).

Objective 4: To analyze the elements of satisfactory living environments (the structural equation) and their effects on QoL (Chapter7).

Objective 5: To find out the acoustic environment in shared activity spaces in RACFs in China (Chapter8).

1.3. Research Methods

In this study, the main research methods are based on Grounded Theory and in-site investigation and the physical environment approaches, including assessment of the comfort levels of indoor physical environments, behavioral observation and observation of crowd density; and exploration of sound environment improvement.

A basic method for analyzing and optimizing the living environment of RACFs is proposed. The method plays a significant part in studying the desires of the elderly in caring facilities. This thesis clearly introduces the special built environment requirements for the elderly and their medical services, and helps architects, engineers and facility managers comprehend the requirements of the elderly during the design and operation stages of care facilities and the importance of improved built environments. This thesis also creates a podium for supplementary large-scale research, which may progress an overall physical and service environment model for RACFs.

1.4. Research Significance

(1) Research: This study attempts to explore older people’s needs for good residential living environments and create a ranking of different physical environmental needs among older people. This study is the first contribution to the knowledge of senior citizens’ perception of sheltered housing of Northeast China, and also provides the theoretical contribution regarding how to facilitate and improve the current residential aged caring facilities.

(2) Practice: The research studies the current situation and issues of RACFs in China. The findings can be used to guide design for the elderly in China to more satisfy the needs of the elderly in residential aged caring facilities environments.

(3）Policy: The results also contribute to management guidance for residential aged caring facilities in China, and provide a reference for improving relevant policies relating to senior citizens.

1.5. Structure of the Dissertation

Overall, the paper includes two major sections of original research work. The first section comprises Chapter 4 and Chapter 5, which can be summarized as a comparison of the quality of facilities for the elderly. Through the comparison of the living environment in China and UK in the forth chapter, the sixth chapter further summarizes the various factors affecting the QoL of the elderly.

The second part reports on specific research and analysis based on the content of the first part, and investigates and analyzes the situation of different elderly care facilities in northern China. Chapter 6, Chapter 7, and Chapter 8 of this part respectively introduce the quality of IEQ in RACFs in northern China; the structural equation of the living factors of RACFs and their inspiration on the QoL; and the acoustic environment of the shared space of the Harbin RACFs.

The structure of each chapter is as follows: Chapter 1 "Introduction" introduces the current situation of elderly care facilities. This chapter mainly summarizes the background of the urgent progress of China's current elderly care facilities, such as the problem of China's population aging, the growth of China's elderly care facilities, China's pension situation, China's active aging, IEQ, and Sheltered housing. In addition, at the ending part of this chapter, the research purpose, significance and structure of this article are also introduced.

Chapter 2, "Literature Review", first reviews previous studies on the deterioration of physical functions in the elderly and then considers research on physical environments, and describes QoL, well-being, and perception. Finally, the review summarizes some studies in China.

Chapter 3, "Methods", explains the various methods used in this research, including grounded theoretical analysis methods, field surveys through physical environment methods, and rating of indoor physical environment comfort.

Chapter 4, "Comparison of the development of Chinese and British pension facilities and its enlightenment to China", compares the differences between Chinese and British pension facilities. In this chapter, I first compare the differences between Chinese and British elderly care institutions, and then select representative elderly apartments in the UK for research, and provide useful information for the construction of elderly care institutions in China.

Chapter 5, " The Elderly's needs for QoL in Northern China ", discusses the analysis of the QoL of the elderly. Through grounded theoretical research and analysis, the factors that influence the QoL of the elderly can be identified as the three main categories: "What do they need; why do they need; and what choices are available to them". These three factors play a significant role in the QoL of the elderly and affect their choice behavior. The theory is based on practice, but to a certain extent, it can ensure the credibility and validity of the research. This chapter draws out the relative systematic influencing elements that influence the QoL of the elderly, and conducts a preliminary analysis of each influencing factor through classification and stratification methods.

Chapter 6, " Indoor Environmental Quality of Residential Aged Care Facilities in Northern China ", discusses the analysis of the IEQ of RACFs. This chapter explores the correlation between the sensitivity of the elderly and the IE of RACFs. Based on the physical environment survey, this study measured the sound, light and thermal environment of four RACFs in different seasons and different spaces, and conducted a questionnaire survey to estimate various aspects of the environment, including IAQ. This chapter also compares the environment of the activity room and the bedroom.

Chapter 7, " Structural equation model of factors affecting the quality of life (QoL) in RACFs ", discusses the analysis of living factors in elderly care facilities. This study evaluated the building composition, which is the structural features of buildings, and indoor physical environment and residents' satisfaction through a large-scale questionnaire survey of rural communities in Northeast China. From the survey results of 1457 participants, 50 items were selected for exploratory analysis, and the above four variables (IEQ, IAQ, AC, QoL) were summarized as the main components. The exploratory analysis includes the differences among: the four sizes of the selected RACFs; the different construction models; the differences between seasons of the year. A fifty-factor structural equation model was established to study the relationship between AC, RS, IEQ and QoL, and the influence of numerous factors on the QoL of the elderly. The results show that IEQ and RS, as intermediate variables, indirectly affect the influence of AC on QoL.

Chapter 8, "Acoustic Environment in Shared Activity Spaces in RACFs: A Case Study in Harbin, China" analyzes the acoustic environment of comprehensive activity space in RACFs in Harbin. The attention of this study is to evaluate the sound comfort of the elderly through field observation, sound measurement and questionnaire surveys in the activity room. The research also explored the impact of different types of music on personal satisfaction, emotions and behavioral responses, and tested the impact of specific environmental factors on people to precisely control the audiovisual variables in specific types of spaces.

Chapter 9, "Conclusion and Future Work", provides a comprehensive overview of the main findings of this research, and puts forward the deficiencies in the research and some tasks that have been completed.

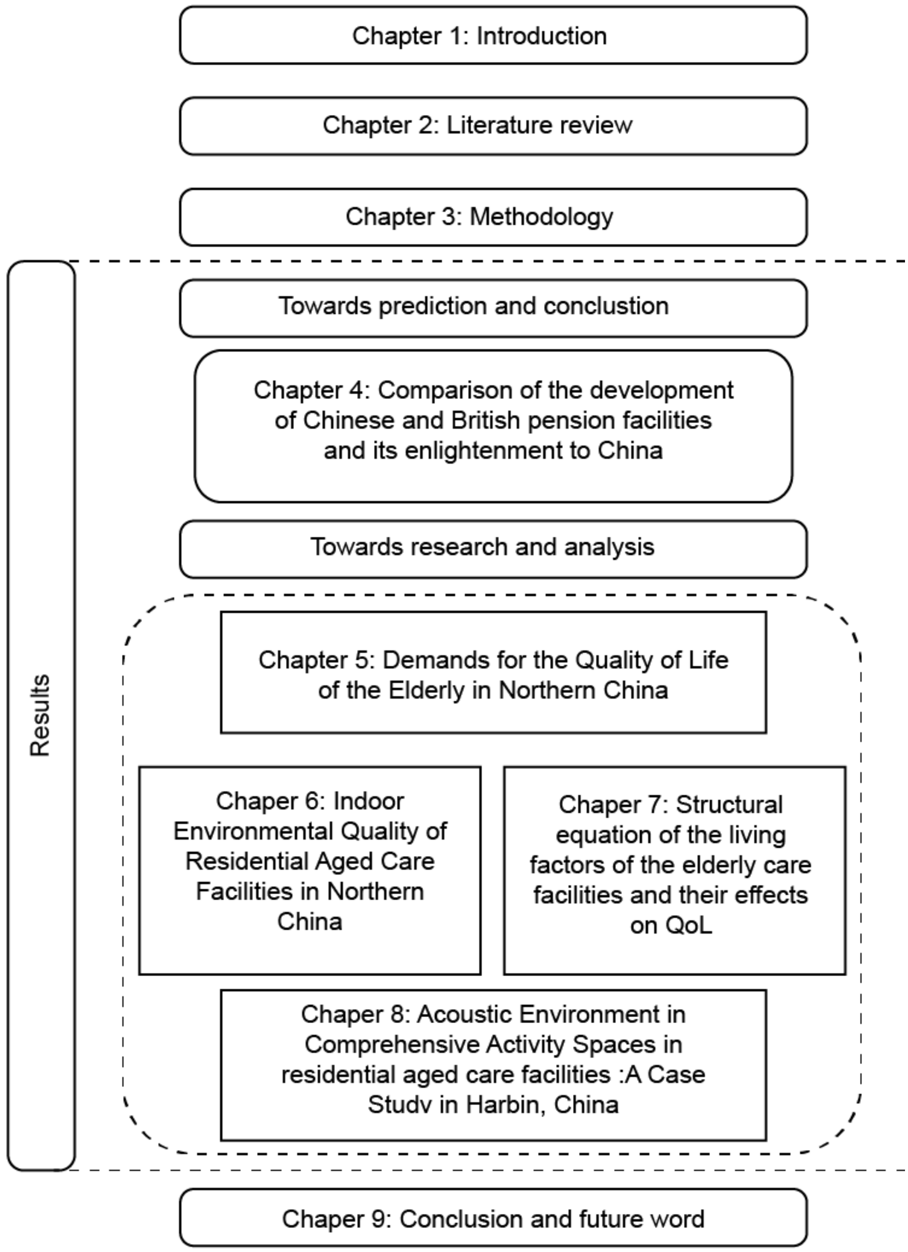


Figure 1-2 Overall thesis structure

2. Literature Review

With the rapid expansion of the economy, the living standards of the Chinese people are constantly improving. However, the term "empty nest elderly" (elderly people whose children no longer live with them) has been mentioned more and more frequently in recent decades. To have better living conditions, an increasing number of young people choose to work in larger cities and the number of elderly people staying at home alone is increasing in China. But the improvement of living environments for the elderly has not received much attention, and due to the lack of experience in building structure for the elderly, the psychological needs of the elderly are often overlooked; as people grow older, there are corresponding changes in both their psychology and physiology aspects. Housing for the elderly is no longer just to meet living requirements, but also needs to solve various security risks. Therefore, designing dwellings suitable for the elderly should receive social attention.

2.1 Age-related Physical Recession

2.1.1 CNCDs

CNCDs, are a general type of disease that requires long courses of treatment. CNCDs are difficult to treat, and even have unknown causes (Sankaran, 2012). According to the 2008 data from the United Nations Health Organization, the number of deaths caused by CNCDs worldwide reached 36 million, while in China, the percentage of the disease burden due to CNCDs is 82% (Peng et al., 2015).

As the current aging process continues to accelerate and people's lifestyles change, CNCDs have become imperative defiance facing contemporary public health. If CNCDs are not effectively treated, damages can be caused to organs such as the heart, brain, kidney, etc. Data show that there is a gradual upward trend in the proportion of deaths from CNCDs in China.

Elderly people with CNCDs need long-term medical services and support, and the burden of CNCDs and related medical expenses are increasing significantly. In China there is an active education program called Kang to make the general public aware of the harm of CNCDs and the importance of prevention and control strategies in China. This health guidance is an effective combination of preventive medicine and health intervention (Daar et al., 2009) which can help patients with CNCDs to fully realize the effectiveness of health behaviors to prevent and treat chronic diseases. Lack of exercise, obesity, high fat diet and smoking are the main causes of chronic diseases. Patients with CNCDs need health guidance, a standard diet, and active exercise. Suitable indoor environment is conducive to the elderly with CNCDs to maintain a relatively healthy state, conducive to the recovery of the disease.

2.1.2 Hearing

Aged-related hearing loss is common among the elderly. About 40 % of the total population globally has aged-related hearing loss over the age of 65 years (Zahnert, 2011). Hearing loss is also demonstrated to be connected to the human auditory cortex (Merabet & Leone, 2010), and drier and thinner skin of the external ear, narrowing of auditory opening, less resilient and thickened tympanic membrane and thicker and longer hair in the external ear canal can produce hearing loss of high-frequency sounds (Hoof et al., 2010). Age-interrelated hearing loss and cross-modal visual distractibility, which is a cross-modal distraction between the auditory and visual modalities regarding the framework of attention orienting and reorienting (Bendixen et al., 2010), were found to be related and that a reasonable sub-clinical hearing loss, which is a pervasive spectacle among the older people was found to affect the processing of visual-audio information. (Brennan et al., 2006) found that hearing loss in the elderly could reduce other sensory functions, such as eye sight. Age-related hearing decline was also found to affect people's perceptions of speech, especially when the background is noisy (Frisina & Frisina, 1997). Presbycusis is considered to be the most common sensory disorder in the elderly, affecting people over 75 years of age. In the United States, presbycusis affects more than 40% of people over the age of 75, and it is becoming more and more common as our society's aging problem gets worse. In 1995, the British National Hearing Impairment Study found that 20% of adults have a certain degree of hearing impairment (hearing threshold greater than 25 dB), and 75% of them are over 60 years old. Recent estimates indicate that by 2030, the number of seniors with severe hearing loss in the United States may increase to 35-40 million (Ciorba et al., 2012). A laboratory study in Japan (Sato, 2005) compared the scores of younger adults and older people in a speech recognition measurement and showed that older testers' scores were 25% lower than the younger adults and the consequence of this percentage is identical to the 5 dB(A) rise of peripheral noise (Sato, 2005).

The elderly with hearing loss are more likely to feel a lack of social participation

(Crews & Campbell, 2004). Hearing is demonstrated to be related to decay in the QoL among the elderly (Crews & Campbell, 2004), increase older people's cognitive load (cognitive theory utilizes evolutionary theory to the cognitive architecture of human and utilizes that architecture to create novel, instructional procedures) (Tun et al., 2009) and reduce their physical functioning.

2.1.3 Vision

Aging-related vision change is one of the most imperative body changes of the aging process, while their visual attention is more likely to be disturbed by irrelevant stimuli, and the flexibility of attention transfer becomes worse. Visual impairments stemming caused by biological aging are diverse, but mainly occurring in three aspects: first, the area of the visual field decreases with age; second, color discrimination decreases with age; and third, for the elderly, when they move from light to dim environment, their adaption to the dark can be impaired. Also, older people are found to need more light than younger people when conducting the same task. Many studies have confirmed that as the elderly population increases, the rate of eye diseases and blindness also increases. From the age of 40, which is the age that the presbyopia (a type of physiological insufficiency of accommodation due to the aging of eyes that lead to decreasing ability to focus clearly on close objects (Strenk et al., 2005) is most likely to occur, eye diseases have increased significantly, and more than half of blind people are over 65 years old. Common causes of blindness in the elderly in the United States are macular degeneration (MD) and glaucoma, cataracts, and diabetic retinopathy (People who have diabetes can have a type of eye disease called diabetic retinopathy, which happens when a high level of blood sugar causes damage to blood vessels in the retina) (DR) (Eichenbaum & Medicine, 2012).

A study in the Netherlands showed that among the elderly 65 years and older, the prevalence of blindness (visual acuity 50.05) was 2.4%, and the prevalence of low vision (0.05 visual acuity 50.3) was 7.8%. Most (79%) visually impaired people (visual acuity 50.3) are elderly people 65 years of age or older (Limburg et al., 2009). Due to the aging of the population, the number of elderly people with visual impairment will greatly increase in the next few decades. In the Netherlands, it is estimated that between 2005 and 2020, the proportion of elderly people with visual impairment increased by 18.7% (Limburg, 2007). The visual impairment will increase the burden on the elderly and restrict them in all aspects of life, which poses a potential threat to maintaining the independence of daily life (Participation of the elderly after vision loss).

Macular degeneration is the main cause of visual impairment in people over 65 years old, accounting for a third of the elderly blind, but ophthalmologists are powerless to cure it (Wang et al., 2016). Intraocular pressure increases producing progressive visual field loss and the incidence of glaucoma also increases. Cataracts are traditionally considered to be the main cause of poor vision in the elderly, and are still an imperative cause of blindness worldwide. More than one million people in the United States have crystal removal surgery every year. Damage to blood vessels in the retina is the cause of blindness in 10% of people over 65 years old.

Senile vision loss is the reduction of the ability to distinguish details of objects from a certain distance due to the aging of visual organs or eye diseases (Elliott et al., 1989). As the crystalline lens of the eyes hardens and the ciliary muscles weaken, the lack of elasticity makes it impossible to form an appropriate convexity when looking at close objects, reduces the refraction of the incident light, causes difficulty in focusing, and reduces the clarity of the retinal image resulting in long-sightedness. Hoof et al. (2010) also found that perceptions of fine details, color and depth become more difficult after the age of 70. Age-related vision loss can also affect older people's perceptions of and different requirements for, lighting conditions. So, we need to pay more attention to the lighting environment to satisfy the needs of the elderly.

2.1.4 Perceived Thermal Comfort

With aging, the ability to adapt body temperature and the circadian rhythms of body temperature and basal metabolism (Havenith, 2001) are affected. Havenith (2001) summarized body changes related to thermal perception, including reduced perspiration capacity; the decline of vascular responsiveness (broadly defined as the capacity of reaction of a blood vessel to a particular stimulus, and lower cardiovascular stability (the capacity of the cardiovascular system to stay stable).

Older people's skin is less sensitive to pain and temperature sensation than that of young people, their self-awareness of cold and heat is reduced, and they have delayed reactions to external temperature changes. Sometimes they need to be reminded of these changes. Holtzclaw (2004) found that elder people complain they feel cold regardless of their actual body temperatures are lower or not. The reason that the awareness of temperature changes is delayed is because of the neurosensory changes caused by the aging process. The elderly not only have decreased body temperature regulation functions, but also have limited tolerance to high and low-temperature environments. The main reasons are as follows: 1) Body temperature regulation involves almost all systems of the whole body. The natural decline of the functions of the various systems in the elderly produces resonance effects in the body), which affects the constant maintenance of body temperature. 2). They have hardened arteries, and at the same time, the reaction of the nervous system to temperature change is reduced causing heat loss at the surface and a reduction in the ability to maintain a constant temperature. 3) The reduction in heat dissipation function of the elderly is related to the reduction of body sweating and the weakening of the skin's blood vessel reflexes (Holowatz & Kenney, 2010).

2.1.5 Other Sensory Change

Hoof et al. (2010) summarized age-related taste and smell changes. The olfactory cells decline and there is a reduced number and size of taste buds, leading to decreased appetite which can be related to older people’s poor nutrition. The olfactory bulb is in the human forebrain, the function is to a percept of odors: Age-related olfactory changes are associated with the reduced number of cells in the nasal lining and the loss of cells in the olfactory bulb. Smell perception is demonstrated to decline significantly with aging. Memory: Generally speaking, almost 40% of people globally aged over 65 could experience certain forms of memory impairment, but there is less loss of meaning recognition than of mechanical memory. The memory capacity of the elderly tends to be affected by education level. Intelligence: Adult intelligence is divided into liquid and crystalline intelligence (Cebula et al., 2015). Liquid intelligence refers to abilities related to perceptual integration, recent memory, thinking agility, attention, reaction speed, etc. It declines with age, and the decline in old age is more obvious; crystalline intelligence refers to acquired knowledge, culture. The ability to accumulate experience, such as vocabulary, comprehension, common sense, etc., generally does not decrease with age, and may even improve. Crystalline intelligence tends not to decline until the age of 70, and the rate of decrease is slow (Cebula et al., 2015).

Emotional aspects: Due to subjective and objective reasons such as physiological aging, changes in social roles, decreased social interaction, and changes in psychological function, the elderly often exhibit negative emotional experiences and reactions, such as nervousness, fear, loneliness, feelings of uselessness and loss, and depression and anxiety (Greene et al., 1982). Feeling of loss: Due to changes in social and family roles, increased economic burdens, and other factors that cause disease distress, the elderly will feel lost due to psychological discomfort (Matt & Dean, 1993). Therefore, two emotions may appear: one is silent, and the expression is indifferent; the other is irritability and temper tantrums. Loneliness: The family is the basic unit of life for the elderly in China, and the elderly would feel lonely when they live alone while their children have their own homes (Yeh & Lo, 2004). Depression: After retirement, the chances of social contact are reduced, as the elderly are physically not able to hang out with friends any more sources of information are reduced, and communication barriers caused by aging such as loss of hearing or sight, or mobility problems can cause the elderly to feel depressed (Lynch et al., 1999). People are indifferent to them; do not have time to talk, and so on. Anxiety: Many elderly people are worried about getting sick, worrying about their ability to take care of themselves, and worrying about becoming an increasing burden on their children (Lowenstein & Gilbar, 2000). This kind of worry will increase with aging and disease, causing anxiety and fear in the elderly, expressed as coldness or impatience. Personality: With the aging process, people's personality characteristics are both sustained and stable side, as well as changing and fluctuating, and stability is more obvious than change when manifested as self-centeredness, stubbornness, conservatism, suspicion, and narrow-mindedness (Lee, 2001).

The elderly also have physical restrictions regarding mobility due to stiffness, arthritis, diseases of joints, liability to fall and break bones. With the need for convenient mobility, a requirement of a living environment emerged.

2.2 Physical Environments

2.2.1 Single-factor Studies

Thermal comfort is an imperative factor studied in multi-unit residential buildings. Acoustic and visual comfort appears less in single-factor research. Research on variables that affect specific aspects of comfort, including occupant characteristics (Indraganti et al., 2010), IEQ (Jin et al., 2010), and outdoor climate conditions (Wei et al., 2011) are single factor analysis One of the main goals. In addition, occupants' acceptability of comfort and the acceptable range of IE are another goal (Becker & Paduk, 2009).

This integration of subjective and objective data assists in assessing how specifically the outdoor climate conditions and IE relate to TC levels and it also avoids biases and subjective judgments that might arise from applying just subjective or just objective methods. On the other hand, the subjective and objective data collected by some studies at different times is another cause of inconsistency. Compared with other studies, collecting inconsistent data may be the root cause of inconsistent results. For example, the questionnaire does not clearly provide a report on the comfort level of the residential area during the survey period. In addition, the questionnaire is also limited by the respondents' understanding (Rowley, 2014).

Some single factors have been applied to studies that have only subjective methods, others are applied to only subjective research (Wei et al., 2011). However, some studies have shown that the reported TC level and occupants' perception in naturally ventilated buildings are not the same as those of models, such as PMV models, and adaptive PPD calculations (Cândido et al., 2011). PMV (Predicted Mean Vote) models was proposed models was proposed by Fanger in 1970s, the PMV model was developed on the basis of a climate simuation experimental study on thermal comfort model. It contains 4 environment variables (air temperature, humidity, wind speed and average temperature) and 2 human factors (metabolic rate and clothing thermal resinoise levels. Lastance) (Fanger, 1970). The PMV thermal comfort model is widely used to evaluate the indoor thermal comfort. The PMV model represents the majority of people feeling of thermal comfort in the same environment, but there is a physiological differences between people, the PMV model does not represent everyone's feelings. Therefore, Fanger proposed the PPD index to represent the percentage of people dissatisfied with the thermal environment.Thus, some researchers believe that it is best to combine subjective and objective ratings.

2.2.2 Indoor Acoustic Environment

Noise from drainage systems and neighbors are the two main sources of IE disquiet recognized in the works. Jeon et al. (2010) pointed out that the most unacceptable sound is floor influence sound generated by activities, and air-borne noise (such as musician's conversation) ranks second, the noise that has the least impact on people is the noise produced by drainage. However, the acoustic comfort of houses with balconies can be improved by reducing outdoor noise (Dahlan et al., 2009). Although affected by subjectivity, external views are still an imperative factor in visual comfort (Bennet & O'Brien, 2017). Studies have shown that the main cause of noise and discomfort is the noise produced by neighbors. This may be due to poor sound insulation of the walls or too dense occupants, causing noise to spread through the shared walls, windows, or floors.

Previous results have shown that when the signal-to-noise ratio exceeds 10 dB, the elderly will more easily understand people's voices. (Kameda & Sakamoto, 2014) An acoustic measurement result for an ordinary room shows that the correlation between the subjective survey results and the objective acoustic parameters is poor, and no reliable conclusions can be drawn. (Cirillo & Martellotta, 2003). The researcher measured the background noise level in five ordinary rooms and five bedrooms in an elderly care facility. The results show that the average background noise levels of ordinary rooms and bedrooms in the daytime are 55.3 dB(A) and 42.7 dB(A), respectively, while at night they are 32.2 dB(A) and 32.1 dB(A), respectively. They found that the peak sound levels were mainly caused by the violent impact of closing doors (such as closets) and the activities of residents and professional nursing staff. (van Hout et al., 2014). Another researcher conducted a survey of 207 hearing-impaired elderly people. They found that in a reverberant environment, the presence of background speakers greatly affected the voice communication of the elderly. (Davies et al., 2001) Their results show that the elderly in this situation will pay more attention to their own hearing loss, rather than the influence of external conditions on communication.

Previous references also had conflicting results when discussing noise levels. Lai et al. (2009) pointed out that when the noise exceeds 70 dB(A), its acceptance will be greatly reduced. Jeon et al. (2010) think this threshold is much lower. It should be noted that 80% of the people in the above report are not satisfied with the 43 dB(A) and 42 dB(A) airborne and drainage noise. In another study, Dahlan et al. (2009) pointed out that auditory discomfort did not change significantly with changes in noise level. The inconsistency of these studies may be caused by the different types of noise sources investigated. Lai et al. (2009) pointed out that residents may have great dissatisfaction with outdoor noise. The latter reported a lower discomfort threshold in the study, pointing out that occupants are less acceptable to outdoor noise sources than indoor noise sources.

The noise and loudness that people perceive may be different. Although weighted SPL is a good method for measuring the volume perceived by the human ear, research has found that it is not very useful for measuring low-frequency sounds (especially low-frequency sounds below 100 Hz) (Waye, 2011). It can minimize the impact of SPL above 60 dB(A) in people’s residential communities, but its use is restricted, such as those occupants exposed to the air noise (heating, air conditioning (HVAC) system), Ventilation and noise from trucks).

In some research projects, sounds were found to have different effects on different people. The acoustic rating could be affected by the source of the sound: for instance, a noisy background sound causes low acoustic satisfaction in a warehouse while natural sounds were demonstrated to have positive effects on occupants' relaxation in laboratory measurements (Mackrill et al., 2014). Among the various natural sounds, running water was demonstrated to be better than other sounds as the background sound for acoustic comfort in a university library (Yang & Moon, 2019). As well as natural sounds, music was found to have a positive influence on acoustic comfort levels.

Currently, there is much good research on the sound environment and there is some research on the impact of sound environment towards human activities, but there is a lack of research intended for the elderly and their living environments. Therefore, coupled with the characteristics of the life of the elderly and their particular needs, special acoustic measurement and research for the elderly have become another imperative aim of acoustic environment research.

2.2.3 Indoor Lighting Environment

The six main parameters of external vision, glare, lighting level, daylight, privacy and uniformity of lighting will affect the visual comfort of the room (Carlucci et al., 2015). A major contribution to these findings is the data collection and sampling gaps. In addition, due to the open windows in the study, this will cause a greater glare to the occupants.

The study found that people prefer lower illuminance levels than the recommended illuminance levels for residential areas (Holton & Reports, 2012). Lai et al. (2009) pointed out that in the case of insufficient illumination, such as rising from 10 lux to 50 lux, its acceptance is continuously improving. But the acceptance level remains basically unchanged after 50 lux, which shows that the lack of light is satisfied.

As people get older, they spend more time indoors, so indoor lighting conditions are very important. Good lighting is of great help to people's daily life. Indoor lighting should provide good working light and sufficient overall lighting. (Küller et al., 2006). The specific room should have corresponding lighting conditions. For people with hearing impairment, the lighting conditions of the home are also very important, because this can help them solve certain problems through vision, thereby making up for their hearing loss (Lin et al., 2004). A study on the relationship between indoor lighting and the quality of life of healthy elderly people shows that improving indoor lighting significantly improves the quality of life of healthy elderly people at home. However, a Norwegian study showed that the indoor lighting levels in the homes of people over 75 years old are far below the recommended level (Karyono et al., 2020).

The assessment of light levels can be taken in three aspects: horizontal illuminance; vertical illuminance; and color temperature. Birren (1979) showed that lighting can have an effect on peoples' perceptions and can reflect people's responses to the environment.

The indoor lighting environment has a significant influence on occupants' daily life and mood. The lighting environment has been demonstrated to have a vital positive impact on the well-being and health of people with dementia (Torrington & Tregenza, 2007). Indoor lighting conditions also have non-visual effects on people, with influence on human physiology and behavior: blue light especially affects people's circadian rhythm, mood and behavior (Webb, 2006), while light as radiation has an influence on human health (Longstreth et al., 1995).

The climatic conditions in Northeast China are relatively harsh, especially in winter. Due to the low latitude of the area and the short sunshine time in winter, the elderly here are easily affected by insufficient sunshine time. However, up to now, there is very little research on the sunshine here and its influence on the lives of the elderly. Therefore, this paper will explore this to fill the gap in this area.

2.2.4 Indoor Thermal Environment

Thermal comfort (TC) may also affect the comfort, health, and life of the elderly (Mendes et al., 2013). Thermal comfort is affected by many factors, including air temperature, surrounding environment, surface temperature, air movement, relative humidity, and air exchange (ventilation) rate (Ormandy & Ezratty, 2012). In addition, the researchers also found that there will be some uncommon groups of microorganisms that live indoors. And it is reported that factors such as temperature, relative humidity, ventilation, and density of occupants will affect the number and spread of certain pathogenic microorganisms. (Kembel et al., 2012). Insufficient air conditioning systems and low ventilation rates increase these risks (Wan et al., 2011).

Section 2.1.1 has shown that TC is the most widely studied aspect of comfort (Höppe, 2002). Similarly, the correlation between TC and indoor thermal environment

(ITE) (such as temperature, RH, and ventilation) has been evaluated by most studies (Azizpour, 2013). The predicted temperature of thermal neutrality and the suitable temperature range for optimal TC have been determined in many studies (Peeters et al., 2009) When the occupant feels neither cold nor warm, but a temperature that feels neutral heat, it is a neutral temperature (Wang et al., 2011). Dear section 3.1.1 (Leivo et al and Brager (1998) manifested that the value of neutral temperature tends to be closer to the average indoor temperature, and to a large extent depends on the average indoor temperature, which is caused by the occupants adapting to indoor conditions. However, the survey literature points out that indoor climate may play a more imperative role than we think.

The occupants may not always like the optimal temperature used to indicate TC, which is the neutral temperature (Brager et al., 2004). Compared with the neutral heat, the occupants prefer a warmer environment in the cold season. Results of the current review also promise this.

Another imperative determinant of TC is airspeed (Gou et al., 2018). The importance of humidity to TC has the opposite result in existing research reports (Wang et al., 2003). Non-thermal parameters have also been shown in the results of related studies to affect TC (Gou et al., 2018).

ISO 7730 can be applied to quantifying human TC and some thermal researchers have measured people's comfort to compare them with the ISO 7730 standard (Heidari & Sharples, 2002). Some studies of the thermal environment were conducted in only one season, but other researchers designed their research to make comparisons between different seasons (mainly to compare summer and winter). For research on neutral temperatures conducted in different seasons, neutral temperatures were found to have about 1℃ difference between short-term and long-term studies in both summer and winter.

Katafygiotou et al. (2014) investigated students' indoor TE in secondary schools in Cyprus and found that students were dissatisfied with the ITE of their school buildings. As well as field surveys in real building space, climate chambers were used in the thermal environment researches (Sollinger et al., 1993). It should be considered in combination with the physical and psychological characteristics of the elderly. At present, there is still a lack of research on the influencing factors of TC and ITE in China. This paper will determine the ITE and other environmental conditions suitable for the elderly based on the adaptability of the elderly to the indoor environment and other responses.

2.2.5 Indoor Air Quality

Many factors may affect health and quality of life, and people will have adverse reactions to pollutants. Although there is a lot of evidence that air pollutants, even at low concentrations, increase the risk of morbidity and death, and cause respiratory and cardiovascular diseases and cancer (Hou et al., 2014), but research on the elderly in this area is limited (Hurd, 1990).

Some research indicates that IAQ can have a significant influence on occupants' health, productivity, and comfort (Wargocki et al., 1999). A lot of research merely evaluated the resident's satisfaction level towards air quality, but did not actually understand the reasons for unsatisfaction. In that case, only a few researchers investigated how the satisfaction of IAQ changes as the environmental parameters change.

While we are concerned about the level of outdoor air pollution, the importance of indoor air quality (IAQ) is also increasing. It is estimated that in developed countries, people spend 80% to 90% of their time indoors every day (Kembel et al., 2012), and the elderly may spend more time indoors. When the elderly inhale indoor air pollutants for a long time (even if the concentration is very low), the harm they suffer is definitely higher than when they inhale outdoor pollutants (Corsi et al., 2012). Fine particles with a diameter of no more than 2.5 Im (PM2.5) can penetrate deep into the lung tissue, causing a decline in human lung function, and causing lung inflammation, respiratory symptoms, cardiovascular disease, and other related lung diseases (COPD) (Wang et al., 2006). Exposure to PM2.5 can also cause oxidative stress on human DNA (Sateri, 2004).

Persily (1997) examined the air exchange rate by measuring the density of CO_2, and found that the acceptance of air quality was positively correlated with the air exchange rate. Yet, other research showed that the reported satisfaction level of IAQ is inconsistent with measured CO_2 which might owe to the physical adaptability and behaviors of the residents or other factors discussed in section 3.1.1 (Leivo et al., 2016). According to the study on the subjective report of why people are unsatisfied with IAQ, odor, poor ventilation, and dust affect the satisfaction level of IAQ. Similar to TE, the parameters that are not the direct indicators of IAQ also influenced the residents' satisfaction level. Similarly, Gou et al. (2018) found that there is a positive relationship between IAQ satisfaction and air velocity and TE. As discussed above, it is possible that when both IAQ and air velocity are poor, the residents would feel uncomfortable.

2.2.6 The Effect of Outdoor Environments on Indoor Comfort

The outdoor environment for the elderly includes many aspects, including the negative factors in the environment, the availability of each element in the public environment(Carlsson, 2004), and the design issues and guidelines for the elderly environment (Shim et al., 2005). The current research on the outdoor environment of RACFs mainly focuses on patients with dementia and how to use gardening as a treatment method, and few studies have paid special attention to the views of the outdoor environment of the elderly in RACFs (Bengtsson & Carlsson, 2006).

Studies have indicated that residents usually relate their perceived indoor comfort with outdoor environment elements (Oseland, 1994). One of the primary factors that influence residents' perceived TE is outdoor climate. The literature regarding multi-unit residential buildings (MURBs) also indicated that outdoor environment elements can considerably influence occupants' perceived comfort in their dwelling communities. Except for outdoor environmental factors, the outdoor substructure is similarly observed as a substantial outdoor parameter that affects residents' comfort indoors. As well as other behavioral, psychological, and physiological adaptations, the adaptation of climate has inspired and facilitated an adaptive TC model development. Regarding naturally ventilated MURBs, outdoor environmental elements can have direct impacts on indoor thermal elements. In that case, the comfort levels of residents change the during daytime and the season of the year. In a warm climate, comparing with morning and night, the high temperature in the afternoon makes the residents feel uncomfortable (Dahlan et al., 2009). Li et al. (2018), on the other hand, discovered that the residents in a “severe cold” climate require a higher temperature than those who live in a cold climate, which has a higher outdoor temperature. This variation can be attributable to residents' personal preferences and adaptations. In addition, the residents’ financial situation would affect their perception of indoor temperature levels. For instance, the residents with lower income might use fewer heating systems to save expenditure, which caused different neutral temperatures and adaptions to similar outdoor environmental conditions (Indraganti & Rao, 2010).

2.2.7 The Effects of Occupant Characteristics

Several studies have shown that men and women have different perceptions of the indoor environment (Lai and Yik, 2007). Kim et al. (2013) indicated that females have greater sensitivity to office indoor environment quality than males for all measured elements, which include acoustic, TC, lighting, IAQ, office layout cleanliness, furnishings and maintenance. Personal data and length of stay in certain places should be taken into account in the research.

2.2.7.1 Age

The literature demonstrates contradictory results about the influence of age on occupants' comfort. Peng and Wu (2015) reported that compared with young residents, the elderly residents are more satisfied with their current indoor environmental conditions. This might be attributable to the elderly residents applying adaptive behaviors, such as adapting to uncomfortable indoor conditions by changing clothing more frequently than younger occupants, or because the houses were always cold or hot with limited ways of changing indoor conditions during the time that they grew up. Jonsson (2012), however, reported that the elderly occupants are less happy with the quality of the building which might be because they are more sensitive to environmental variation. Older occupants have a narrower TC range and a higher sensitivity to temperature declines compared to younger occupants.

2.2.7.2 Gender

Due to gender differences, the perception of changes in comfort mainly depends on observing the TC level. Female residents perceive higher temperatures as neutral than that of men and are willing to wear more clothes to feel warmer.

A woman has less chance to adapt to weather by perspiration because they have lower sweating rate than that of men, which considerably influences their TC level. Also, perspiration functions are also related to ages (Lee et al., 2016). The difference of time of residing also results in a difference in adaptability. For instance, Indraganti and Rao (2010) discovered that females were more satisfied and tolerant with the indoor residence environment which might due to the surveyed female residents had been in their residences for a longer period of time comparing with the male residents, which result in a higher degree of adaptation.

2.2.7.3 Education Level

Among the residents in long-term care facilities, education level and whether they suffered from some diseases were found to affect perceptions of comfort. Some non-physical factors, like occupants' education level, were found to have a connection with comfort perception (Castaldo et al., 2018).

First of all, people's comfort will have an impact on people's educational process. A good environment will positively promote people's learning process, which in turn will help to obtain good learning results. On the contrary, it will hinder the education process. At the same time, people's level of education will have a negative effect on comfort. Generally speaking, people with a higher education level are more likely to feel comfortable.

2.2.7.4 Location

In terms of space design, the dynamic connection of the main spaces can facilitate the activities of the elderly. For instance, the elderly may get up frequently at night, so the distance between the bedroom and the bathroom should be minimized. In addition to the design of the individual senior housing, in addition to meeting the needs of the elderly who are in good health, the space design should also consider flexible transformation to adapt to the physical changes of the elderly (Tan, 2006).

In addition to the layout of the various rooms in the room, the location of the entire residence also needs to be optimized. Factors that need to be considered include traffic, lighting, floor height, etc. For example, for the elderly, their rooms should be set up on the lower floors, and, as much as possible, with a sunny side.

2.2.7.5 Relationship with Neighbors

Research of comfort in workplace backgrounds have indicated that interpersonal relationships, for instance, with supervisors and coworkers, are vital determinants of indoor environments comfort, for instance, Park et al. (2016) surveyed occupants in the same building about their closeness with other residents of the homes, the frequency of gift exchanges and visits to investigate the influence of residents' attitude to their neighbors regarding their levels of AC. The researchers discovered that attitude to neighbors has an impact on the coping mechanism utilized to alleviate acoustic discomfort caused by the noise of neighbors, in other words, the less contact and more bad feelings they would have, and less satisfaction with noise levels.

2.2.7.6 Ownership and Economic Status

Previous studies indicate that economic status and ownership can affect occupants' comfort perceived from indoor environmental elements. Indraganti and Rao (2010) discovered that residents from higher economic groups have lower comfort temperature ranges and acceptance comparing to those from lower economic groups. Lee et al. (2012) also conveyed a like connection between acoustic satisfaction as well as income level. Residents who live in rented units normally have lower comfort levels which might due to their limited control towards indoor conditions.

2.2.7.7 Other Characteristics

Apart from the characteristics of occupants discussed above, studies also indicated a crucial correlation between comfort and several other characteristics, which include health, energy-saving awareness, marital status, lifestyle, and pride in residence. Meanwhile, mental pressure is another factor that can make occupants more sensitive to acoustic conditions (Dahlan, 2015); while similarly, smokers normally have higher sensitivity and dissatisfaction with indoor conditions. The awareness about maintenance and energy use, the time spent in apartments, as well as the sense of pride about the residential buildings also has positive influences on residents' comfort levels. Previous studies also evaluated the effects of job, previous time stayed in countryside, and length of time in residence on occupant comfort in MURBs, but failed to discover any vital relationships (Jin et al., 2010).

2.3 Quality of Life

The elderly are likely to be increasingly poor and reliant on subsidized care. Thus, the QoL of the elderly is a significant indicator for evaluating the happiness of the elderly in a region. The assessment of "QoL" was first projected by the American economist. QoL is a multi-dimensional concept, now commonly including four aspects: psychological status, objective environment, expected QoL, and behavioral ability (Sarvimäki & Hult, 2000). Since the 1960s, QoL has gradually become a common research field for many disciplines. Different disciplines have different research priorities, resulting in different definitions of QoL. China's research on the QoL started late, and the social indicators connected to the QoL only began to be studied in the 1980s Zhao & Kanda, 2000).

In addition to the common characteristics contributing to QoL and the individual's subjective satisfaction with life and the pros and cons of objective material conditions, the elderly have particular needs for good QoL. Compared with the general population, the main factors that are highly relative to the QoL of the elderly are physical health status (chronic disease), economic income, mental health, age, gender, and social support. Physical health is an especially sensitive indicator that reflects the QoL of the elderly group. Scholars have suggested that age and the number of diseases have a greater influence on the QoL of disabled elderly people (Helena, 2010).

Elderly people have reduced metabolic function, reduced anabolism, and increased catabolism, especially protein catabolism is greater than anabolism; reduced basal metabolism, reduced lean body tissue, and increased fat tissue. Elderly people suffer from decreased digestive function, loss of teeth, dullness of action and taste, which affects appetite, reduced intestinal digestive fluid secretion, and reduced functions of digestion and absorption (Shamburek & Farrar, 1990). Changes in the body composition of the elderly: the number of cells decreases, muscle atrophy, organs decrease, and function decreases (Bindels et al., 2012); body water decreases, affecting body temperature regulation, the capacity of the elderly to adapt to variations in ambient temperature decreases; bone tissue minerals decrease, bone density decreases, and Osteoporosis may occur (Health & Services, 2004).

2.4 Perception and Wellbeing

In understanding perceptions of the physical environment - acoustic, lighting, thermal and IAQ - Davies et al. (Davies et al., 2013) focused on the perception of soundscape using qualitative methods. They found that soundscape perception is influenced by cognitive activities.

Beranek (1966) conducted a survey of peoples' noise tolerance comparing southern Europe and northern Europe, and found that there was a 5-10 dB(A) greater tolerance of noise in southern Europe. Broadbent (1953) found a quite similar result. They investigated occupants' tolerance of noise in office buildings in the UK and Pakistan and showed that workers in the UK have lower noise tolerance than Pakistani workers, even if the sound level was relatively lower in the UK. The great differences between the two cultures in many aspects were found in terms of selecting and assessing living environments, noise levels, sleep disturbance and annoyance, sound preference and activities.

Based on the above variables and characteristics that affect the living quality of the elderly, the literature of situations in China is illustrated in the following part.

2.5 Studies in China

2.5.1 Institution-based Endowment mode Innovation

Men (2010) compared the advantages and disadvantages of three endowment modes, i.e. home-based endowment, welfare institution-based endowment and endowment in the apartment for the aged. The study found that endowments in apartments for the aged can better meet the increasing endowment demand of the elderly. A feasibility analysis of the market potential for the development of endowments in apartments for the aged in China has been conducted. An (2015) shows the problems involved in the development and difficulties of developing RACFs in Shenyang regarding the increasing number of the elderly and the financial hardship. The countermeasures and suggestions for developing RACFs in Shenyang are put forward in terms of the government’s duty to subsidize RACFs

Currently, the study of institution-based endowment modes is at a stage of divergent thinking in China (Bartlett & Phillips, 1997). All innovative forms of institution-based endowment modes are under exploration, basically divided into three types: formation of new RACFs through the integration of previous different RACFs (Douglas et al., 2017); redefinition of traditional RACFs through innovative operation modes (Bihan, 2012); solution to some specific problems with RACFs based on experience from elsewhere to improve traditional institution-based endowment modes (Tuckett, 2005).

Based on these three kinds of innovations, several new forms of institution-based endowment modes have appeared. In this thesis, it is necessary to compare and testthese new institution-based endowment modes to find a new operable mode suitable for the endowment demand in China.

2.5.2 Endowment Demands

Due to numerous factors, including regional culture, lifestyle, health conditions and economic conditions, a variety of differences in the demand for elderly care are found, which is also called endowment demand (Iwarsson, 1997). Therefore, endowment demand, as an imperative factor in endowment mode research, calls for systematic study based on collection and sorting of information obtained from a large number of people, groups and projects, summarizing laws and studying countermeasures, focused on finding the basic requirement of the institution-based endowment (Gaspar et al., 2018).

The endowment demands of the elderly reflect the actual needs and expectations of the elderly for nursing. This is the basis for guaranteeing the satisfaction of the elderly and an important indicator for the work of architectural designers and nursing staff. However, at present, people do not pay enough attention to the needs of the elderly in this area, and there are few related theories. This has led to people often neglecting the real desires of the elderly and making it difficult for nursing staff to meet the needs of the elderly.

2.5.2.1 The elderly's demand for RACFs

a) Endowment Demand in Different Regions

Generally speaking, the difference in endowment demand is most significantly reflected in regional differences (Shepherd & Soule, 1998). Much research has been based on specific regions, involving research on the needs of the elderly in the local area in terms of daily care and psychological comfort (Alimohammadi et al., 2015). Questionnaires, interviews and so on have been used to collect relevant information for analysis from the elderly, endowment service personnel and management personnel respectively (Pashiardis et al., 2005).

Bing (2012) pays attention to existing problems in current community-based endowment services, such as lack of variety, shortage of funds, and low quality of community service personnel, lack of professional personnel and low levels of management service. He suggested improvements to daily care for the elderly; family services; health care services; mental protection; maintenance of rights and interests; awareness of community-based endowment services; widening of sources of funding; strengthening human resource training for community-based endowment services; specialization of community service personnel, and procedures for volunteer participation.

The above studies on endowment demands in different regions can show the elderly's demands in every aspect involving daily life, interpersonal communication, emotional communication, medical and health care, and the like. It has also been shown that these demands are closely linked with the characteristics of the local natural and humanist environments.

b) Endowment Demand-based RACFs

Some of the studies are on future development and innovation modes of RACFs based on analysis of endowment demands to identify the demands of endowment facilities or institutions and the construction of them. It is through innovation in the endowment institution mode, that satisfaction of demand can be realized.

In the Analysis of Current Elders' Demand for Endowment Apartments (Shen & Yong, 2015), elders' demand for apartments is analyzed in three aspects: the reasons for wanting elderly care accommodation; factors considered during selection of endowment apartments; and their demands for appropriate physical facilities and good environments. The factors considered by the elders during selection of endowment apartments include location, traffic, occupancy fee, medical conditions, nursing level, catering services, physical facilities and supporting services. (Shen & Yong, 2015) investigated 19 facilities for the aged with 331 questionnaire responses. The results show that in terms of daily care, the elderly people's most imperative needs were to have better and more nutritious food and assisted bathing, while in terms of medical care, demand for accompanied medical treatment and house calls and regular physical checkups by designated medical personnel rank 1st and 2nd respectively. In terms of psychological care, there was a high level of demand for accompanied reading, walking, chatting and psychological counseling. A similar survey conducted by Guo et al. (2016) in Guangzhou with 153 old people aged 61-102 in facilities for the aged, focused on older people's physical, psychological and spiritual needs. Stepwise regression analysis shows that the two factors, "Gender" and "Chronic Illness" have the greatest effect on elders' demand for facilities and services.

Currently, research on elders' demand is mainly based on the survey of subjective satisfaction. However, due to the presence of some differences in cognitive capacity and different assessment criteria of human subjective satisfaction, the wider applicability of the conclusions drawn from this research is poor.

2.5.2.2 'Empty-nester' Demand

Data show that the current empty nest (elderly people whose children no longer live with them) percentage of the elderly in China has reached nearly 50% Empty nesters, as an imperative section of the elderly group, have different demands from other elders in some aspects. Empty nesters are also the main population who receive services from the institution-based endowment mode.

Jia (2009) focused on the empty nesters in Beijing and they summarized the problems involved in every aspect of older people's lives. Medical and healthcare are imperative demands for empty nesters. Because the children of empty nesters are not around and there are no people around them who can care for them, it is difficult for them to get support and help if they have health problems. Thus, health support with a focus on chronic disease prevention and treatment, prevention of complications and provision of health knowledge should be conducted to satisfy the healthcare demands of empty nesters.

2.5.3 Study on the Physical Environment of RACFs

Research into the physical environment of aged facilities in China is generally divided into five aspects: acoustic environment; lighting environment; thermal environment; physical environment; and the spatial environment of residential facilities for elderly.

2.5.3.1 Acoustic Environment

Tang (2010) studied people's preferences for, and feelings about the dominant sound in underground commercial space. Based statistics identifying dominant sounds in underground commercial spaces, 21 groups of adjectives, were used to conduct in-depth analysis in a survey regarding people's perception of underground sound in commercial environments. The impact of the preference of sounds on people's ratings towards underground commercial environments is verified in Dong's study (Dong, 2012) based on the "Analysis and Study of the Sound Environment in Public Space in Urban Residential Areas of Harbin" (Originally in Chinese) based on the simulation analysis of typical urban residential areas in Harbin, the overall features of the sound environment were analyzed, taking into account the effects of characteristics of the respondents and of the physical environments. And it was found that sound environment is not the major factor that affect human activities, but people would consider the quality of sounds when they are satisfied with other factors that affect their living quality. Jia (2012) conducted a survey on the relationship between crowd behavior and soundscape which found that the crowds in the soundscape environment (the acoustic environment that perceived by humans in context) have such behavioral expressions as sound prejudgment (to prejudge the possible sounds that may occur in an environment), sound attraction (the attention attracted by sounds in an environment) and sound expectations (what kind of sounds do people expect in an environment).

Currently, a good basis has been created for research on the acoustic environment and there are some useful studies of acoustic environments of different kinds, but there is a lack of research intended for the elderly and their living environments.

2.5.3.2 Lighting Environment

Bin (2010) takes Beijing as an example, and carries out a simulation analysis of the effects of architectural and window forms on the distribution of indoor lighting coefficients and the heat loss indexes of buildings.

By adjusting the quality and quantity of light, appropriate color scheme and contrast, an indoor color atmosphere suitable for the life of the elderly can be generated. Therefore, the light environment can bring positive feelings to users, and at the same time, it will become a stimulating and attractive space (Guerry et al., 2021).

From this, it is possible to judge the overall effect of changes in an architectural form on indoor lighting and heat loss index of buildings. Liu and Zhang (2010) conducted a survey on the visual comfort of indoor lighting and the bright environment in living rooms. Based on the Weber-Fechner Law, a mathematical model for visual comfort is established, with visual comfort formulas and curves in four light environments in the living room obtained. The result shows that the established mathematical model for visual comfort can reflect the objective law (objective regularity) of visual comfort and provide a quantitative theoretical basis for indoor energy-saving lighting design.

Research on the domestic light environment does not include special research on elders' needs for good lighting environments. Due to changes are visual perception in the elderly, their needs for the light environment are different from other groups (Kim & Tokura, 2000). Therefore, a study of subjective and objective ratings of light environments can help quantify elders' needs.

2.5.3.3 Thermal Environment

The elderly are unique in physiology and psychology, so their requirements for indoor temperature are different from others, and they usually have higher requirements (Hwang & Chen, 2010). For example, human metabolism will decrease with age, so the elderly are less able to adapt to changes in environmental temperature. The basal metabolic rate of the elderly is on average 4.7 W/m^2 lower than those of 20-30 years old

(Fanger, 1970). So far, there are few related thermal comfort criteria to solve the thermal comfort problem of the elderly in the indoor environment.

According to an analysis (reference originally in Chinese) of Liu (2013), a method combining objective measurement and subjective investigation is used to conduct a systematic analysis of the thermal environment in the atrium space of shopping malls in terms of the space environment, the physical environment and individual differences; and corresponding design methods and control strategies are presented. Thermal environment correlation factors were analyzed and the relationship between each correlation factor and the thermal environment was summarized by Yu (2013). Through the analysis of the numerical simulation, the thermal environment characteristics and influencing factors in each area of the Shenzhen OCT Community (OCT is the name of a community, which combines culture, ecology, tourism, entertainment, shopping, catering, hotels, clubs and other diversified formats in one community) are summarized, based on which the factors conducive to the thermal environment in the Shenzhen OCT Community are summarized. The residents' overall perception of the TC in the Shenzhen OCT Community was satisfied, but unsatisfied towards the East Cluster Residential Area.

People's perception of the thermal environment varies between different regions. Research on cold regions is an imperative field as residents have particular demands towards living quality. Ce (2013) focused on the winter TC of shopping malls in cold regions. Ratings of the physical environment and subjective questionnaires were distributed in four large shopping malls in two cities, Harbin and Changchun. The distribution and characters of change of the indoor physical environment of the shopping malls were analyzed in two dimensions: time and space. The result of the research indicated that the indoor temperature of shopping malls in cold regions is very high, and the indoor relative humidity is very low, with poor ventilation and uneven indoor thermal change. Through the summary and analysis of influencing factors for TC, instructional strategies for the improvement of the winter thermal environment of shopping mall buildings in cold regions were suggested.

The climate in the Northeast is cold, and the thermal environment is relatively poor compared to most other regions. Therefore, this paper will summarize other research results and theories, explore the impact of the cold climate on the lives of the elderly, and ways to improve the thermal environment in Northeast China.

2.5.3.4 The Physical Environment

Han et al. (2012) studied the factors that affect designs for creating comfortable underground street environments in Chongqing. Through literature research, relevant theories influencing the design and development of the physical environment of underground streets were analyzed and the general development situation of underground streets in Chongqing and the practice of environment design for underground street environments at home and abroad are discussed. With these design principles as criteria, the design strategies for sound, light and air environmental comfort of underground streets in Chongqing are drawn up. And according to their survey of in-patients' comfort ratings of the physical environment of a hospital ward, questionnaires were used to investigate comfort ratings of a ward in terms of temperature, humidity, IAQ, bed spacing, acoustic and color. 69.5% of the inpatients considered the physical environment of the ward to be comfortable or very comfortable, with the ranking of high too low for temperature, humidity, acoustic, IAQ, bed spacing and color.

To sum up, currently, there is little research into the physical environment intended for the elderly in China, which means that research on the physical environment needs to be more specifically focused in relation to various needs of different groups of people, With the elderly as the target group, research on how the physical environment of RACFs should be adapted to the life of the elderly to meet their needs should make the elders' demands for suitable physical environments as a new goal and basis for spatial design of RACFs.

2.5.4 The Space Environment of Residential Facilities for the Elderly

Currently, the research on the space environment of RACFs in China is mostly behavioral psychology of the elderly, with a focus placed on research into communication among the elderly in terms of types of spatial environments.

Lu et al. (2010) Institution-based Endowment Facility Space Composition Modes in North China studies institution-based RACFs in Shenyang and Dalian cities in Liaoning Province and explores the mutual inner link between building space composition modes and the elders' behavioral domains. And it was found that 70% of the RACFs in North China are operated by private business, but the leading facilities are still those that run by governments; the number of female elderly residents are more than those of male, and their financial income mainly cone from their children; more than 90% elders live in RACFs because no one can take care of them at home; and their major leisure include chatting and playing cards.

You (2014) also paid attention to the communication space of apartments for the aged. He analyzed elders' special communication behaviors in three aspects: human and human; human and environment; human and society. Based on the behavior of communication between the elders and others, the space forms and design strategies they correspond to be discussed. This study suggests design focus and methods for the public environment of apartments for the aged in China.

Li (2014) carried out a comparative study of long-term occupancy types of endowment facilities involving different levels of nursing care. The demand differences in bedroom type, public space, auxiliary nursing space, are analyzed and the key points of designing adaptability of the residential facilities for the elderly are presented, which are elevator distribution, structural system, construction of the piping system, public area and auxiliary areas.

From reviewing studies of the space environment of RACFs, it is found that the design and construction of RACFs in China are mostly based on behavioral analysis of the elderly, and especially on the analysis of communication activities of the elderly. The behavioral is mainly derived from observation, interviews and rating, which reflects the greater effect of subjective factors on the design of the space environment of RACFs, without consideration or research related to objective factors, such as the form of the actual physical environment. The physical environment, as a significant factor affecting the daily life quality of the elderly, cannot be ignored as afield for further research. A study based on the combination of subjective and objective influencing factors would make the design of space environments for RACFs more comprehensive, diversified and appropriate.

2.6 Summary and Conclusion

A good living environment is an imperative condition for enabling the elderly to live comfortably at home. Some studies have found that the living environment has imperative effects on the life satisfaction of the elderly. Housing and the surrounding environment are essential to improve QoL for the elderly. Whether the living environment meets the needs of the elderly will affect their mental and physical health and community participation. At present, the contradiction between increases in the aging population and unfavorable living environments for them is becoming more and more obvious. Given this background, finding the factors that restrict the QoL of the elderly in the living environment has become the key to improving China's healthy aging policy system. This thesis intends to explore ways to optimize living environments and improve the QoL of the elderly by analyzing the factors and conditions of living environments that influence the QoL of the elderly with the aim of better meeting their specific needs.

3.Methodology

3.1 Overall framework

The framework of the whole study is shown in Figure 1-1. The results for Objective 1 (Chapter 4) were used to decide the participants of interviews for Objective 2 (Chapter 5) and study sites for Objective 3 (Chapter 6), and the results for Objective 2 reflected the studies for Objective 3 (Chapter 6) to a certain degree. For Objective 4 (Chapter 7), the results obtained in the former three chapters contributed to the field study in terms of details of questionnaire design and measurement of the corresponding physical environmental indicators. The details of laboratory experiments for Objective 5 were decided by results from Objective1, Objective 2, Objective 3, and Objective 4.

At present, there is relatively little research on RACFs in China, and this field is still blank. Thus, the thesis focuses on the scientific study of the status quo of RACFs in three Northeastern provinces of China to discover the elderly's needs for living environments in sheltered housing and their perceptions of indoor physical environments. The main research subjects and methods were decided based on comparative studies (Objective 1). Knowledge of older people's needs in the living environment for the aged in the Northeast Region of China was learned from interviews, by which the importance of the physical environment was assessed (Objective 2). By doing measurements of the indoor physical environment, the characteristics of indoor physical environments were listed (Objective 3). In order to know older peoples' assessment of indoor physical environments, the questionnaires and corresponding physical environments in occupants' housing were considered (Objective 4). These studies all affect the details of the field experiments. According to the analysis of the former four chapters, the indicators with significant relevance for older people's experience were chosen as the measurement subject in Chapter 8.

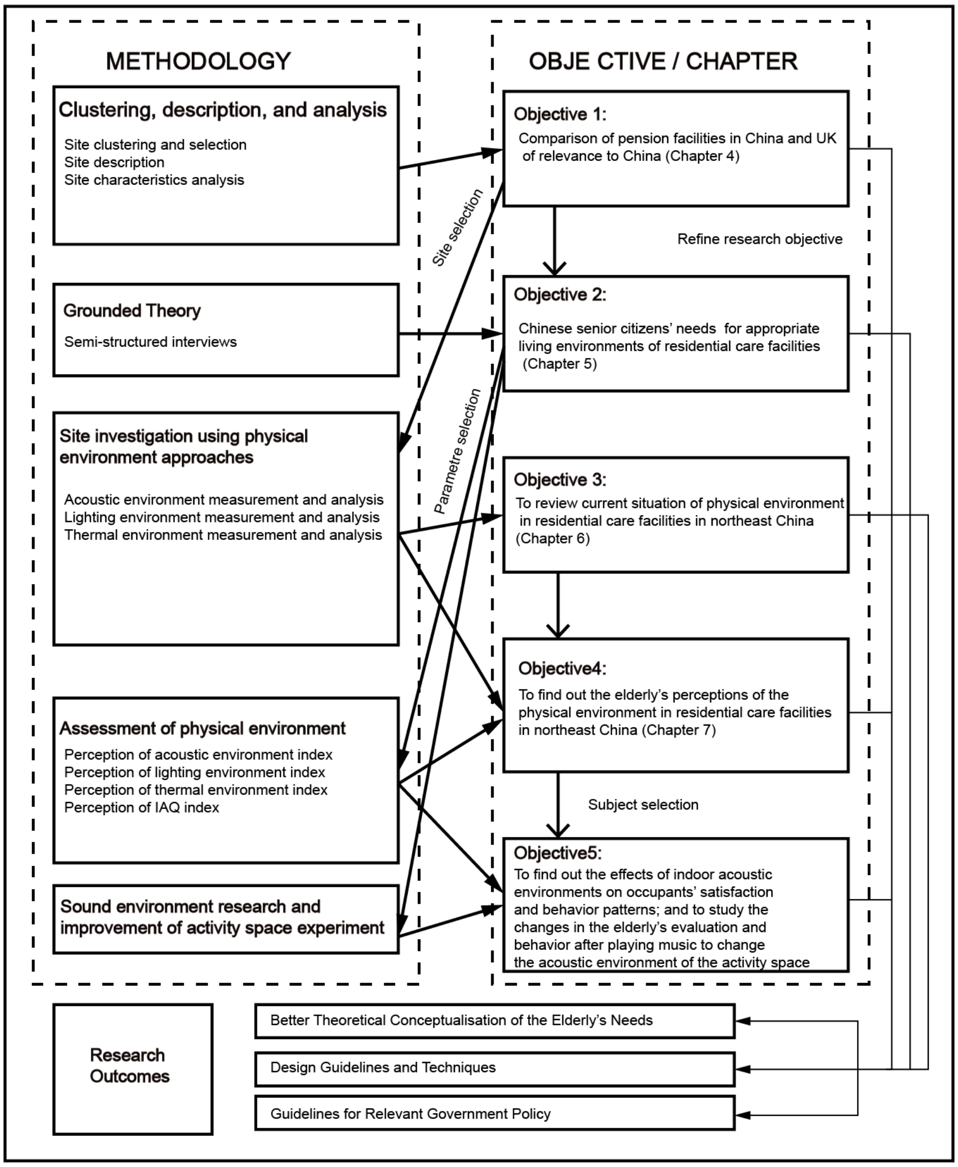


Figure 3-1 Research framework

3.2 Grounded Theory

This chapter presents the fundamental research theory used for developing methods, analyzing results, and optimizing residential environments for senior facilities. Grounded Theory (GT) is most suitable for theoretical construction. GT starts with actual observations, discovers research problems, collects data and materials, and continuously compares and analyzes the data to abstract and conceptualize it, further summarize and refine concepts and categories, and build theories on this basis.

3.2.1 Concept

Grounded Theory (GT), also known as Foundational Theory, is a special methodology established by materials by two scholars at Columbia University, Glaser and Strauss(Glaser & Strauss, 2017). This qualitative method is a way of establishing a “bottom-up” form of substantive theory; in another word, it is based on systematic collection of data, inductive analysis gradually forms a relevant theoretical framework.

At present, for the study of the residential environment, quantitative analysis alone is not enough, because there are many influencing factors in reality that cannot be quantified, which will lead to the one-sidedness of the research results. Therefore, to take the non-material environment of the residential environment, or the residents’ perceptions and subjective rating toward the living environment as the research object, it is essential to conduct a qualitative analysis on it, determine the research elements of the environment, and determine which factors will affect the resident's subjective assessment of their living environment. The analytical process of the grounded theory comprises data coding; checking, developing, and integrating the theoretical classifications; as well as portraying analytic narratives all the way through the inquiry (Charmaz & Belgrave, 2007), and according to (Strauss & Corbin, 1990), GT has been regarded as one of the most influential modes to carry out qualitative research, thus, we believe GT is suitable for acoustic environment research.

Grounded Theory studies social details without pre-assumptions. It provides a guideline for data collection and analysis through coding, memo, classification, and theorization. The research tries to stay open to people's own descriptions and indicators that appear in the rating from which to establish a data-based rating framework.

In the data analysis process, most codes were from participants' original descriptions, and meanings of modifiers were processed in Chinese and translated into English for the next analysis steps.

3.2.2 Research Steps

According to Corbin and Strauss (1990), the procedures of grounded theory can be broken down into the following procedures: 1. Data analysis as soon as the data is collected. 2. Conceptualize the raw data, as the theories cannot be established with actual activities or incidents as observed. 3. Group the concepts with the same phenomenon into categories. 4. Sampling. Based on the concepts that are formed at the previous step, the groups of individuals or organizations can be selected. 5. Utilizing constant comparison to support analysis. As an incident is noted, it should be compared with other incidents for differences and similarities. 6. Examine the data for regularity and patterns, which helps to provide order to data and assist with integration. 7. Build the process into the theory. 8. Finally, an integral part of grounded theory is creating theoretical memos.

Also, Charmaz and Belgrave (2007) explain that a rooted theoretical approach facilitates to process of data in an alternative way and through early analytical writing to explore ideas about data, which can optimize other methods regarding qualitative data analysis. Grounded theories can be constructed with information from a variety of data fields, such as interviews, records, and reports. Rooted theories are usually taken by researchers.

Several types of data are collected in this study, and various data collection strategies have been invoked.

3.2.2.1 Structured interview

The interview is equally popular with observation in qualitative research. A structured interview is a formal interview that contains a list of topics and questions to be included in the conversation during the interview. A structured interview refers to the kind of interview that the interviewer prepares a specific series of predetermined questions; while an unstructured interview refers to the kind of interview that the questions asked by interviewers are not predetermined, and a semi-structured interview is a combination of the previous two which contains predetermined questions and spontaneous questions. Before observation, informal or unstructured interviews and semi-structured interviews are usually conducted so that researchers have a better understanding of the topics likely to be relevant. It is helpful to develop meaningfully and focused on semi-structured questions.

According to Patton (2014), the advantages of structured interviews:

1) Mitigate interviewer bias. Since the interview questions are predominant, the interviewers' subjective judgments can be removed.

2) The execution can be faster than that of semi-structured interviews and unstructured interviews due to the limited categories of responses in structured interviews.

3) As participants will answer the same predetermined questions, it is available to compare their responses.

3.2.2.2 Coding

The source of data for this study is information obtained from semi-structured interviews with interviewees. Semi-structured interviews can not only avoid the shortcomings of structured interviews that are inflexible and often do not obtain in-depth information, but also make up for the shortcomings of unstructured interviews which can be time-consuming, labor-intensive, and difficult to analyze quantitatively. Recording the interview is followed by transcription, and then coding, which generates the foundation of the corresponding analysis. Grounded Theory coding requires asking analytical questions about the collected data (Charmaz, 2007).

Analysis based on Grounded Theory includes at least two main steps:

1) Initial coding step, which involves naming each word, line, or data segment;

2) Centralized, selective focused coding (FC), which utilizes the most imperative or frequent initial code to classify, integrate, synthesize, and organize large amounts of data.

There are three different methods of initial coding: Incident-by-Incident, Line-by-Line and Word-by-Word. The advantage of initial coding is summarized as follows:

It enables researchers to focus on and simplify the specific characteristics of data. And researchers can identify significant sections of text and index them to relate them to a theme in the data.

The third type of coding is “axial coding”. Axial coding associates classification with subclassification specifies the attributes and scales of the categories and regroups the data created in the initial coding process to make the emerging analysis coherent (Charmaz, 2007).

Theoretical Coding is another imperative method for coding data. Theoretical codes enable possible correlations among categories that you developed regarding the keycodes (Charmaz, 2007).

Coding relies on sufficient information from in-depth interviews. The process of coding full interview transcriptions helps to give researchers more ideas and brings a deeper level of understanding of the research.

3.2.2.3 Memo Writing

Memo writing is a key step between the collection of data and writing a draft paper. When writing a memo, the researcher reflects on the code in the course of the coding and analysis process. Memo writing is the fundamental procedure for researchers to result in grounded theory (Lempert, 2007). It is a distillation that enables researchers to transform data into theory, and researchers can discover patterns through sorting, analyzing, and coding the raw data and interpret and theorize these patterns (Huan & Fengkui, 2010).

3.2.3 The elderly’s demands towards the QoL in Residential Buildings

Rioux and Werner (2011) found that there are four factors affect the elderly’s residential satisfaction. The satisfaction subscales are local area (activity, safety, and aesthetics); access to shops and services (transport, proximity, and walkability); social relations with neighbors; (positive regard, mutual help and respect for privacy); and home interior (pleasant, accommodation, chose to live here and prefer not to move).

A qualitative study conducted by Wong et al. (2014) in Hong Kong about the effect of indoor environments on dementia residents in residential care homes, found that among the various characteristics of indoor environments, the AE, TE, and lighting are ranked as the most crucial influencing factors.

Thus, based on these three most significant elements affecting the older residents’ QoL, to learn more about how to improve these factors in the RACFs to better satisfy the residents, I intended to utilize in-site investigation to explore the physical environment of the RACFs we selected, and to utilize questionnaires and interviews to have a deeper insight regarding the demand of older residents living in these facilities, which will be illustrated explicitly in the following contents.

3.3 In-site Investigations Using Physical Environment Approaches

The environmental factors that define the quality of indoor environments including the perceived comfort of four elements, which are acoustic, thermal, and lighting, as well as IAQ, which were the factors that we focused on during the investigation in the research site.

The selection of scientific and appropriate methods is also a significant aspect of research to improve the quality of indoor environmental measurement. Studies use both questionnaires or interviews to find out participants’ perceptions of indoor physical environments, and also measurements of physical parameters of the physical characteristics of indoor physical environments and these are the most common methods for assessing occupants' comfort levels in relation to indoor physical environments (Crociata et al., 2012). In this study, the physical environment includes AE, LE, TE, and IAQ in RACFs. The objective is to find the characteristics of indoor physical environment quality and to understand the perceptions of the physical environment among older people. In the subsequent comparative measurements, poor physical environment factors found from the survey and physical measurements are treated as the main aspects requiring improvement.

3.3.1 Approach to Analysis of the Acoustic Environment

Response ratings to noise are subjective, and all sounds that affect people's learning, work and rest can be considered noise. Noise has different characteristics from other forms of pollution. According to the WHO (1996) report, in the aspect of public health, it is the second-most prevalent environmental stress factor. Therefore, the monitoring and rating of the acoustic environment are very imperative for aged care residents. The noise level in the rooms of senior people should not exceed 50 dB in the daytime and 40 dB during the night (Medicine, 2008).

The major method for studying the acoustic environment is sound measurement. Tavossi (2003) concluded that the most significant factors that affect the acoustic environment are the RT and SPL, which will be measured with the following methods.

As well as SPL, reverberation time (RT) is another imperative parameter of spatial acoustic characteristics; Reverberation time is when the sound source stops transmitting sound, the required time for sound level decaying by 60 dB, to illustrate, if the sound takes 10 seconds to decay from 100 dB to 40 dB in a room, the reverberation time is 10 seconds (Roberts, 2018). The RT was measured during the night when the activity room was closed and unoccupied. Sometimes it is inconvenient to carry the playback device, and we can only replace the white noise with puncturing balloons, clapping hands, etc., which is 500 Hz. In order to make the overall measurement results the same, the 500 Hz white noise was played at the measurement points with the adoption of the OS002 12-sided nondirectional sound source. The formula for calculating reverberation time is

$$T_{60} = 0.161 \frac{V}{S\ \bar{a} + 4mV} \quad (7.1.67) \ldots\ldots\ldots\ldots\ldots ①$$

(T= Reverberation time；V= The room volume; S= Internal surface area; 4m= Air absorption coefficient；$\bar{a}$：Average sound absorption coefficient）

The sound pressure level (SPL) measured in dB is a significant indicator of our research. The rating of the sound level is highly related to LAeq. Yet, a significant difference has been found between acoustic sound valuations and the subjective perception of the sound level environment, which is, people are inclined to have higher tolerance towards acoustic environment rating.

The measurement of SPL was conducted in the activity room for 18 hours with 5 to 30 elderly residents. During each measurement, the settings of BSAB801 sound level meters (801) were applied to the A-weighted equivalent sound pressure level (LAeq) and the fast mode was measured and recorded. For each measurement point, sound pressure meters were set to A-weighted equivalent sound pressure level (LAeq) and fast mode, and every 10 seconds an instantaneous reading was recorded. For avoiding the variability of a sound source, which would decrease the accuracy of the research findings, each LAeq was measured 10 times at each measurement point; with each measuring point measured hourly, and the result of this measurement point would be the average of the ten sets of data.

There are many other methods for monitoring noise. In this study, the measurements have been carried out in public activity rooms and connection spaces (including corridors, rest spaces in corridors, lobbies) of thirty-four selected sheltered housing in Northeast China. The acoustic assessment approaches include the measurement of SPL in normal usage, the background noise of each room, and the reverberation time of each room. Other sets of measurements which include observation of the elderly behavior, surveys, and questionnaires were also conducted in RACFs in China.

The results of interviews providing subjective assessments and the results of objective measurement of sound sources can be used to inform good design for AC in elderly accommodation. These measurements will be integrated with the results with questionnaires and interviews. The research can play a crucial role in arranging the public and private spaces of senior facilities, to better suit the extra requirements of senior care.

3.3.2 Recording and Analysis of Lighting Environment

Visual comfort refers to the subjective reaction regarding the quality and quantity of light at a given time in a given space. The visual comfort lies in our feasibility to control the light around us. According to European Standard EN12665 (NSAI, 2011), the lighting requirements in space include the following components:

Sufficient illumination for movement and safety, supporting conditions that will facilitate color perception and visual performance and ccceptable visual comfort is perceived by the occupants living in that space.

Light condition measurements are significant regarding photomorphogenesis, and for learning that impacts on specific wavelengths, like UV radiation on physiological processes. Light conditions are best examined in those places, in which the elderly people are living, such as the RACFs, with less time spent in private areas, like bedrooms. Since most activities in common spaces take place during the day, all light measurements were taken in the daytime, and the measurement time was 18 hours. T-10A Illuminance Meters (0.01 - 299,000 lux (±5%) and GPH-1001 brightness Maters (20 cd/m^2~2000 kcd/m^2) were used in the measurement.

Illuminance usually refers to the light level, which is the amount of light per unit area and is measured in lux. The measurements of illuminances can be best conducted at the eye sight line (also known as ocular illuminance or corneal) (Ev), at 1.6 m high, and at chair level of 0.66 m high horizontally, and also at table level of 0.9 m high vertically (Eh). These heights demonstrate the elderly walking around the communal areas or standing upright in corridors as well as holding something in their laps or performing a task while seated beside a table. Vertical measurements were carried out in the corridors. Measurements of horizontal and vertical levels illuminance were arranged separately in zones and were distinguished based on the distance from the windows.

3.3.2.1 Factors Affecting Lighting Environments

Bellia et al. (2011) concluded that the lighting environment depends on the following aspects: the physiological condition of the human eye; the distribution of light and its amount in space; and the light source. Internal levels of light can also be affected by seasons, weather, building location and window orientation. They also summarize four factors for assessing the visual environment: "light quantity", "uniformity of light", "light quality in rendered colors" and "prediction of occupant glare risk". During the research, the three light index evaluated were lighting equipment, light distribution, and interior lighting.

Research confirms that different spaces require various illuminances. The instrument used to measure illumination was the Illuminance Meters T-10A. However, there are no suggested reference values for spaces in accommodation for the aged. The Chinese Standard (GB 50034-2019, 2013), gives general illuminance reference values for a residential building but does not give illuminance standards for elderly persons' facilities. European Standard (E. STANDARD, 2002) suggests a reference value of 500 lx for workplaces.

Daylight and artificial illuminance can have different effects on occupants (Boyce, 1973). A study was carried out in the Netherland on the effect of lighting conditions on independently-living older people. The daylight (daytime) and artificial (evening/night) illuminance in the occupants' living rooms were measured at the position where they sit and questionnaires were used to record their experience. The indoor illuminance for both horizontal and vertical illuminances was measured. They measured the indoor illuminance at 1.6 m high horizontally (at table level of 0.9 m high and at chair level of 0.6 m high) in Dutch RACFs.

While there is no suggested or standard reference value for spaces in senior facilities, Europe and China have both adopted local standards to regulate building codes for RACFs for seniors.

Brightness is also one of the five major indoor environmental parameters. The instrument utilized to measure brightness was the GPH-1001 Brightness Meters.

3.3.2.2 Approaches to the Assessment of Lighting Environments

In this research, the measurements of the lighting environment comprise the daylight and artificial illuminance and brightness measurements at the horizontal and vertical direction of in public activity rooms and interior circulation areas of five RACFs. A multi-point method was adopted, which means that each room was arranged with four to sixteen measurement points. Each measurement point was at least 1.0 m from walls and windows and 1.2 m from the floor.

Light environment rating indicators are divided into subjective and objective categories. The subjective category focuses on the psychological environment, such as first impressions or feelings of comfort or discomfort with the lighting environment, which are then followed by measurements of objective indicators.

The data from the measurements were transferred to Microsoft EXCEL files and were entered into the statistical analysis program SPSS for further analysis.

3.3.3 Recording and Analysis of Thermal Environments

Rating of existing building thermal environments is mainly divided into subjective rating and objective rating. Subjective ratings mostly use questionnaire survey methods to investigate occupant temperature comfort (Ricciardi et al., 2016). The responses can be organized in a Bayesian 7-level TC rating method (Bedford, 1936): much too hot (3); too hot (2); comfortably warm (1); comfortable (0); comfortably cool (-1); too cool (-2); much too cool (-3). The three thermal-environment indexes are temperature, relative humidity, and ventilation, and the correlation of these indexes was also tested and evaluated in five RACFs in Northeast China. The instrument utilized to measure temperature was a K-type thermocouple, and the instrument utilized to measure the relativity humidity was RH sensors. In addition, questionnaires were also utilized for the elderly residents to evaluate their satisfaction with the thermal environment.

The two main factors of the thermal environment, which are air temperature and relative humidity, should be measured. The activities and dressing of the elderly are very similar. According to the foregoing, the neutral temperature of this PMV (Predicted Mean Vote) model is similar to the directly measured air temperature. Moreover, these two indicators can be directly improved. Therefore, only air temperature and relative humidity were measured. PMV and the ISO7730: 2005(E) (ISO, 2005) Standard were not used in the research. Because according to some existing specifications, indoor temperature and relative humidity can be directly measured, and these two factors are the most important feelings of the elderly, and they are also the easiest to control (Sunwoo et al., 2006).

3.4 Assessment of the Indoor Physical Environment

3.4.1 Questionnaire Survey and Analysis

A questionnaire is a research instrument that contains a series of questions that are typically a mixture of open-ended and close-ended questions (QuestionPro, 2020). A structured questionnaire consists of close-ended questions and scaled questions, while unstructured questions are not pre-dominant questions that allow respondents to express themselves openly (Guest, 2019). In this research, both closed-ended and open-ended questions were devised in the questionnaire, which made the questionnaires a mix of structured and unstructured, which can also be called a semi-structured questionnaire. Through analyzing the data from the measurement of the physical environment, which includes the overall rating of respondents towards the RACFs they are living in, the rating of light environment, acoustic environment, and thermal environment, and responses to the corresponding questionnaire, participants' rating of the characteristics of the environment of buildings and the relevance of all factors were found. Many studies use questionnaires as the main method of research. Krüger et al. (2004) used a questionnaire in schools of the Federal Center of Technological Education of the State Paranm to collect teachers' perceptions of annoyance caused by noise. The answers were entered with a 7-points scale, ranging from 0 to 6 from not annoying to extremely annoying. Kamaruzzaman et al. (2015) applied the 7-point Likert scale questionnaire to measure the satisfaction level of occupants and the perceived significance of the refurbishment or design of office conditions in Malaysia.

Subjective research is an indispensable aspect of understanding subjective assessments, and because they rely on time and place-specific variables, they can produce different results. This thesis studies the differences between educational levels, age groups, gender, current living environment, health status, family members, and income.

In this study, the questionnaire was the main method of collecting qualitative information and was designed to include the rating of different parameters of the indoor physical environment. The question-s setting is mainly intended to study the ratings of the elderly living in the RACF we selected regarding the acoustic, thermal, and light environment, as well as IAQ and overall environment of sheltered housing, which would provide more information about the relationship between each physical environment indicator and the occupants' overall environment rating and the factors influencing their rating of the level of comfort for each physical environment indicator.

In this study, the personal information including gender, age, education, and family relationships was recorded in the questionnaire survey, as well as observational information such as respondents' clothing (tops, bottoms recorded respectively), activity status, and the location was recorded by the researcher during the interviews.

The contents of our questionnaires mainly include:

Respondents' use of the space surveyed and respondents' rating of their mental and physical health;

Overall rating of the environment in the space;

Rating of the lighting condition in the space;

Rating of the acoustic condition in the space;

Rating of the thermal condition and air condition in the space;

Personal information.

Most of the questions in this questionnaire are in different scales, only two of them are open-ended questions there are “How long have you lived here?” and “Which floor are you living on?”

3.4.2 Questionnaire Scale Selection

A scale measures people's subjective responses by using a set of pre-defined words, tags, and scales to express qualitative data with quantitative figures. It usually involves Semantic Differential Scales, Rating Scales, Likert Scales, etc. In the Likert Scales, a graduated scale is used to study the respondents' opinions on the topics of the survey. This research involves five-point and seven-point questionnaire surveys, as shown in Tables 3-1 and 3-2, both of them were used to design the questions of questionnaires for the elderly participants living in the RACFs selected. In the previous pilot experiment, a 5-point scale was used, but it is not easy to choose a 5-point scale. Moreover, the 5-point scale is not accurate for the study of the elderly. Therefore, a 7-point scale was used in the following formal investigations.

Table 3-1 Examples of five-point likert scales

The perception on the whole living environment	Strong unsatisfied	Unsatisfied	Neutral	satisfied	Strong satisfied
	1	**2**	**3**	**4**	**5**
The perception on the comfort level	Strong uncomfortable	uncomfortable	Neutral	comfortable	Strong comfortable
	1	**2**	**3**	**4**	**5**

Table 3-2 Example of seven-point likert scales

How do you feel like the whole acoustic environment?	Strong unsatisfied	unsatisfied	somewhat unsatisfied	Neutral	somewhat satisfied	satisfied	Strong satisfied
	1	2	3	4	5	6	7

The example question regarding happiness is illustrated as below:

Generally speaking, do you think you’re happy? Please score between 0 and 10. 0 represents very unhappy and 10 represents strongly happy.

Strong unhappy □ □ □ □ □ □ □ □ □ □ □ Strong happy

0 1 2 3 4 5 6 7 8 9 10

In this study, the questionnaires were made in Chinese, and it has been translated into English (see Appendix A，B and C)

3.5 Observation of Behavior and Crowd Density

3.5.1 Research Background and Behavioral Observation Method

The behavioral observation method, also known as the behavior place observation method, is a research method in behavioral architecture. Post-occupancy rating (POE) concentrates on the occupants in a building regarding their needs, which provides insight into design better buildings in the future (Preiser et al., 2015). rating. By the 1980s, POE was gradually promoted from dormitory, apartment, and later hospital research to assess occupants' needs in these environments (Cooper et al., 1991), to the investigation and study of open space environments, such as parks, squares, and other urban open spaces.

The observation method can directly record the behavior and performance of the subject without affecting the subject. The elderly's performance in different acoustic environments in RACFs was recorded, and their emotions were observed. When the acoustic environment changes, the observation of whether the behavior of the elderly has changed was conducted.

Visual recording is an imperative research method when observing and studying the behavior of people, for example, a camera with HD video was utilized to record the children's playing in playgrounds in Harbin, China (Meng et al., 2020). In behavior measurement and cameras were set in different locations.

With behavior observation, it is also feasible to identify the influence of the acoustic environment on human activities. In basketball games, players can get excited when they hear music and shouts; artists look for inspiration in music; whistle sounds can be restless, and so on. Meng et al. (2020) conducted a survey on the effect of the acoustic environment on human behavior in fast-food restaurants in Harbin, China. The acoustic environment can also affect human gestures and movements, and people who exercise are generally unaffected by human sounds but are affected by music. In that case, the observation method is the most straightforward way to record the elderly's behaviors under various indoor environment elements.

3.5.2 Density

An investigation of acoustic measurements indicates that increases in crowd density in a specific environment that leads to changes in SPLs and subjective loudness (SL) (Meng et al., 2017a). They compared the SPLs of the open-air market that was operating in Harbin, China, and found that the SL in the cloth sales areas and food sales areas were lower than that of the vegetable area when there was the same crowd density.

However, crowd density has a greater effect on some areas of the market than others. While the density is low, the research respondents reported that they could still hear the sound of footsteps and tearing and opening plastic bags in the presence of talking and vendors hawking. The SPLs increase in various areas as the density of the crowd increases, and vendors' hawking and people talking sounds are the main sound sources, with the highest SPLs in the fruit and vegetable areas. Therefore, Meng et al. (2017) suggest that the well-planned arrangements and zonings of temporary open-air markets can better adjust the AC. The result of this study regarding market arrangements and zonings can be used for reference in our research towards the indoor construction arrangement of RACFs.

3.6 Acoustic environment improvement experiment

A field experiment about the acoustic environment was conducted after the analysis of survey data, and in-site physical environment measurements such as SPL and room temperature. This study focuses on the acoustic environment and confirms that it has significant effects on research participants' perceptions of their RACF.

3.6.1 Sound Sources

Previous studies have explored and studied the classification of sound sources and evaluated the size of soundscapes. Normally, sound sources can be divided into human activity sounds, natural sounds, and technical sounds. The five major sound types that were evaluated were activity sounds, speech sounds, machine sounds, background music, and foreground music.

Sound is always present. The countryside is full of natural sounds, while the cities are full of human activity sounds. People tend to find some sounds comfortable, such as the sound of birdsong, running water, or light music. However, some sounds are disturbing, such as car horns, shouting, and construction sounds, etc. Most countries have environmental quality standards for noise to control and monitor the impact of the acoustic environment on people's lives.

At present, the main source of environmental noise in the world is traffic noise. If industrial areas are close to living areas, industrial noise can also be a major source of noise pollution. In addition, construction machinery, entertainment facilities, and even some office and home equipment are all sources of noise pollution. Harmful sounds can cause various health conditions for people, such as hypertension, hearing loss, tinnitus, or sleep disturbances; (Kerns et al., 2018). In addition, according to the World Health Organization（WHO）, the elderly and children are most vulnerable to the impacts of the acoustic environment, leading to cardiovascular disease in the elderly, increasing the probability of coronary heart disease, while children may be permanently affected by hearing loss.

It is of great importance to study different sound sources. Not only because inappropriate acoustic environment might cause severe problems for the vulnerable elderly, but also because noise pollution becomes more and more common nowadays in urban aged facilities. To prevent harmful impacts on human health, better learning and awareness of the elements that contribute to sources of pollution is needed. Meanwhile, research has been conducted to evaluate people’s preferences for different sound sources caused by daily urban activities, transportation, for instance (Wu et al., 2019). In general, sound sources can be effectively arranged and combined to achieve more comfortable acoustic environments.

3.6.2 The Effects of Sound on Residents’ Perceptions of Environment

Sound has many impacts on the environment which are not easy to detect. It exists in human perception and sub-consciousness. Previous research found that sound sources dominated people's behavior and emotions (Zhang et al., 2018). Natural sounds can cause people to relax, and mechanical sounds and human-made activities can produce stress.

Assessment of acoustic environment has a positive correlation with the degree of relaxation. Based on the research result of Zhang et al. (2018), changes to soundscapes can improve the assessment of acoustic environment in public open space. Yu and Kang (2010) conducted a survey of sound preferences, and the results showed that preferences were mainly affected by age and education. The survey showed that sound preferences are not significantly affected by gender, occupation, or residence status.

Older respondents and those with higher incomes were more inclined to prefer musical environments, while low-income individuals were more likely to prefer the sound of human activity. Research by Szeremeta and Zannin (2009) in Brazil found tourists and local residents had different perceptions of comfortable sounds, that tourists are able to perceive abundant sound information, such as tone, volume, and timber, which have different impacts on tourists' satisfaction. However, people have different needs for sound different environments. For example, people prefer to hear clear broadcast sounds in a train station (Wu et al., 2020).

As crowd density increases, people's preference for sounds of broadcasts and human activity decreases. People's perception of sound is not only derived from hearing - but vision can also cause people to have different reactions and emotions in response to the same sound. As far as comfort is concerned, people liked to hear broadcast sounds (the announcements that staff made through broadcast at train stations) the most, while they are most irritated by mechanical sounds and the noise made by luggage case wheels in the train station (Wu et al., 2020).

3.6.3 Controlling the Acoustic Environment

Studying the acoustic environment is a complex and diverse subject. The control of the acoustic environment not only depends on legal protection and people's consciousness but also on scientific methods to avoid the impact of sound on humans. Ear protection and hearing aid products are constantly being developed and with the encouragement of the government in China, some manufacturers are also developing quieter tools and equipment, such as quiet air conditioners, noise-free refrigerators, electric cars, etc. These developments have drawn on studies of people's perceptions of acoustic environments, using space, background music, and density of people to eliminate the negative impacts of sound on people.

3.6.3.1 The Deployment of Music

Many researchers have investigated the effect of music in retail and hospital spaces (Yi & Kang, 2019a). Research on health care design and planning has shown that there is a close collation between human health and environmental characteristics, which supports Ulrich's Active Distraction Theory that advocates the introduction of soothing sounds (such as bird song, music, or water sounds) into hospital design to reduce stress in patients. Similarly, sound masking (an ambient background sound applied to match human speech frequency to achieve greater speech privacy) has been proposed, such as the use of sounds of the ocean, music, and random sounds to enhance the auditory quality of the design of hospital wards.

Music has been deployed for a long time to treat diseases and restore mental and physical harmony and has been shown to have a positive psychological, physical, and social impact on individuals (Arnett & Adolescence, 1991).

3.6.3.2 Elimination of Background Noise

Music can reduce blood pressure, stress, and post-operative trauma. Similarly, music has been utilized for treatment in a series of mental disorders, and according to a research of Chu et al. (2014), group music therapy can effectively reduce depression in the elderly with dementia.

On the other hand, noise is generally treated as a stress stimulus which can have negative psychological and physiological influences on people's health (Choiniere, 2010), and the subjective stress caused by a noise among employees and patients have been fully recorded and the potential for increased work stress, anger, and employee burnout has been identified.

Raimbault et al. (2002) reported that the perception of sound related to acoustic indicators like the standard deviation (a measure of the amount of dispersion or variation of a set of values) or background noise of short LAeq. Some landscape elements, such as greening measures and water areas, are able to adjust people's I perception of the acoustic environment. The natural sounds like running water effectively improve the AC in urban open communal areas.

3.6.3.3 Choice of Types of Music

Not all types of music produce good results, while life experiences, different musical tastes, and preferences can also greatly affect responses (Lundqvist et al., 2009).

In fact, if appropriate music is used, it can improve attention or stimulate the execu People who listen to music at high volume will have a noticeable hearing loss. They can't detect the weak sound that normal people can hear. In indoor environments, optional music can reduce social annoyance and nervousness. Music can promote communication between sales representatives and customers, which can increase the customer's willingness to shop and increase or decrease the possibility of personal exploration and browsing. Indeed, pleasant music will promote impulse sales, while music rhythm can affect customers' pace, increasing transaction speed.

3.6.3.4 The Use of Background Music in Public Environments

Yi and Kang (2019a) surveyed customer satisfaction and variable background music in public places in Harbin China. An excellent acoustic environment can bring people a sense of joy and satisfaction, and at the same time increase customer spending power and willingness to purchase. Whether indoor or outdoor, the design of the acoustic environment is imperative. It not only has positive effects on perception, enhancing people's QoL but also promotes economic development.

Mackrill et al. (2014) prepared steady-state sound clips, natural sound clips, and written sound source information to play in the Sound Room Laboratory in the UK. According to a previous study of Yi and Kang (2019) in public spaces in shopping malls in Harbin of China found that the background music (BGM) can significantly improve satisfaction and facilitate approach behavior; when there is BGM, the rating in large spaces is higher than that of smaller spaces; and when there is no music, men showed comparable higher rating than that of women.

3.7 Summary and Conclusion

This chapter presented the research theory for analyzing and optimizing the residential environment of senior facilities. Several well-prove rating strategies have been introduced and discussed, and examples have been illustrated to validate the assessment process. These methods play crucial roles in studying the needs of the elderly in the environment of senior facilities.

This chapter determines the follow-up research methods, including acoustic environment, lighting environment, thermal conditions, etc. Finally, the corresponding factors will be determined through observation of the activities of the elderly. For the acoustic environment, field measurements will be used to determine the reasonable sound, light, and heat settings by changing the sound settings, temperature, and lighting conditions in-site, observing the activities of the elderly and receiving feedback from the elderly. The method in this chapter will lay the foundation for the subsequent experimental process

4. Comparison of the Development of Chinese and British Aged Care Facilities and the Relevance to China

The RACFs as the main providers of social services in the pension system are an important part of achieving a comprehensive state-based aged care (Lu, 2015). As one of the countries with a high proportion of aging people, the United Kingdom has developed a system and model adapted to its own characteristics through decades of development. At the policy level, the British government has also developed clear relevant specifications and standards for the establishment of various kinds of accommodation for the aged. For the elderly with different health conditions and care needs, different types facilities have been established, such as community care and day care.

In this chapter, I first compare the differences between the RACFs in China and UK, then select representative aged care facilities in the UK for research, and explores useful inspiration for the construction of RACFs in China.

4.1 Comparing Studies of the Major Features of Chinese and British RACFs

4.1.1 The Framework for Comparison

According to a previous comparison (Mu & Kang, 2017), the difference in the overall spatial scale and spatial function of Chinese and the UK RACFs attributes to the different values, life habit and aging condition of these two nations. In this section, the current situation of RACFs, the relevant policies, and the various types of these RACFs in China and in the UK are illustrated and critically discussed.

4.1.1.1 Policy

Based on a Research Report on the Development of Chinese Pension Organizations (2015), in the current supply of senior care facilities in China, low-end and high-end senior care facilities are increasing, but the supply of mid-range pension facilities is still insufficient. Low-end pension facilities generally have low investment and relatively low operating costs to meet the needs of low-end pension services. High-end pension facilities run by companies with strong finances I attract high-income people to luxurious living environments and diversified pension services, but the high cost can only be afforded by a few elderly people.

The proportion of private RACFs is relatively small as most of the special elderly housing projects in UK are owned and operated by local governments, and the scale of the commercialized real estate market for the elderly is limited. In the UK, the government controls the structure of the entire social pension system. The British national medical service system, the NHS (National Health Service), undertakes the important task of protecting public health care in the UK (Taylor et al., 2007).

The Chinese government pays significant attention to the subsidy policy for the elderly, which is providing more affordable RACFs, and has gradually established an rating mechanism for these facilities. In 2019, Beijing promulgated the “Beijing Comprehensive Assessment Methods for the Capacity of the Elderly (Trial)”, to lay the foundation for a classification of pension facilities. Gradually, the use unified norms and standards in policies, operations, management, and supervision has been adopted to provide comprehensive guidance for the construction of pension facilities.

4.1.1.2 Types of Facilities

The types of RACFs in China can be roughly classified into three categories: residential care, supportive care and nursing care. The specific categories are elderly apartments, welfare homes, RACFs, and RACFs. However, the distinction between the functions of pension facilities of different types is not clear enough, and the recipients, services and functions are basically similar (Lin, 2008).

In the United Kingdom, a system of elderly care facilities for people with different conditions and needs, such as ordinary retirement homes, elderly apartments, RACFs, RACFs and additional RACFs, has been formed (Sun & Yang, 2011). The NHS and local government have established clear accommodation and service standards, according to elderly peoples’ different requirements. The elderly care facilities provide guidance to help the elderly and their families make decisions about which facilities suit their needs best.

The national health care system is managed by the Ministry of Health and Social Security and implements a hierarchical system. Primary health care (or basic health care) consists of family clinics and community clinics, and is responsible for providing community medical and referral services. In 1974, the United Kingdom established the Local Social Service Bureau. According to the division of functions, the Ministry of

Health and Social Security is mainly responsible for the management and supervision of the national health service system, and the Local Social Service Bureau is mainly responsible for the purchase of elderly services, the evaluation of services for the elderly, and the allocation of service resources.

After the elderly move in, the RACFs provide sufficient support while helping the elderly lives a more independent life. They ensure there are enough single rooms for residents' privacy, beliefs and spiritual needs and end-of-life care must meet the requirements of the Gold Standards Framework.

According to the British laws and regulations on community care, almost all communities are equipped with relevant auxiliary facilities, services and assistance policies for the elderly. The British Care Quality Commission (CQC) has established regulations and standards for elderly care services in England. The prospective and current residents and their families can check whether the facilities meet the various standards.

In addition to ensuring the overall thermal balance of the human body, the indoor thermal environment should also pay attention to the special temperature requirements of individual parts of the body, such as the head and feet. In addition, in addition to winter and summer air conditioning design conditions, the impact of local climate and internal load changes on the indoor temperature should be analyzed. Pollution-free sunlight is one of the good indoor light sources. However, a comfortable and healthy light environment should be convenient for reading control and adjustment. Therefore, the strong light should be adjusted according to different times and places to avoid affecting the high quality of sunlight.

The maximum noise in the living environment of the elderly cannot exceed 60 d during the day, and the recommended value is 50 dB; the maximum noise at night cannot exceed 50 dB, and the recommended value is 40 dB. National regulations stipulate that the living room (hall) of residential buildings should have direct daylighting, the daylighting coefficient of side daylighting should not be lower than 2.0%, and the indoor natural illuminance should not be lower than 300 lux [24]; for the aisle space, the side daylighting coefficient should not be lower than 1.0%.

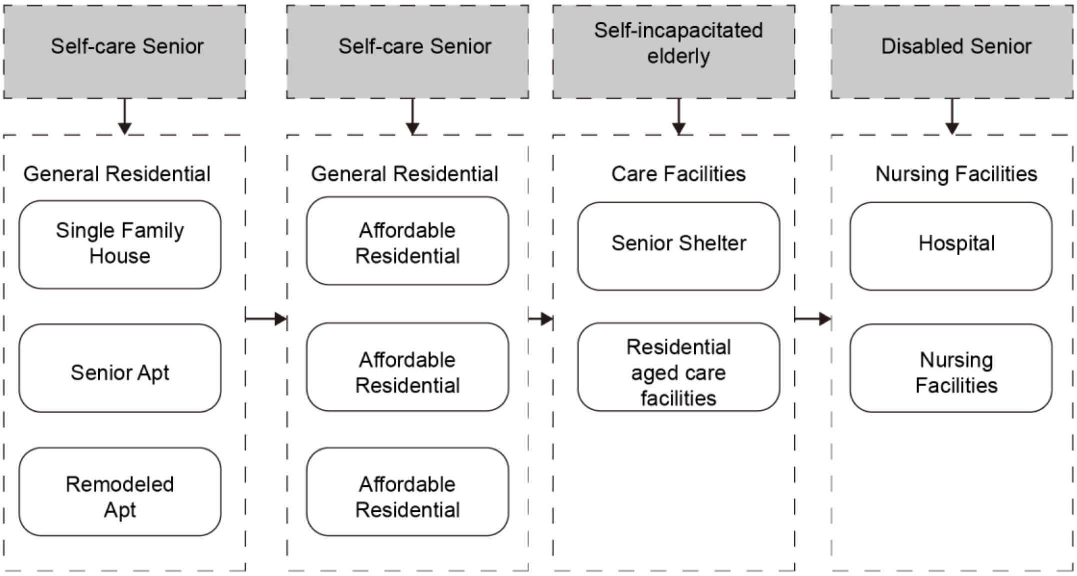


Figure 4-1 The classification and target groups of UK aged care facilities

In addition to the above classifications, the United Kingdom has also put forward clear standards and requirements for facilities, staff qualifications and other aspects of residential and RACFs. With the right qualifications and standards, aged care RACFs can be set up independently or in a form of the general RACFs (Table 4-1).

Table 4-1 Type of RACFs in the UK for different elderly

Types of RACFs	Indoor environment	The needs of elderly patients	Physical and Mental Conditions
Alzheimer Care Center	Appetite-stimulating environmental colors and activity rooms	Stable living environment and easy-to-use furniture	Alzheimer Seniors
RACFs for the disabled	Recovery training rooms and stepless slope	Barrier-free facilities and rehabilitation training	Disabled Seniors
RACFs for mentally handicapped	Containing a lot of reminders	Help in life and easy-to-use tools	Mentally Handicapped Seniors
Visually Impaired RACFs	Large characters and voice reminders	Visual aids	Visually Impaired Seniors
RACFs for the elderly with learning disabilities	A lot of learning space	Easy-to-use furniture and tools	Elderly with Learning Disabilities
RACFs for the elderly with reduced mobility	Recovery training rooms and stepless slope	Daily life, psychological care, and family support	Elderly with physical dysfunction

The classification of pension facilities in the UK is relatively clear, hierarchically ordered and targeted. From self-care elders to semi-incapacitated and incapacitated elders, senior care facilities at all levels can be targeted for the corresponding elderly people to select the ACFs that are best fit to their circumstances and demands (Rosenberg & Everitt, 2001), and transitions between different types of senior care facilities are possible.

The correspondence between the different needs of seniors in China and elderly care facilities is not strong enough, and he functions of different pension facilities overlap (Figure4-2). On the basis of the existing classification, China could further clarify the functions of pension facilities and refine their classification.

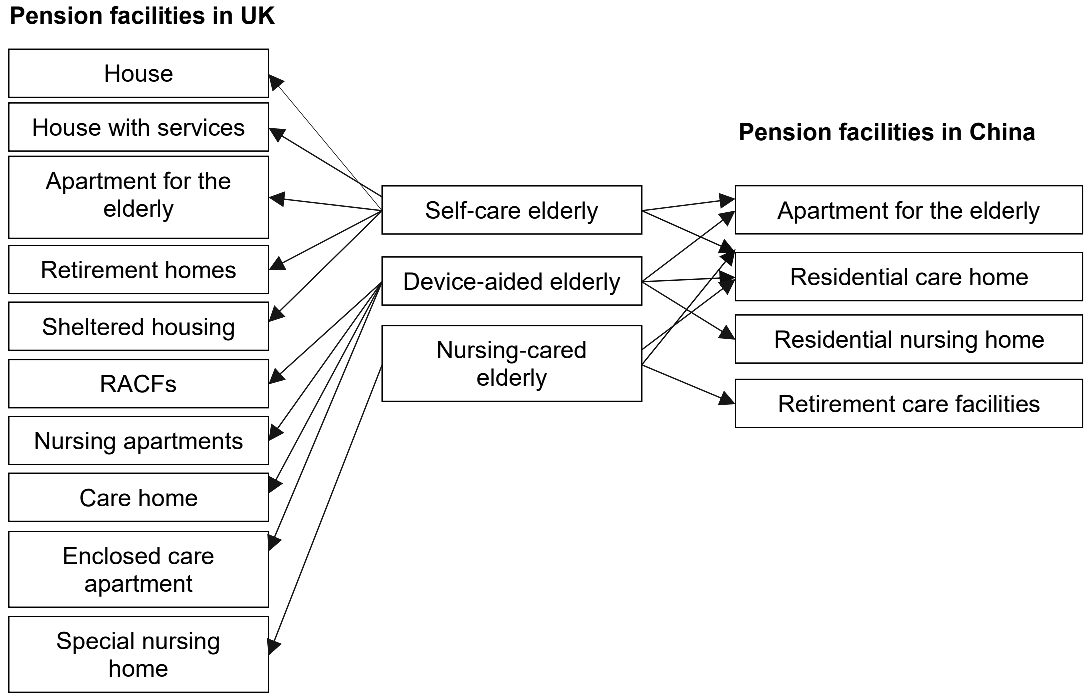


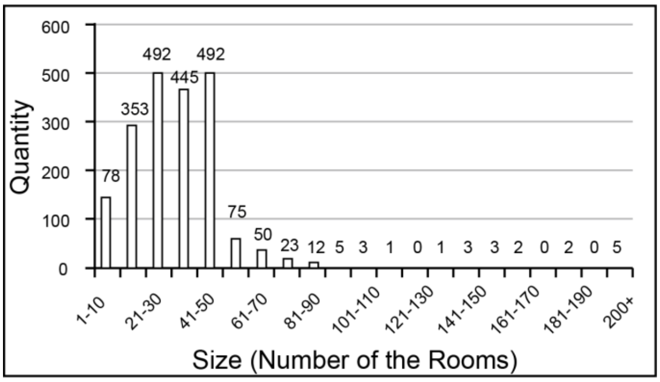
Figure 4-2 Comparison of the classification of Chinese and UK pension facilities

4.1.1.3 Scale and Location

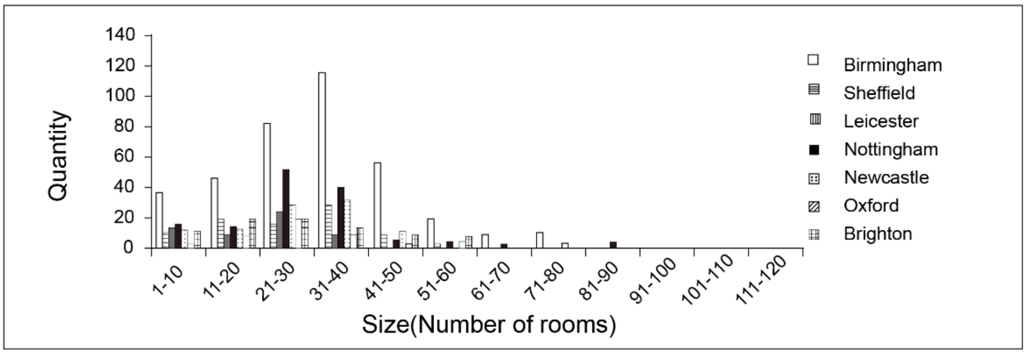
Many of the newly-built elderly care facilities in China in recent years are large-scale developments located on the outskirts of cities, most of which provide hundreds of beds. The characteristics of such facilities are: the location is on the outskirts of the city, the scale is large, and the supporting service facilities are comprehensive.

The advantages of site selection in the suburbs are that construction land around the city is more available and indicators of temperature, humidity and IAQ, in the suburbs are better than those in the city center. In addition, site selection can be combined with holiday accommodation and attractions in the suburb, and locations with surrounding scenic areas have become desirable locations to build elderly care facilities. From the perspective of operation, a large-scale pension facility is conducive to the centralized use of resources, and a larger numbers of pension facilities are also conducive to the development of a more comprehensive pension service.

The size of UK RACFs is generally small and the locations are diversified. For example, as an international metropolis, London has the largest concentration of urban population in the country, but most of the RACFs are built with no more than 50 rooms, and each room generally has one to two beds. The number of RACFs in different suburbs around London are roughly equivalent (Figure 4-3). Although the number of elderly care facilities in other cities in the UK is less than that of London, the scale ratio is almost the same as that of London. Most of the RACFs do not exceed 50 rooms, and few have more than 100 rooms (Figure 4-3).



(A)



(B)

Figure 4-3. Statistics of the number of apartments for the elderly in different sizes in London(A) and other cities in the UK(B)

(The Figure is based on the information registered on the website: https://www.carehome.co.uk/)

The comparison of the number and scale of RACFs in Beijing and London demonstrates that the number of the RACFs in London is equivalent to twice that of Beijing and the population of Beijing is about three times the population of London. The per capita share of RACFs in the city of London is about six times that of Beijing. RACFs of fewer than 50 beds make up the vast majority of facilities in London and there are no large RACFs with more than 200 beds. In Beijing, the majority of facilities are also under 50 beds, but the proportion is low. The proportion of large RACFs is larger than that of London (Figure 4-3).

Comparing the number and scale of RACFs between Sheffield and Shenyang, non-capital cities in China and UK shows that the population of Shenyang city is about 7.22 million in 2019 (statista, 2020), and the population of Sheffield is about 730,000 (UN, 2020). Sheffield and Shenyang have almost the same number of RACFs, however, the data still shows a large difference (Figure 4-4). The data of the number of ACFs of different sizes in Sheffield is similar to that of London, and the proportion of the number of RACFs of different sizes in Shenyang is also similar to that of Beijing. This indicates that compared with British cities, there are more large-scale pension institutions in Chinese cities, and per capita, fewer small and medium-sized pension institutions.

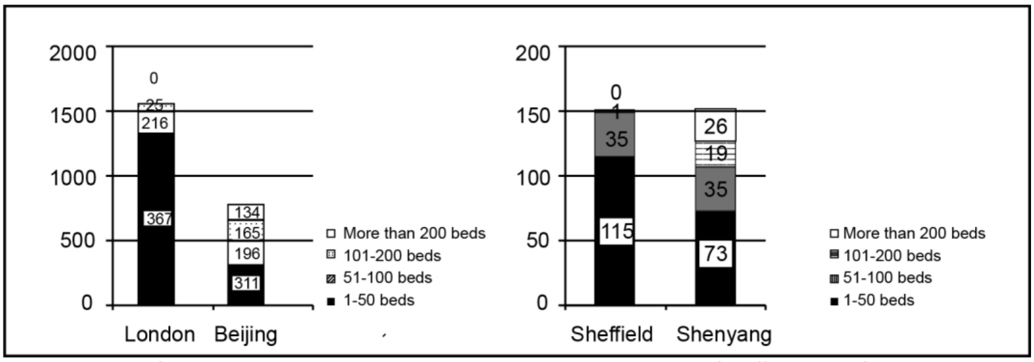


Figure 4-4. RACFs scale comparison between London and Beijing, Sheffield and Shenyang

(The Figure is based on the information registered on the website: https://www.carehome.co.uk/)

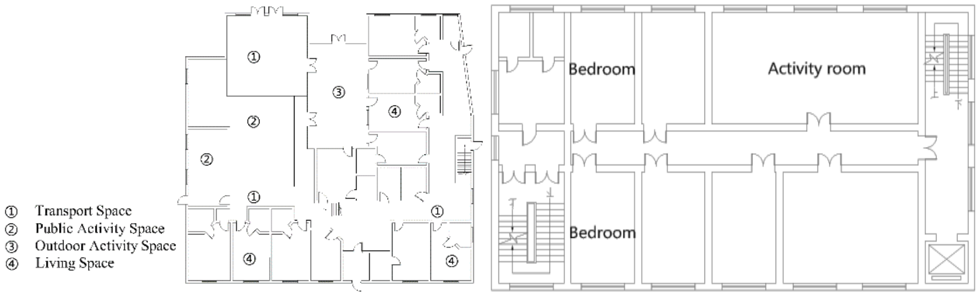
Independent elderly people want to live in or close to a community they are familiar with. Therefore, it is generally better to choose elderly care facilities in urban residential areas. In this way, it is possible to gradually establish elderly care service facilities in the ordinary residence communities, mainly based on small-scale elderly care facilities distributed throughout urban residential areas, so, as to make better use of urban public resources and save the cost of elderly care.

4.1.2 Comparison of Building Space Patterns

4.1.2.1 Small-scale Pension Facilities

Small-scale pension facilities have fewer people living in them, the layout of the space is more flexible, and it is easier to create a living environment with a family atmosphere. Figure 4-5A is a plan view of the Heatherwood RACFs in the United Kingdom. This is a typical layout pattern of elderly care facilities, so it can be analyzed here. If it is a special case, there is no analytical value. The core area of this small residential aged care facility is the integrated living area, including the foyer, event space and dining area. The individual units of the elderly surround it, and residents can gather in the living room at the same time. Floor-to-ceiling glass doors are used to separate the living room from the outdoor garden. The several spaces are connected to each other and the line of sight is transparent. The outdoor garden is not only a landscape, but also an extension of the living area. The indoor and outdoor spaces combine organically and penetrate each other. Family-style space organization creates a warm atmosphere for this small pension institution. Figure 4-5B is a plan view of a small pension facility in Changchun, China. The building adopts a linear layout with elderly bedrooms and activity rooms on both sides of the corridor. Among them, the south-facing rooms are arranged with bedrooms as much as possible, and the concentrated activity room is in the north room. More rooms get good lighting, and the indoor and outdoor spaces are clearly separated. But the space lacks fun. The south-facing rooms are arranged with bedrooms as much as possible, and the concentrated activity room is in the north room. More rooms get good lighting, and the indoor and outdoor.

It can be seen from the figure that the UK RACFs have more rooms, more detailed area division, and rooms are basically connected to each other, which has higher requirements for sound insulation. However, China's RACFs have fewer rooms, and the types of rooms are not many, and most of them are separated by a corridor. Based on this design, the mobile room does not seem to affect the bedroom, but in fact, the sound insulation conditions of domestic RACFs still need to be improved, and the control of sound is a problem that every elderly care institution must consider. Moreover, lighting, heating in winter, air quality and other issues are also very interesting. Therefore, this article will explore the above factors.



(A) (B)

Figure 4-5. Space organization of a small residential aged care facility in the UK (A) and in Changchun (B)

4.1.2.2 Large-scale Pension Facilities

The characteristic of the spatial organization is that the circular plan is divided into several sections by several integrated living units, and each integrated living unit serves one of the sections. According to the detailed drawing of the integrated living unit, it can be seen that the unit forms several highly intensive core areas on the plan integrating functions such as catering, leisure, bathing, storage, and office. By inserting such a unit into a flat surface, daily activities can be concentrated efficiently.

British seniors live relatively private rooms comparing to whom in China, and daily interactions take place in the common living room. The elderly in China attach more importance to sunlight, and there are fewer public activities. Except for some chess and card activities, daily exchanges will be conducted in the form of mutual visits to a resident's room.

Certain small-scale pension facilities in China pay more attention to economy than to quality. They tend to adopt a simple spatial organization, inclined to the architectural model of hospitals or collective dormitories (Zook et al., 2012). The British small-scale pension facilities pay more attention to the creation of a family atmosphere, and the space is more like a residence than an institution. The spatial layout tends to reduce the sense of scale of the building space, forming a small living group. In UK, large-scale elderly care facilities pay more attention to the layering of the space. Small-scale elderly care facilities pay more attention to the flexibility of the space. It could be said that large-scale pension facilities are composed of several small-scale pension facilities. China's elderly care facilities tend to focus more on the acquisition of explicit indicators, such as sunlight, area, and economy, but they do not pay enough attention to some less measurable indicators such as spatial quality. Some large and small old-age care facilities may equally adopt the form of public buildings in which it is not easy to form a small-scale living space, and public communication space is also slightly inadequate.

4.2 The Relevance for China of RACFs Development in the UK

The elderly in China live in old-age institutions in order to receive old age services. However, most elderly people in China would prefer to live with their children in the community environment they are familiar with, as their physical circumstances permit. The kind of living form can satisfy old people's desire for independent life but at the same time, allow them to obtain suitable services is a contradiction to be resolved urgently.

Through the investigation of domestic and foreign RACFs, it was found that the independent seniors staying move to pension institutions in order to obtain services such as catering, laundry and life assistance.

Independent seniors could extend their time living in their communities if these needs were met; and this will become a transitional living model for the independent elderly. When the elderly are unable to take care of themselves, they would be able to move to a residential aged care facility to receive professional medical and social care services suitable for their needs which would be a better allocation of social pension resources.

The UK's exploration of the retirement housing model is relatively mature than that of China and a diversified old-age living model meets the various living needs of elderly people. This type of aged care facility provides the residents with better autonomy, privacy, and more economical, which is suitable for China to satisfy the current needs for RACFs (Mu et al., 2017). A guaranteed elderly apartment (sheltered housing) is a unique old-age housing model created by the United Kingdom (Lu, 2015), suitable for the elderly who can live independently. China is currently conducting research into and analysis of old-age care facilities.

The next section covers the development history and architectural features of RACFs in the UK, and by analyzing the architectural forms and models, examines forms of affordable elderly housing facilities that satisfy the needs of the elderly in China.

4.2.1 The History of the Development of RACFs in the UK

The UK has a relatively more explicit and comprehensive pension system comparing with China. First, the UK has established a home care service system by the support of community care. It provides varied and sufficient services for the independent elderly who can take care of themselves. At the same time, it has also formed a system of elderly care facilities with various conditions, such as retirement homes, elderly apartments, and RACFs (Dong, 2005). According to the physical condition of the individual, clear occupancy and service standards have been formulated to ensure that the elderly receive the appropriate services. The elderly can generally find suitable retirement facilities according to the standards. The aged care facility is a kind of old-age living mode between home-based and institutional old age. In recent years, the community pensions established in the United Kingdom have also challenged these original pension facilities because the senior are now more able to reside in the community with the support of elderly care services, rather than moving to an elderly care facility early.

The United Kingdom has formed an old-age housing system for home-based elderly care, affordable elderly apartments and elderly care institutions. The system provides various models to cover the different elderly people with different needs of caring and facilities in the country.

(a) Origin and Development

The affordable senior apartment in the United Kingdom is a transitional form of accommodation between independent housing and institutional care.

After World War II, both the government and society were facing huge pressures for old-age care. There was an urgent demand for transitional old-age care facilities to satisfy the needs of a large number of seniors at low cost, and due to the loss in World War II, the government and society couldn’t build the comprehensive forms of RACFs to satisfy all the elderly (Surong, 2010).

In the late 1950s, many single elderly people occupied large houses in public housing estates, but there was also strong demand for public housing for larger families. The affordable senior apartment is a form of residence for the elderly proposed in UK in the 1860s to enhance the QoL of the elderly (Gomez et al., 1991).

After World War II, many other developed countries focused on housing policies for the elderly, usually in two types of accommodation:

(1) Elderly people with low incomes but able to live independently but needing a decent and affordable apartment;

(2) Elderly people suffering from chronic diseases and disabilities, needing physical care and daily assistance (Noam, 1976).

The emergence of RACFs provided a suitable aged-care model for low-income elderly at the time. By combining apartment rental and elderly support services, elderly people could be provided with independent living environments and suitable services. The vast majority of RACFs are owned and operated by private institutions. The elderly have long-term leases without needing to buy property. RACFs have long been recognized by pension professionals and government policy-makers as a form of housing that best meets the living needs of the elderly. The United Kingdom has the largest number of affordable senior apartments in Europe (Fairhurst & Eileen, 2000) which reduce the high cost of long-term traditional elderly care for the elderly and society. Meanwhile, the affordable old-age apartment also provides security for the old people. People are able to live in a familiar environment, and there can be a transition to care facilities in the future.

After about 30 years of increases in building RACFs, the size of stock in the UK was already stable in 1980. There are approximately 465,000 such retirement facilities in England, and these apartments have become the most common type of pension facility in the UK (Heumann, 1980).

Later, other Western countries borrowed from the British experience to develop affordable senior apartments.The interior and exterior view and floor plan of a newly-built affordable senior apartment in Paris are similar to those in the United Kingdom, adopting small-scale buildings to provide a family-oriented living environment. At the same time, the apartments provide communal activity space for residents to use together. In these areas, there are help desks for residents.

(b) Basic Characteristics

RACFs units are generally small with a simple layout. Equipped with functions such as laundry room, restaurant and communal activity room, the apartments satisfy the needs of the elderly's daily basic life and social interaction. The development has administrators and service personnel available to meet residents' needs. This kind of apartment ensures that the elderly can afford it while the service provided is satisfied, which meets the living needs of the majority of self-care elderly in the city.

RACFs are mainly for the independent elderly or who occasionally need short-term care (Heumann, 1980). Each household is relatively independent, and the elderly can live according to their own habits, without the influence of various management constraints and restrictions. The administrator is only responsible for the management of the apartment and does not intervene in the life of the residents.

The apartment is equipped with an emergency call system to assist the elderly in case of emergency or accident.

In the UK in 1988, at first 85% of the RACFs were established by the government, and 15% were built by non-profit institutions (Weal, 1988). RACFs owned by the government and non-profit organizations, and is rented or leased to eligible residents, meaning they do not need to finance mortgages late in life.

(c) Types of Accommodation

In 1967, the British government promulgated design standards for the first RACFs. These standards determined the detailed requirements of architectural designs for the two types of RACFs, which include independent living without management personnel and communal facilities (Beckman, 1969).

Currently, RACFs in the UK are divided into three categories: residences for independent elderly, staffed with administrators; accommodation for frail elderly people who need auxiliary facilities and services but less independent living space, so communal space is increased; accommodation for the elderly with special services and care, based on the second category (Zhang et al., 2012).Issues Emerging over Time In the beginning, RACFs were very popular, but gradually there were voices of doubt. People were concerned about whether the design of RACFs could really meet the needs of elderly care.

Explorations showed that the original concept of RACFs was no longer meeting the needs of the elderly, and many apartment managers believe that there needed to be special RACFs designed to serve people with specific needs (Tinker & Anthea, 1991). Therefore, new and more diversified affordable old-age apartments came into being, which provided people for whom the standard apartments were not suitable for the elderly to continue living independently (Hanson, 2001). More and more managers came to believe that the development of RACFs should ensure a balance between suitability for active and inactive elderly.

In the UK, RACFs have dominated the pension market for decades, but recently there are signs that this dominance in the pension sector will give way to home community care. With the development of home care for the elderly in the United Kingdom and excessive construction in some areas, some affordable old-age apartments face difficulties being rented out (Tinker, 1997).

In China, although community care has been carried out in some regions, it is still too early for professional teams to spread it on a large scale. Until then, there is still a need for RACFs.

4.2.2 The Business Model and Economic Indicators of RACFs

4.2.2.1 Business Model

In the UK, there are four main sources of the supply of RACFs. They are: local governments, housing associations, non-profit organizations, and private developers. These are different ways to provide RACFs, as shown in Table 4-2. These four supply sources have different business models.

Table 4-2 Four types of resources of affordable senior facilities

(The table is based on the information registered on the website: https://www.carehome.co.uk/)

Sources	Local Government	Housing Association	Volunteer Organization	Private Developer
Supply Method	Rent	Sale or Rent	Rent	Sale

Local governments generally cooperate with housing associations to formulate more detailed distribution policies for the RACFs they provide, to ensure that the elderly who are economically and healthily underprivileged can be given priority to be admitted (Clapham & David, 1997). Policies tend to give priority to providing RACFs for people living in the local area so that the elderly can live as long as possible in the community environment they are familiar with. As non-profit organizations, Housing Associations allow the elderly to purchase part of the property rights. When the elderly leave the apartment in the future, they transfer their property rights to the next occupant.

The proportion of RACFs built by private developers is relatively low, and most of them are sold rather than rented. However, because of the better quality of the houses and living environment, they are very popular with the elderly who can afford them (Parry & Thompson, 1993).

4.2.2.2 Construction Cost

Table 4-3 shows a building cost model of a three-story elderly apartment in northern England. The building has a total construction area of 6,855m^2 and contains 77 one- or two-bedroom apartments. The Table shows the construction cost of this type of elderly apartment and the proportion of various aspects of the cost.

Table 4-3 Building cost model of an old senior apartment in UK

(The table is based on the information registered on the website: https://www.carehome.co.uk/)

Project	Cost（Pounds）	Percentage（%）
Site Construction	673350	8.83
Framework	411720	5.40
Roofing	277242	3.64
Stairs	42525	0.56
Exterior Doors and Windows	786980	10.32
Interior Doors and Windows	608515	7.98
Wall Decoration	376455	4.94
Floor	124460	1.63
Ceiling	179549	2.36
Infrastructure pipeline	342231	4.49
Janitor tools	152500	2
Mechanical Facilities	2261850	29.67
Design and construction costs	1385038	18.17
Total	7622668	100

4.2.2.3 Financial Assistance policy and Living Cost

If the low-income elderly who apply RACFs are eligible for government subsidies, 70% of their living expenses can be covered. Local government has fixed welfare expenditures each year to support the elderly in various types of elderly apartments (Tinker & Hanson, 2007) Local governments and non-profit housing associations enable the elderly to purchase property rights of RACFs at low prices. Generally, properties are sold to the elderly at 70% of the property price of the market price. The British government introduced a new housing subsidy policy in 2016 and from 2019, the ceiling of housing subsidies in various places will no longer be applied to RACFs that already have housing subsidies. At the same time, starting from 2017, the rent for RACFs was gradually reduced.

Monthly rents for RACFs range from £300 to £700 in 2020 and additional administrator or emergency cost an additional £90 a month; the weekly cost of nursing care is about £480-640 and the total annual cost of nursing care is about £28,500. This cost is an annual cost, part of which is borne by insurance and the government, and the elderly only need to bear part of this cost (Fedration, 2020).

In China, the fees of RACFs are usually divided into nursing expenses, housing expenses, and food expenses (Shum et al., 2015). Nursing fees will vary depending on the elderly's ability to take care of themselves, usually between 320 yuan and 800 yuan. Housing costs range from 300 yuan to 1,000 yuan. The rooms are divided into single rooms, double rooms, and multiple rooms. The more people in the room, the lower the price. As for food expenses, it is set on a non-profit basis and charged according to the actual situation (Fitzpatrick et al., 2016).

The service expenditures in RACFs are relatively low comparing with that of China. The elderly can afford the apartment while having access to the services. Therefore, in terms of service cost, living in RACFs is a great choice for the elderly if their physical condition permits.

4.2.3 Analysis of the Architectural Characteristics of RACFs

4.2.3.1 Design Principles

The purpose of RACFs is to support the independent seniors with a high-quality living environment. To ensure the autonomy of such people, meanwhile, emphasise should be made to protect their privacy, and staff should minimize their involvement in the life of the elderly. This not only maintains the independence of the elderly, but also reduces the financial and mental burdens of elderly living, enabling the elderly to live in a familiar urban environment as if they were living at home. Thus, RACFs must comply with the above design principle in terms of site selection, layout, and functional configuration.

In the following sections, the scale and location of RACFs in UK and the city of London are demonstrated, as well as the distances towards the city center by RACFs in small and medium-sized cities in the UK. The overall arrangement of affordable elderly facilities will be illustrated by comparing the floor plan of three of these facilities in UK.

4.2.3.2 Scale and Location

First, as shown in Figure 4-3, the size of RACFs in British cities is mostly fewer than 50 units. Large, medium and small cities have shown consistency in the scale of RACFs. Since the population of London is much larger than other cities, the total number of RACFs in metropolitan London is significantly greater than in other cities (Figure 4-3). Second, as shown in Figure 4-6, the vast majority of RACFs in small and medium-sized cities are within five miles of the city center, and mainly within two to three miles. As shown in Figure4-7, London has a larger urban area, and the distribution of RACFs is more extensive with most of the affordable senior apartments being within 10 miles of the city center.

According to the characteristics shown in the data, the layout of the RACFs are closely related to type and style of the residential area. The combination of RACFs and residential communities is conducive to the formation of an old-age residence system composed of ordinary houses and RACFs. Such a system of coexistence in the community is a guarantee for the elderly to live in peace.

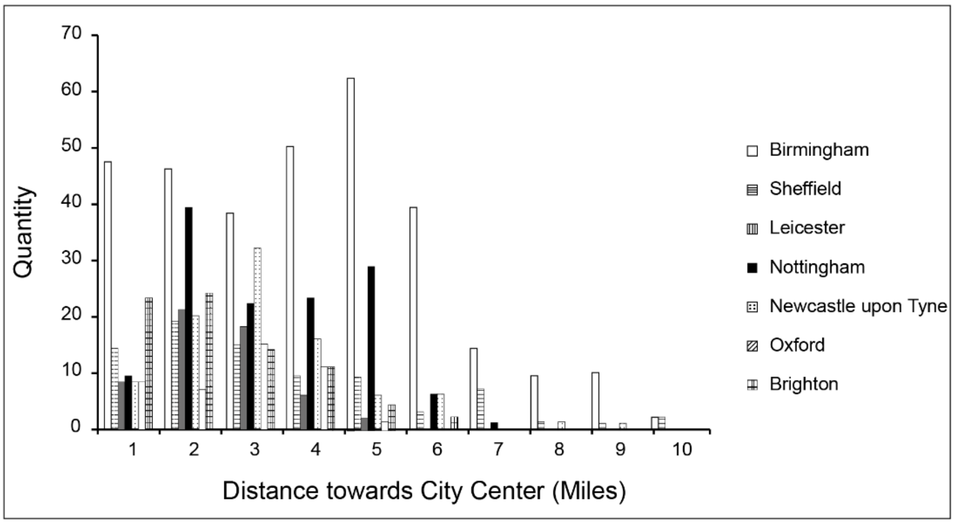


Figure 4-6 Distances towards the city center by RACFs in small and medium-sized cities in the UK (The Figure is based on the information registered on the website: https://www.carehome.co.uk/)

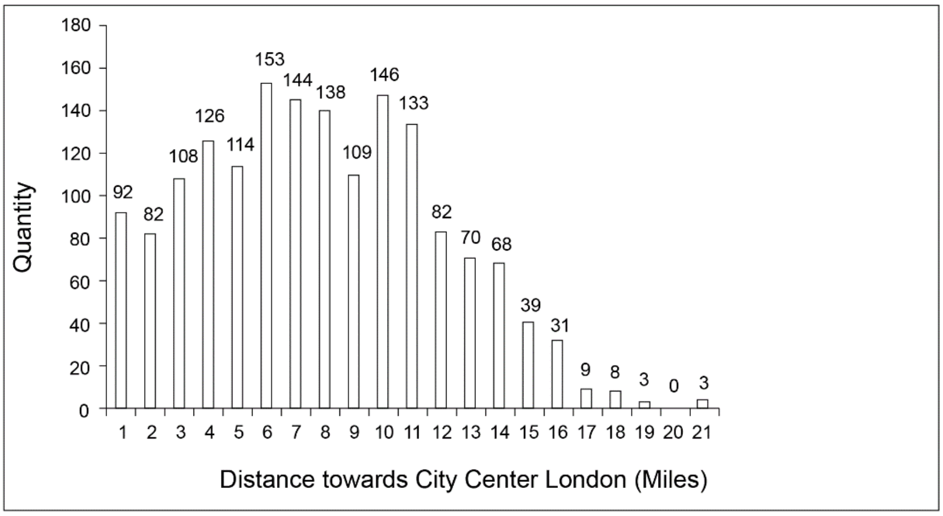


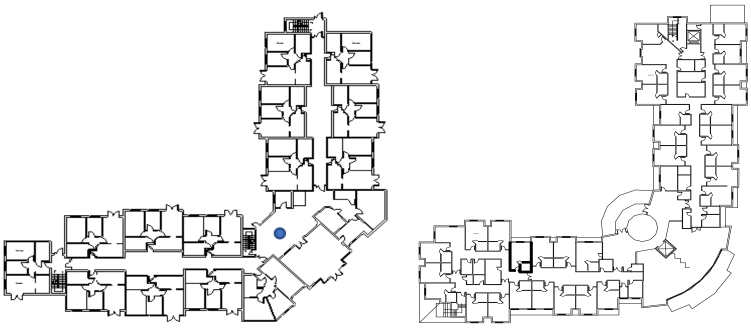
Figure 4-7 Distances towards the city center by RACFs in small and medium-sized cities in London (The Figure is based on the information registered on the website: https://www.carehome.co.uk/)

4.2.3.3 Overall Arrangement

Affordable senior apartments include residential units and shared spaces within apartments. The living units are mainly single rooms, and the shared areas mainly include: common living room, dining room, laundry room and management room. As shown in Figure 4-8a the floor plan of the apartment is "L" shaped, and the living units on both sides are arranged in rows and columns, and around a centralized shared space.

Figure 4-8b is a standard plane of a residential aged care facility in the United Kingdom. It can be noticed from comparison with figure 4-8a that the residential aged care facility has a nursing station (blue), but the RACFs does not.

Figure 4-9 shows the standard floor plan of another affordable senior apartment. There is no centralized shared space, but a smaller shared living space. Setting the service room and management room at a location to enable the staff easily access each residential unit for services.



(A) Standard floor plan of affordable senior apartment in UK

(*http://agdesignltd.co.uk/portfolio.html*)

(B) Standard floor plan of affordable senior apartment in UK

(*http://grahamcare.co.uk/developments/hawk*hurst/)

Figure 4-8. Comparison of the floor plans of two senior facilities

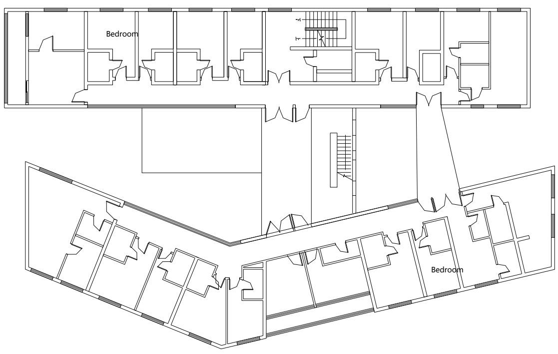
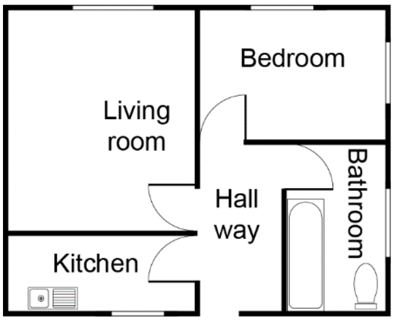


Figure 4-9. Floor plan of an aged care facility in UK

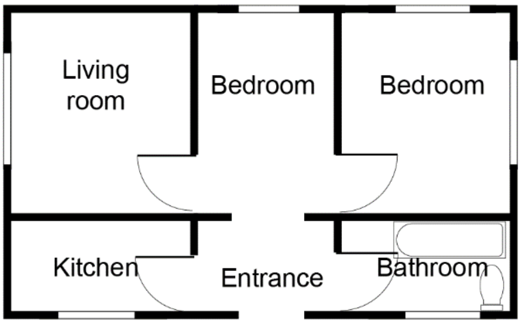
(*http://www.theplan.it/award/2015/health/psychiatric-center-and-sheltered-housing*)

4.2.3.4 In-suite space model

According to the investigation case, the following common nested space organization models can be summarized



(A)



(B)

Figure 4-10 Interior layout of both types: centralized (A) and paralleled (B)

(Eddison, 2016)

(a) Centralized.

It is centered on the foyer, and other functional spaces are arranged around the foyer. This type of apartment is generally small in size, so the layout is more space-saving.

(b) Paralleled.

Main spaces such as the living room and bedroom are arranged next to each other, and auxiliary spaces such as the kitchen, bathroom and entrance hall are arranged close to each other. This type of apartment is generally large and can be extended to both sides.

The two types of construction styles are relatively simple, and the layout is compact, which is convenient for forming the complete unit and the overall arrangement of space.

The following features of the rooms in the RACFs suite are summarized: The room is small but multi-functional. The rooms are generally small in size, but all basic functions are readily available, such as fitted cupboard, televisions, fireplace, etc. The elderly do not need large rooms to meet the needs of their daily lives. Having a smaller space reduces the cost of living, and can be more suitable for the physical weakness of the frail elderly.

The RACFs pay more attention to public living space than that of ordinary apartments. Compared with ordinary apartments, the shared space in RACFs development is more important. The daily life of the elderly is spent in the shared space of apartment during the day; therefore, enough shared space is needed for social activities to promote public communication among them. As shown in Figure 4-11.

(A) Communal living space

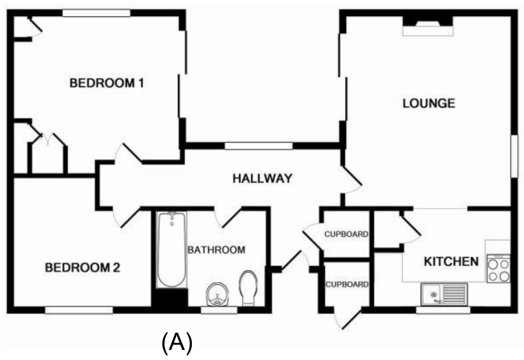
(B) Communal living space

Figure 4-11. Living room of the affordable senior facilities
(NWH, 2020)

The relatively independent living units ensure privacy. This layout also guarantees the family living environment of the RACFs and softens its institutional attribute to create an atmosphere of family life for the elderly.

4.2.3.5 Function Configuration

The rooms of the RACFs mainly include: bedroom, living room, kitchen, restroom, storage room, and entrance hall and transportation space. In a more compact and intensive way, it provides the elderly with the core functions necessary for daily life.



(A)

(B)

Figure 4-12. Basic Floor plan

A: (LADDER, 2013) B: (Eddison, 2016)

The bedrooms of affordable senior apartments are generally 1-2. As shown in Figure4-12. Suite A has two bedrooms and Suite B has one bedroom. One of the two bedrooms can be used as a sitting room.

(A)

(B)

Figure 4-13. Bedrooms

A: (Agents, 2013) B: (NWH, 2020)

The living room is the main space for the daily life of the British elderly. As shown in Figure 4-14, the general area is large, and it accounts for the largest proportion of space among various rooms. At the same time, the living room and the kitchen are arranged adjacent to each other, which save space and facilitates dining, as shown in Figure 4-13.

(A)

(B)

Figure 4-14. The living room is the main daily living space for the seniors

A-http://agdesignltd.co.uk/portfolio.html *B-http://grahamcare.co.uk/developments/hawkhurst/*

A

B

Figure 4-15. The kitchen is small and the functional design is relatively intensive
http://www.theplan.it/award/2015/health/psychiatric-center-and-sheltered-housing

The required facilities are provided in the bathroom. Since the elderly who are able to take care of themselves do not need too many barrier-free facilities, the design of the bathroom only needs to meet normal functional and safety needs, similar to an ordinary apartment, as shown in Figure 4-16.

Figure 4-16. Bathroom

(LADDER, 2013)

The storage room is generally off the corridor or hallway. Although the space is not large, storage space is still indispensable for the elderly. It can be used to store sundries and is far away from common areas of life, so it will not affect the daily life of the elderly.

4.2.4 Possibility of Developing RACFs in China

4.2.4.1 The Basis for the Development of Affordable Apartments in China

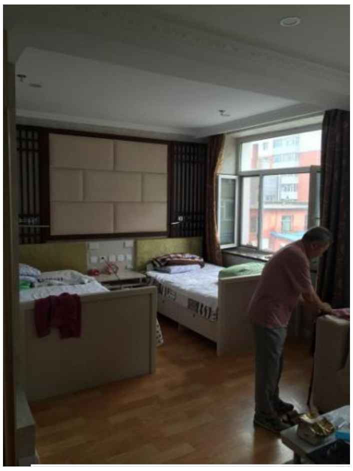
The current national situation of China's aging population is that the elderly generally cannot afford the cost of high-end elderly care facilities. The aging population in China is large and its aging rate is fast. Due to the "4-2-1" (4 grandparents, 2 parents, 1 child) family structure, the family's ability to care for the elderly is weakened, and the demand for social aged care services is gradually increasing.

Self-care elders are still the majority of the elderly population at present, accounting for 91.1% of the elderly population (https://www.unforgettable.org /blog/comparing-the-cost-of-care-at-home-sheltered-housing-and-care-homes/). There is a great demand for simple life services and less so for professional care. But at present, a large number of elder care facilities in China are medical-related facilities. Meanwhile, the financial situation of a large number of elderly people is low.

The difference between China’s existing senior apartments and the ideal RACFs is not clear. There is centralized management of institutional residential facilities and their attributes are closer to care homes in the UK. Yet, the construction of affordable senior apartments is relatively simple and poor comparing with that in the UK, and is suitable for simultaneous construction in the development of urban residential areas. Consumers are gradually paying more attention to suitable houses for older people and the construction of RACFs can improve the quality of residential development: from the perspectives of the government, residents and developers, RACFs will be welcomed by the market.

4.2.4.2 Attempts to Build an RACFs in China

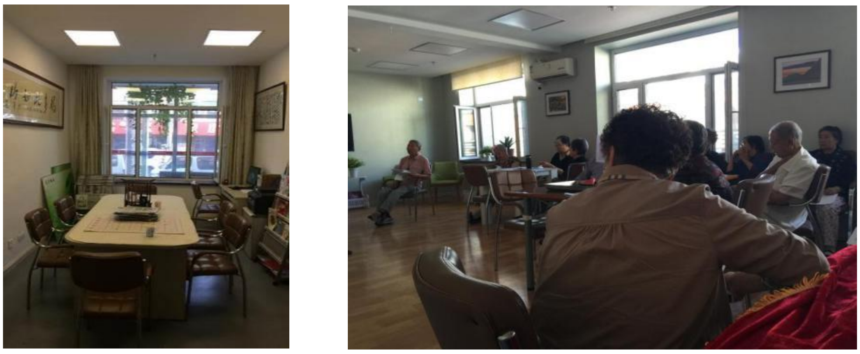
Through the survey carried out in this research, it was found that with the increasing demand for RACFs in China, some of the accommodation being offered already has a number of the characteristics of RACFs which have been positively evaluated by resident occupants. Figure 4-17a shows the living space of an elderly apartment in China. The suite is compact, with the bedroom and living room in one space. In the building, functional spaces such as shared activity rooms and reading rooms are concentrated together. As shown in Figure 4-17b, the elderly are able to carry out activities according to their own interests in the shared activity space. The apartment provides laundry and catering services. The elderly can also choose health care and rehabilitation services according to their needs. The apartment is located in a residential area in Harbin and the surrounding area has easily available supporting facilities. Elderly people living here generally feel that they can live independently, and they do not have a heavy financial burden. They can get the services they need every day and can easily go out and integrate into city life.



(A) Bedroom

(B) Living room

Figure 4-17. Private space of type A apartment in China (Photos taken by the author)



(A) Reading room (B) Recreation area

Figure 4-18 Public space of type A apartment (Photos taken by the author)

Figure 4-18 is a photo of the living space of another senior apartment of Type B. The apartment is located close to the city's central business district and in a high-end development. Compared with that of Apartment Type A, the space of the elderly apartment Type B is larger, the design is more like a residential unit, and is more comfortable. Figure 4-19 shows the shared activity room of an apartment Type B. In addition to the seats, simple dining facilities are also set up. Similar to the configuration mode of the British shared living room, the elderly can prepare drinks and light food and create more possibilities for daily social activities. The apartment complex is large and provides a variety of activity spaces such as rehabilitation rooms, calligraphy and painting rooms. The quality of the living environment is good, but the residential fees and costs of living are relatively high, and the elderly with ordinary incomes are generally unable to afford them. And because these better-off elderly residents can afford it, if they get sick, they tend to go directly to the larger hospitals the supporting community hospitals are not used.

(A) Bedroom (B) Living Room

Figure 4-19 Private space of senior apartment in China
(Photos taken by the author)

(A) Tea Room (B) Recreation Area

Figure 4-20 Public space of type B senior apartment (Photos taken by the author)

At the current stage in China, although there is a great demand for elderly apartments, it is necessary to take into account the long-term development and the parallel development of community home care and elderly care models, in other words, the construction of RACFs should not be rushed blindly, that it is essential to take into account the long-term development and the parallel development of community home care and elderly care models.

4.3 Impact of Policy on the Development of Chinese Pension Agencies

4.3.1 China's Development Policy for Pension Agencies in the Past Decades

Since the "Twelfth National Five-Year Plan for China's Aging Population Development" issued by the state in 2011, which proposes the establishment of a home-based, community-based and institutional-supported pension service system, all cities have vigorously developed policies for elderly facilities and services by encouraging capital investment into the pension field.

The government has stepped up its efforts to support social organizations in setting up or operating public welfare aged care institutions since the initiation of the "Twelfth Five-Year Plan", and to support private capital investment in the establishment of specialized aged care service facilities. In 2013, the Ministry of Civil Affairs announced the "Measures for the Establishment of Pension Agencies" to further relax the access requirements for the construction of pension institutions.

The "Implementation of Encouraging Private Capital to Participate in the Aged-Care

Industry Development" issued in 2015, proposes to carry out the pilot work of transforming public pension institutions into enterprises or social organizations (Zhang, 2015).

The "Several Ideas on systematically Opening the Aged-Care Service Market and Enhancing the Quality of Aged-Care Services", issued in 2016, states the aim to "Simplify procedures for the establishment of for-profit pension institutions" (Zhuang, 2017).

The 2017 "Notice on Printing and Distributing the Thirteenth Five-Year Plan for the Development of the Aged Enterprise and the establishment of the Pension System" proposed that private capital, private business and even public citizens should all make contribution to the establishment of pension institutions to further liberalize the access conditions and enhance the support and service guidance for the establishment of RACFs (Wen, 2019).

In 2018, the "Implementation Plan for Improving the Mechanism and System for Promoting Consumption (2018-2020)" was issued, proposing to abolish the establishment permission of pension institutions, which means that since then it is not required for private organizations to obtain permission from governments to establish RACFs (He, 2018).

As can be seen from these policies, the national level encourages private business to develop the establishment of RACFs by gradually relaxing the requirements to get permission from the authorities. These policies have resulted in a significant rise in the number of RACFs and the number of beds in these facilities. Civilian elderly institutions occupy a large proportion of urban elderly institutions. As shown in Figure 4-21, the RACFs in major cities in the north make up a great percentage of the general population in China.

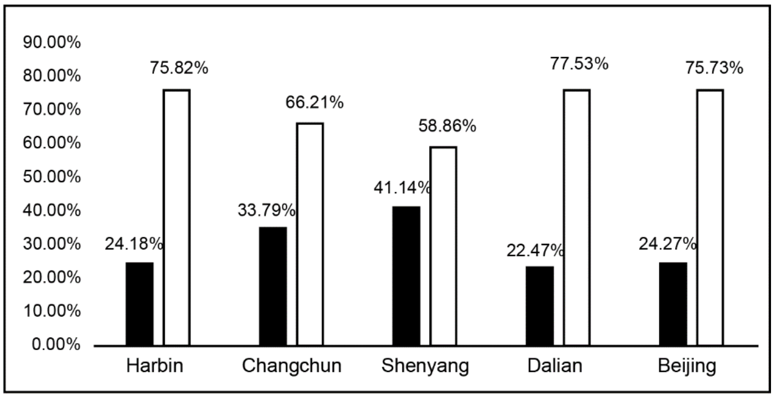


Figure 4-21. Proportion of state-owned and private pension institutions in major cities in northern China

(The figure is based on the information registered on the website: http://www.yanglaocn.com/)

4.3.2 Contradictions in the Development of Pension Institutions

Despite the increase in the number of aged care facility beds encouraged by the policy, there are still a great number of seniors who have not been able to get places in RACFs. According to statistics, there were about 3.33 million seniors in Beijing till the end of 2017 ("White Papers of the Chinese Government," 2018), of whom about 17%, or 520,000, require professional care, and best given RACFs. But only 41,000 people are accommodated in RACFs. The proportion of met demand is less than 10%, yet only 10% of RACFs in Beijing have reached 100%, occupancy rate, while the average occupancy rate of all pension institutions is only about 50% (Table 4-4). This shows that on one hand, a great number of seniors who are in need of care are not in RACFs; and on the other, the occupancy rate of RACFs is generally low, with a large number of vacant beds.

Table 4-4 Statistics on the occupancy rate of elderly care institutions in Beijing（2018）

(The table is based on the information registered on the website: http://mzj.beijing.gov.cn/)

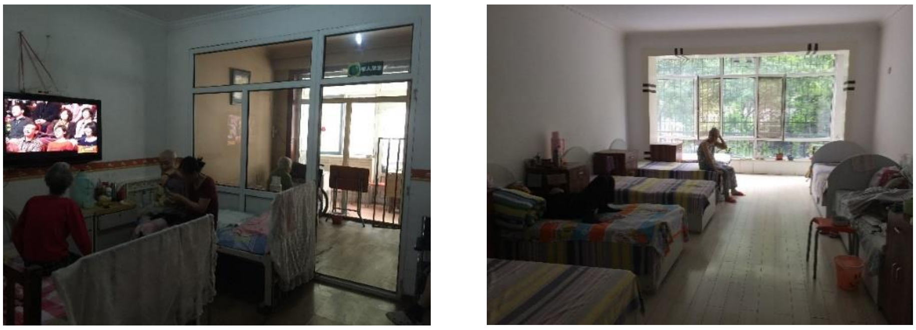
Occupancy（%）	Number of Agencies	Percentage（%）	Effective Percentage（%）	Accumulated Percentage（%）
0	12	2.6	2.6	2.6
1-9	29	6.3	6.4	9.0
10-19	44	9.6	9.7	18.7
20-29	46	10.0	10.1	28.8
30-39	57	12．4	12.5	41.3
40-49	43	9.3	9.5	50.8
50-59	34	7.4	7.5	58.2
60-69	32	7.0	7.0	65.3
70-79	37	8.0	8.1	73.4
80-89	42	9.1	9.2	82.6
90-99	30	6.5	6.6	89.2
100	49	10.7	10.8	100.0
Loss	5	1.1		
	460	100.0	100.0	

This contradictory phenomenon shows that the main problem encountered by the development of China's RACFs at this stage is the mismatch between supply and demand for the RACFs.

4.3.3 Analysis of the Contradiction between Supply and Demand for Pension Institutions

The difference between the number of the elderly and the proportion of who need to live in pension institutions shows the mismatches with the number of beds in pension institutions in China. The state has vigorously developed RACFs for the civilian population. The beds of RACFs has increased significantly and various high-, middle-, and low-cost pension institutions have developed (Feng et al., 2012). Except for providing the necessary aged service facilities, newly-built aged care institutions generally emphasize to add more beds, but do not mention the relaxation of standards for service personnel, physical environment and other conditions, so that these quickly-built care institutions often have many problems.

For example, a small RACFs transformed from a residential house might accommodate too many elderly people, resulting in too little space per occupant and poor living conditions. Figure 4-22A shows a small residential aged care facility renovated in a residential building with the indoor balcony and living room converted into bedrooms. Six elderly people share one room: the space is crowded, the mutual interference is serious, and the quality of the living environment is poor.



(A) Before remodel/renovation (B) After remodel/renovation

Figure 4-22 A small-sized remodeled pension facility in Harbin

(Photos taken by the author)

Large-scale RACFs tend to build old-age care institutions according to real estate development strategies because many have real estate investment backgrounds. Pursue large-scale, high-end. Such a strategy to a certain extent guarantees the essential living environment of pension institutions. However, due to the excessive pursuit of the number of beds and area indicators, the diversity and flexibility of the space are ignored. As a result, a large number of elderly care institutions have a single space, and the living units are mainly arranged in a linear shape. As shown in Figure 4-23, the space is too monotonous, lacks fun and humane care, and is a low-quality living space.

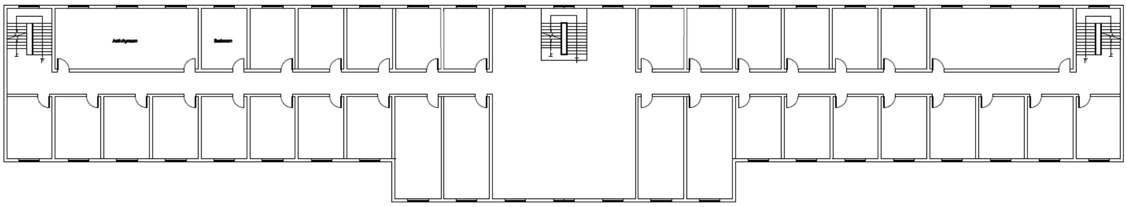


Figure 4-23. The floor plan of a large pension facility in Shenyang (Drawn by the author)

A large number of elderly care institutions are constructed in accordance with hotel standards, and a much effort and investment is put into improving the quality of decoration and equipment. However, not enough investment is put into or attention paid to the physiological and psychological effects of the environment. Many large-scale elder care institutions are either high-end hotels or apartment dormitories that do not provide a living environment tailored to the characteristics of the elderly. As shown in Figure 4-24, the activity hall of a pension facility is expensive, but because it is not comfortable or attractive to use, the actual utilization rate is very low, which is a waste of the space.

Figure 4-24. The hallway of a pension facility in Harbin (Photo taken by the author)

Compared with young people, the mental and physical characteristics of the elderly are more sensitive to changes in the living environment and have higher requirements for environmental comfort: changes in physical indicators such as sound, light and heat have more obvious impacts on the elderly. The requirements for environmental comfort are higher than the pursuit of interior decoration. Therefore, greater investment should be made in ensuring the comfort of the physical environment.

In essence, although small and large pension institutions have different investment costs and implementation methods, the fundamental purpose is the same: they are both focused on providing more beds per given area. In terms of indicators, although the number of beds has increased, the quality of the living environment has not been enhanced. If old-age care institutions are not effectively improving the elderly’s quality of living environment, this is undoubtedly a misunderstanding of the needs of old-age care and is a waste of social resources.

At present, in this regard, China cannot yet fully learn from the experience of developed countries. Because after moving into an apartment for the elderly, the living conditions of the Chinese elderly are different from those of the foreign elderly. The life of the elderly in developed countries is much simpler than in their own homes. However, in China, after moving into the elderly apartments in China, except for some additional services, their lives have not changed much in nature, which is determined by the national conditions and cultures of different countries. Therefore, the construction of China's RACFs must not only learn advanced technologies from developed countries, but also combine domestic characteristics to make RACFs truly suitable for the elderly in China.

Through the encouragement of national policies, a large amount of private capital has entered the pension field, and a large number of pension institutions have sprung up in a short period. The pursuit of business interests and the inertia of real estate development thinking mean that economic indicators obscure the exploration of the real practical needs of the elderly. It is necessary to gradually increase the emphasis on factors such as environmental quality and service level that are more closely connected to the QoL of the elderly. Only in this way can the supply and demand for aged accommodation be truly matched.

4.4 Summary

Old-age facilities in China are in short supply, making the growth of the number of beds a long-term measure of development while insufficient attention is paid to the quality of old-age facilities. There are also certain problems in resource allocation. The system of matching types of RACFs to the needs of residents in the UK is more distinct and logical. The functional characteristic of various types of elderly care facilities is clear; the percentage of small-scale RACFs is higher, making it easier to integrate with the community; the family-oriented space model is used to create a warm living atmosphere. These aspects have lessons for China.

In the UK, the general area of RACFs is usually very large, which is convenient for the elderly to move around and receive guests; the living room and the kitchen are generally adjacent, so that the elderly can easily enter and exit the kitchen for dining; the bathroom facilities are very complete, but for the elderly who can take care of themselves, they do not need too many barrier-free facilities, so the bathroom is not much different from other ordinary apartments; finally there is a storage room in the corridor, which can be used to store sundries, and will not affect the elderly's other activity. In contrast, although China's RACfs also has all the above-mentioned facilities, there is a certain gap between them and the UK in terms of quality and spatial arrangement. These deficiencies have greatly affected the quality of life of the elderly in RACfs, and also reduced the satisfaction of the elderly. Therefore, it is necessary to conduct research on domestic RACfs to explore the psychological needs of the elderly and to improve relevant buildings in a targeted manner.

Against the background of China's current aging population without corresponding increases in incomes, self-care elderly people are increasingly demanding simple life support services. But there are relatively few elderly care facilities that provide such services. The UK's guaranteed elderly apartment model is more suitable for the elderly with such needs. Drawing on the UK's experience, is helpful for exploring possible elderly care facilities that satisfy the needs of China's elderly care.

China is constantly introducing relevant policies to provide a basis for the establishment of RACFs. China and UK have different national conditions, and China cannot simply copy the British experience. But the UK's positive and negative experiences can still inspire China in terms of the development of China's RACFs.

5. The Elderly’s Needs for QoL in Northern China

5.1 Background

5.1.1 Introduction

To investigate the factors affecting the elderly’s QoL, 305 elderly people in city Harbin were selected and separated into three groups in accordance with the type of accommodation: home-based care; community care; and RACFs. These three groups of people were interviewed by questionnaire and the responses hierarchically coded in a framework of grounded theory; "what needs", "why needs" and "what choice". This chapter summarizes and tentatively analyses the factors related to the respondents’ living environments and QoL.

5.1.2 Quality of Life

QoL stands for the rating and experience of an individual's living conditions related to their expectations, purposes, standards and concerns in various cultures and value systems (Rose et al., 2002). It is a crucial predictor of the wellbeing and longevity for the elderly. At present, as a significant social institution to provide comprehensive aged-care services, such as food, living, sanitation, life care, health management, as well as recreational and sports activities, it is mainly run by the state and supplemented by the private sector. The RACFs run by the government, with low output, high input, low efficiency, and high consumption do not only waste many national resources, but have poor management services and lack of internal motivation as well (Elliott et al., 2015). According to a previous study on the patients satisfaction of hospitals in China’s low-temperature regions (Wu et al., 2020), there are four basic factors that could affect patients’ satisfaction, including individual characteristics (age, sex, educational background), perceived quality (professional service quality of staff), loyalty intention (interpersonal communication of staff), and environmental expectations (the patients’ expectation towards the hospital building environment). But as for the private RACFs, either the price is too high, the vast majority of people can't afford, or the service quality is poor. The policy support is weak, legal system construction is lagging behind, supporting measures are not perfect, and the role of social aged care is still lower than that of family aged care (Waltonmoss et al., 2005). In the context of rapidly aging population, how to improve and maintain the elderly's quality of life of has become a significant social problem. To ensure that priority is given to the living conditions of the elderly, the United Nations has adopted five principles for older persons: independence, participation, care, self-sufficiency and dignity (Roberts & Bowers, 2014). These are all part of the requirements and personal needs of the elderly for the aged care institutions. Nowadays, relevant agencies have given the elderly enough hardware guarantees, but these guarantees lack a certain degree of pertinence. It should be understood that the physical and mental health of each elderly person, family, and economic conditions are different, so the requirements of the elderly for environmental factors are also various. Any factors in a certain environment, including man-made and non-man-made, will greatly affect the mood of the elderly. Therefore, a face-to-face exchanges with some elderly people was conducted which can learned about the needs of theelderly for facilities and their current psychological state.

A good family atmosphere help provide more possibilities for the elderly to participate in social activities. The elderly would have a higher quality of life if they feel their life is rich and meaningful. However, a tense or bad family atmosphere can significantly damage the elderly 's QoL of, leading to mental illness and negative emotions, and increase the risk of suicide. Whereas, a good family atmosphere is positive to support the elderly's quality of life and can protect the mental and physical wellbeing of the elderly (Haines et al., 2017).

China has entered into an aging society while the aging problem will become increasingly serious (Hong, 2010). The question of has become a major strategic issue affecting China's future development. RACFs are an important way for many old people to choose to enjoy their old age. But often, after elderly people move into RACFs from home, they often feel psychological maladjustment and loneliness due to the change of environment and lifestyle. If these problems are not noticed in time, psychological problems can easily occur. However, the services provided by domestic RACFs are mostly focused on basic needs and the psychological needs of the elderly is barely considered. (Chantal et al., 2016) Therefore, this paper has identified some common psychological needs of the elderly through interviews with the elderly.

Although the elderly can find social interactions with other residents in elderly care institutions, there is still a lot to do to find real happiness for the elderly in those institutions.

With the rapid economic growth, a growing number of elderly people can quite from work at an earlier age and retire with pensions (Schormans et al., 2006). It is now important that people of working age should be guided in making rational use of their pre-existing resources to enhance the quality of life in their later years. At present, RACFs in urban areas have developed rapidly because they have many resources and provide fine QoL for the residents. But the need to improve the QoL for the elderly more generally and the resources available are insufficient. Existing home-based elderly care activities are still inadequate and only provide casual leisure and entertainment (Elsinga et al., 2017).

The research for this focus on the QoL of the elderly was undertaken through interviews and observations which are described in the next section.

5.2 Methods and Participants

5.2.1 Approach

The main method of investigation was a questionnaire survey, using general information questionnaire to investigate the age, education level, gender, family economic status, marital status, number of children, aged care mode, chronic disease, and so on. Organized and assisted by the staff of RACFs, a one-on-one survey was implemented in a Harbin RACF. Before the investigation, all investigators were trained in order to standardize the investigation.

5.2.2 Participants and Analysis

Since there are many uncertain factors in the main content of this study, a grounded theory was adopted. The living environment in urban and rural areas can be very distinct. In-depth interactions with research respondents allow more comprehensive and effective understanding of the influencing factors of rural-urban elderly living environment, and build a systematic theoretical model of the influencing factors. In this study, some elderly people in Harbin were selected as the research objects.

A total of 158 elderly people aged 60 and over were investigated in a Harbin. Since six of the interviews were incomplete, 152 effective responses were collected, with an effective rate of 96.82%. Among them, 63 (41.44%) were in home-based care; 38 (25%) were in community-based care; and 51 (33.56%) were in RACFs. Among them, home care and RACFs had the same male to female ratio. The former had 32 males and females, and the latter had 25. However, community care had more men than women;

home care had more elderly people with higher education than the latter two; in home care, most elderly people had no more than two children, while most people in RACFs and community care had more than two.

The numbers of responses from different care centers were: 12 from Renkang elderly care center; 9 from Aiyuan elderly care service center; 10 from Hongxing elderly care center; 10 from Love elderly care apartments; and 10 from Everbright apartments. Among respondents, 80 were male (52.63%) and 72 were female (47.37%); the participants aged from 60 to 91, and the average age is 75.78 (± 7.69) years old. Other demographic characteristics are illustrated in Table 5-1. Comparing the data of the three groups of elderly people, it was found that the proportion of home-based care is higher, there is a greater number of children, and the economic status is higher (P<0.05) compared with community and institutional care. There is no material difference in other basic data of these three groups (P>0.05).

Table 5-1. Comparison of the general situation of the elderly in different ways of providing for the aged in urban areas

Factor	Sub-Factor	Reciprocal	Aged care mode		
			Home care for the aged n=64	Community care n=38	RACFs n=50
Gender	Man	80	32	23	25
	Woman	72	32	15	25
Age	60~80	97	39	28	30
	≥81	55	25	10	20
Education level	Elementary school and below	45	16	13	16
	junior middle school	37	15	8	14
	High school or technical secondary school	46	17	13	16
	Junior college or above	24	12	5	7
Marriage	In marriage	110	51	28	31
	Divorce or bereavement	42	13	10	19
Number of children	≥2	82	45	16	21
	＜2	70	19	23	28
Economic situation	≥3000	43	24	8	11
	＜3000	109	40	30	39
Types of chronic diseases	Yes	92	39	23	30
	No	60	24	15	21

There were statistically great differences in the total scores of physical function, social function, mental health, emotional function and overall health of the elderly in the three groups (P < 0.05), but no great difference in other indicators for the three groups existed (P > 0.05).

The category scores and total scores of physical function, mental health, emotional function and overall health of the home-based elderly care group were higher than those of the community and intuitional elderly care groups. Variance analysis was used to compare the differences of physical and physiological status among the three groups.The social function of the community-based elderly care group was higher compared to the home and institutional elderly care groups (P < 0.05), and the mental health scores of the community-based elderly care group were higher than that of the institutional elderly care group (P < 0.05) (Table 5-2).

Table 5-2 Comparison of the QoL of the elderly in different ways of providing for the aged in urban areas (x ± s, points)

Project	Score	Home care group n=128	Community care group n=77	Institutional endowment group	F value	P value
physiological function	79.66±8.05	83.14±8.96	78.29±7.91	77.43±7.82	21.649	0.000
Physiological function	65.58±6.62	66.43±6.79	65.13±6.72	65.19±6.82	1.296	0.275
Social function	74.41±7.58	74.12±7.92	80.14±8.59	68.97±7.96	95.090	0.000
Somatic pain	76.27±7.73	75.41±7.63	76.09±7.85	77.31±7.82	1.691	0.185
Mental health	55.36±5.82	59.43±6.07	54.15±5.62	52.48±5.29	56.273	0.000
Emotional function	67.29±6.85	72.35±7.41	65.41±6.87	64.10±6.69	60.145	0.000
Vitality	51.56±5.51	52.13±5.49	51.30±5.27	51.19±5.44	1.422	0.242
General health	57.69±5.81	61.43±6.25	56.41±5.78	55.13±5.59	52.703	0.000
Total score	78.65±7.96	84.12±8.59	76.41±7.96	75.43±7.62	53.918	0.000

5.2.3 Questionnaire and Interview

305 seniors in Harbin were selected and separated into three groups in accordance with the type of accommodation, which are home based care, community care, and RACFs. The participants were interviewed by questionnaires and the responses hierarchically coded in a framework of grounded theory; "what needs", "why needs" and "what choice".

In order to effectively select the research objects and improve the quality of research data acquisition, the selected communities are extensive. Rich villa communities, ordinary residential communities and urban-rural areas are selected (Adra et al., 2017). The selected RACFs have costs of less than 3000 and more than 3000. Such a choice determines that the object selected by this research has universality.

During the process of the interview, 40 interviews were randomly selected for concept extraction and model construction, then the theoretical saturation measurement was conducted to ensure that no new concepts and categories emerge, finally 152 interviews were obtained in total. The objects selected by this research are shown in Table 5-3.

Table 5-3 Interviewee information form

Number	Gender	Age	Place of retirement
R1	Male	63	At home
R2	Male	65	At home
R3	Male	67	At home
R4	Male	66	At home
R5	Male	71	At home
R6	Male	75	At home
R7	Male	82	At home
R8	Male	89	At home
R9	Male	76	At home
R10	Male	74	At home
R11	Female	63	At home
R12	Female	62	At home
R13	Female	64	At home
R14	Female	67	At home
R15	Female	68	At home
R16	Female	69	At home
R17	Female	74	At home
R18	Female	76	At home
R19	Female	79	At home
R20	Female	85	At home
A1	Male	62	Bead house
A2	Male	67	Bead house
A3	Male	69	Bead house
A4	Male	73	Bead house
A5	Male	101	Bead house
A6	Female	95	Bead house
A7	Female	96	Bead house
A8	Female	89	Bead house
A9	Female	76	Bead house
A10	Female	64	Bead house
C1	Male	66	Community
C2	Male	62	Community
C3	Male	68	Community
C4	Male	64	Community
C5	Male	75	Community
C6	Female	83	Community
C7	Female	85	Community
C8	Female	87	Community
C9	Female	92	Community
C10	Female	96	Community

(1) Open coding. The Grounded theory was in 1967 presented by Barney Glaser and Anselm Strauss in their monograph The Discovery of Grounded Theory, which

emphasizes the progressive case selection and data collection, as well as the repeated comparison between theory and data (Strauss & Corbin, 1994). There are a variety of open coding, such as line-by-line coding, which is significant to establish concepts and classifications (Khandkar, 2009). In the open coding stage, the interview transcripts and notes of 40respondents were organized, screened, compared, the keywords refined and important opinions repeatedly appearing in the text noted. In the coding process, I looked for "the influencing factors on the elderly's choice of living environment" as the starting point. After repeated reading and comparison, 260 original sentences with primary concepts were extracted from nearly 400000 words of interview transcripts. However, due to the similarity of meaning and semantic intersection among many sentences, 73 concepts were selected. Finally, cluster analysis and preliminary categorization were carried out for 73 concepts, and the main factors influencing the participation of rural elderly in leisure education were extracted, forming 24 initial categories.

(2) Axial coding is a series of procedures which re-categorizes data open coding, and creates connections among different categories (Strauss & Corbin, 1990). When coding the main axis according to the relationship between the categories, the 24 main categories were divided into eight relationship categories: life needs, food needs, medical needs, entertainment needs, companionship needs, religious needs, natural environment needs and needs for convenient traffic facilities around.

(3). Selective coding. The process through which a core category eventually becomes the basis for grounded theory (Babchuk, 1996). Based on the research objectives of this thesis, two main categories are summarized: the individual's immediate environment; and the external environment; and the core category of "what needs: the needs of the elderly for living environment" is identified. From the connection between the 24 initial categories, the eight relationship categories and the two main categories, a model of the influences on the elderly's needs for an adequate living environment was constructed.

(4). Theoretical saturation measurement. Theoretical saturation is related to the theoretical sampling for grounded theory (Bloor, 2006). Therefore, the preliminary formed categories are taken as the measurement standard of theoretical saturation measurement, and the remaining 112 interviews texts are coded and analyzed based on the same principles. The results showed that no new category appeared, indicating that the research theory established in this paper has reached saturation.

5.3 Results

5.3.1 Basic Needs of the Elderly

(1) Open coding. The relationship between concept and initial category is presented in Table 5-4.

Table 5-4 The categories of the formation of open coding (in English)

Number	conceptualization	Initial category
1	Need quiet space	Quietness
2	Cold in winter, warmth needed	Heating
3	A bed used for sleeping. It needs to be soft	Furniture
4	Air conditioning and TV are needed in winter	Furniture and home appliances
5	Community volunteers	Service personnel
6	Old people can travel	Freedom
7	The corridor is clean	Sanitation
8	The old people don't like to go down the stairs. They usually go downhill	Barrier-free facilities
9	Prefer to live on the first floor	Floor
10	Good light at home	Lighting, illuminance, and brightness
11	Don't like going to public toilets	Private toilet and bathroom
12	High floor	Elevator.
13	Don't like living with children	Private living space
14	Old age homes eat big pot of rice	Differentiated diet
15	Go to the hospital every Tuesday to get the medicine	Medical facilities
16	Play cards or chess	Recreational facilities
17	Get up in the morning, read the newspaper	Newspaper
18	Like to listen to Huangmei Opera on computer	Network
19	Like to stay with peers	Peer company
20	Be willing to make young friends in RACFs	The company of young people
21	Having a dog is like having a baby	Pet company
22	Like to go to church	Religion
23	Like gardening	Gardening
24	There's a supermarket near the house	Convenient transportation facilities

The following open coding tables illustrate the original responses of the elderly residents. Through these answers, how elderly people feel about the physical environment of elderly care facilities could be understand. Based on these, the problems existing in the physical environment of the elderly care facilities could be found and solve them in a targeted manner(see table 5-5, 5-6 and 5-7).

Table 5-5 The open coding of elderly living environment responses

The original response	The primary concept	Secondary Category
We feel disturbed when it is too noisy, it affects us chatting, and may leads to conflicts among residents. 噪音大了不好，噪音大了影响聊天，容易引起我们人之间的矛盾	Quietness	Residential Need
In this climate environment in the north, it is essential to keep the indoor environment warm 就是没供暖之前这段室内有点冷，应该给我们供暖早一	Heating	

点或者增加一些措施。		
Although there are fans in the room in summer, they are not enough. Without air conditioning, I still feel very stuffy and hot. 就这个电扇，觉得这个公寓不太够，还是有点闷	Furniture	
The residential RACFs is very clean and clear. 卫生，特别干净，还挺敞亮的	Sanitation	
They supplied 7 to 12 different types of meals today. They have two of their own vegetable cultivation rooms. Elderly can easily lack of protein, and they dealt with it very well, the food here is very good for health despite some elderly don't understand this and complain about the flavour of the food. 今天这里有 7 到 12 种不同的菜。他们有两个自己种蔬菜的地方。老年人很容易缺蛋白质，他们的蛋白质处理得很好，有些老年人不了解，抱怨食物的不好吃，但这里的食物还是挺健康的。	Dietary differentiation	Dietary Need
There's a physiotherapy device in our medical room. I'll do it in the morning after breakfast and have a foot massage every day. 每天早上起来我们就出去活动，五点半我们就出去做操，做完操呢，我们就去做理疗，做完理疗去吃饭，吃完早饭呢	Medical facility	Medical Need
They have a lot of facilities here that we can do exercise. 这里有很多设施，我们可以锻炼身体。	Recreational facility	Entertainment Need
I normally read newspapers and news on the internet. Computers provide more content than that of newspaper, but computers are not available here now, and they don't have any elderly newspapers. Besides, the font on the papers is very small, which we usually adjust to much larger size when we read news on computers at home. 我主要是看报纸，上网看新闻，一直保持阅读习惯。电脑新闻比报纸丰富。在这现在不能上网，看报纸也不是特别方便，这没有老年报。而且这些报纸还是字体小。我在家看新闻电脑字体都调的比较大	Newspaper	
Few days ago, my son took me home to live for few days, but I just want to come back here only on day after, it is not that I don't like my son's place, I just prefer spending time with people of my age. 前几天我儿子带我回家住了几天，但我第二天就想回来了，不是说我不喜欢他家，我只是喜欢和跟我差不多年纪的人在一块。	Peer companion	Companion Need
It is very convenient when I want to hang out at markets or parks. 周围的有市场，广场，公园什么，都很方便	Traffic convenience	Need for convenient traffic facilities

Table 5-6 The underlying reasons of elderly needs

The original response	The primary concept	Secondary Category
I think the residential RACFs can be further improved, such as inspecting pulse, blood pressure and sleep condition to arrange activities and dietary menus for elderly. Many elderly have constipation issues, and they may supply food with rich fiber to deal with it. 我认为可以进一步改善养老院，例如检查脉搏，血压和睡眠状况，据此来安排老年人的活动和饮食菜单。 许多老人有便秘，他们可能会用一些有营养的食物来治。	The elderly health conditions	Sense of safety
There must be medical facilities. 需要有一些医疗设施	Medical facilities.	
The stairs are too steep. 这的楼梯还是比较陡的	Barrier-free facilities	
We feel disturbed when it is too noisy, it affects us chatting, and may leads to conflicts among residents. 噪音大了不好，噪音大了影响聊天，容易引起我们人之间的矛盾	Quietness	Sense of Comfort
In this climate environment in the north, it is important to keep the indoor environment warm 就是没供暖之前这段室内有点冷，应该给我们供暖早一点或者增加一些措施	Heating	
We can really use the table lamps; it is pretty dark to read in the room. 我们得用台灯； 在房间里看书很黑。	Lighting and natural lighting	
Although there are fans in the room in summer, they are not enough. Without air conditioning, I still feel very stuffy and hot. 就这个电扇，觉得这个公寓不太够，还是有点闷	Furniture	
.In addition, I think a group of leaders and staff who can be considerate and close to the elderly and care for the elderly should be trained in the residential aged care facilities. 另外，我认为应该对导干部进行培训，让他们学会体贴老人，照顾老人。	Service Personnel	Sense of Decency
The problem is that there are no enough bathrooms, everyone has to use the one on the second floor, it's too crowded. 你看我们这个楼层里也有浴室，但是不给开，说浪费，必须都去二楼那个，还只开一天，都排不开了，太挤了。	Private bathroom	
It's very clean here. 卫生，特别干净，还挺敞亮的	Sanitation	
I really feel happy now, literally, sometimes even better than home. There is no need to worry about anything, all I have to do is eat is relax. 工作人员呢也特别和蔼，比在家里的家人还关心你。一天到晚不断地问寒问暖的	No worries	
I really want a bird. 我想养只鸟	Traditional concept	Traditional concept
I met someone in the gym who is in her 60s. She	Pets	Loneliness

likes spending time with me rather than people of her age, 我在体育馆里遇到了一个 60 多岁的人。她喜欢和我在一起，而不是那些同龄人		
	Companion of young people	Sense of belonging

Table 5-7 The reasons why elderly choose RACFs rather than home

The original response	The primary concept	Secondary Category
I really feel happy and pleasant, even better than home as you don't need to worry about anything here, all you need to do is relax and have fun. 工作人员呢也特别和蔼，比在家里的家人还关心你。一天到晚不断地问寒问暖的	Free from worry	Personality
They supply a variety of food here which you will never have at home. 饮食非常好，对于我来说，我家条件不是太好，我才来这儿	Dietary	Dietary Need
Kids can be very exhausted after work, they have their own kids and literally don't have time to look after us. 孩子们下班后可能很累，他们也有孩子，没有时间照顾我们。	Children issues	Children issues
We really need elevators here. 需要有电梯	Elevator	Residential Need
Another problem is that we don't have any single bathrooms here, everyone has to share the one on the second floor to take shower, which only opens on Wednesday, and they actually have few idle bathrooms here but they don't open them and told us it would be a waste. 现在的主要问题是浴室没有，都给集中到二楼的那个浴室，还都周三一周一次开放，大家都对这个意见挺大的。你看我们这个楼层里也有浴室，但是不给开，说浪费，必须都去二楼那个，还只开一天，都排不开了，太挤了	Private bathroom	Residential Need
We feel disturbed when it is too noisy, it affects us chatting, and may leads to conflicts among residents. 噪音大了不好，噪音大了影响聊天，容易引起我们人之间的矛盾	Quietness	
In this climate environment in the north, it is relevant to keep the environment indoors warm. 就是没供暖之前这段室内有点冷，应	Heating	

该给我们供暖早一点或者增加一些措施。		
The stairs are too steep. 这的楼梯还是比较陡的	Barrier-free facilities	
In terms of physical environment, it would be good to add a desk lamp in this room, so it is convenient to read books. 在环境上，最好增加一个台灯，方便读书。	Illuminance and brightness	
It's not good without an elevator. It's really not good for the elderly without an elevator. If there's no elevator in this place, I can't come to live here 没有电梯不行。 这对老人不好。 如果没有电梯，我就不能住在这里	Elevator	
A lot of elderly residents suddenly have faith when they get old to support themselves move forward. Residential aged care facilities should take this phenomenon into consideration, such as a Buddha Hall or a church 许多老年人突然有了信仰，支持自己的生活。养老院应考虑到这些，例如佛堂或教堂	Religious facility	Religious Need

(2) Axial coding. It was found that different elderly people have different material needs, cultural needs, natural environment needs and traffic convenience needs, which is mainly affected by the internal needs of the elderly. It relates to "what needs", in which material and cultural needs relate to their own environmental needs. And the need for natural environment prelude and traffic convenience relate to the external environment need. The relationship is shown in Table 5-8.

Table 5-8 Categories formed by axial coding

Number	Main category	Secondary categories	Relationship category	Initial category
1	Own environmental requirements	Material needs	Residence requirements	Quiet Heating Furniture Furniture and home appliances Service personal Freedom Sanitation Barrier-free facilities Floor Lighting, illuminance

				and brightness Private toilet and bathroom Elevator. Private living space
			Dietary needs	Differentiated diet
			Medical needs	Medical facilities
		Cultural needs	Entertainment needs	Recreational facilities Newspaper Network
			Companionship needs	Peer company The company of young people Pets company
			Religious needs	Religion
2	External environmental requirements	Natural environment need	Natural environment need	Green
		Traffic convenience needs	Traffic convenience needs	Convenient transportation

The main point of axial coding is to find the relation between the main and the secondary categories to create the main category coding(see table5-9, 5-10 and 5-11).

Table 5-9. Elderly residential needs open coding

The main category	The secondary category
Material Need	Residential Needs Dietary Needs Medical Needs
Culture Need	Entertainment Needs Companion Needs Religious Needs
Environment Need	Natural Environment Needs Traffic Facilities Convenience Needs

Table 5-10. The deeper insight of the elderly needs

The main category	The secondary category
Material Need	Sense of safety Sense of comfort Sense of dignity
Spiritual Need	Sense of trust Children issues Sense of collective identity Sense of helplessness

	Public consensus
	Traditional concept
	Sense of privacy
	Sense of loneliness
	Sense of social belonging
	Sense of social understanding

Table 5-11. Reasons why elderly choose RACFs rather than home

The main category	The secondary category
Personal reason	Elderly's personal reasons
	Children
Government policy guidance	Government policy guidance
Social structural reason	Social structural reason
The main category	The secondary category
Need	Residential Need
	Dietary Needs
	Medical Needs
	Entertainment
	Companionship Needs
	Religious Needs
	Natural Environment Needs
	Needs for convenient traffic facilities around
Trust	Trust from others
Price	Price

5.3.2 Social Environment

In traditional Chinese families, it is usual and a pervasive phenomenon to care for the elderly people at home. With the decreasing size of the family and the increase in social mobility the younger generation's concept of life has changed, and many young people leave their parents alone so they can work in other places, which leads to more and more elderly people living in RACFs and other social aged care institutions (Herbert, 2018).

Thus, residential aged care facilities will become more and more important with the acceleration of aging in China. At the same time, the aged care model of society will also change from the current reliance on the family to a social aged care model (Rudnik, 2016). Due to the poor health of the elderly, and changes in the physical environment can easily cause changes in the lives of the elderly. Any deficiencies in this area may damage the health of the elderly. Therefore, the elderly attach great importance to the physical environment. Ensuring the perfection of the environment is the basis for improving the quality of life of the elderly in RACFs.

The problems of the elderly in RACFs include their material needs and spiritual needs. To solve the problem faced by the elderly in RACFs, attention should be paid to their emotional needs. However, it is difficult to satisfy them in care homes, so emotional satisfaction is extremely dependent on the family.

Due to the decline of social status and the changes to the body with age, the dependence of the elderly on society and their relatives increases. The main reasons for this kind of dependence are: not knowing how to face life after retirement; not knowing how to continue to give play to the leftover enthusiasm after retirement; increasing emotional dependence on children; negative emotions when children do not have time to meet elders' needs; and the increasing influence of traditional ideas. These needs should be understood and ways should be found to meet the elderly's special needs, to deal with the problems faced by the elderly and to deal with the hardship faced by the social aged care.

Home-based elderly with happy family environments may not be willing to change their living environment. But their needs for different environments change over time (Naumann, 2004). The next section illustrates the physical environment needs of the elderly, including three major factors, which are acoustic environment, light environment and thermal environment.

5.3.3 Physical Environment Needs of the Elderly for Living Environment

The physical environment inside a building refers to the separate basic material elements with different functions, but it can be improved according to the overall perception of human environment, generally including light environment, acoustic environment and thermal environment.

5.3.3.1 The Influence of Acoustic Environment on the Elderly

Acoustic environment refers to all sound conditions that people perceive through their ears and this perception is affected by (Brown et al., 2015) hearing loss in the elderly. It is a process of primary degeneration with two main causes: one is cochlear lesions; the other is the decline of central cognitive function in the elderly (Wingfield et al., 2005). The acoustic environment will also influence the physical and mental wellbeing of the elderly. The elderly with poor mental states are more likely to have negative reactions when they experience noise than elderly people with good mental states. Once the elderly are awakened from sleep, it is very difficult for them to fall asleep again, which seriously affects their quality of sleep, leading to their increased risks of falls and hardship with memory and concentration, and affecting their physical and mental health. Noise particularly affects the elderly with dementia which can lead to over-excitement and destructive behavior.

In a controlled experiment on the influence of noise on the middle-aged and older people, it was found that noise affected the nervous system of middle-aged and older people and eventually led to the increased blood pressure. In the experiment, it was found that the probability of fatty liver and blood lipid abnormality in the group subjected to noise was higher compared to the control group. Noise causes a response of the autonomic nerve regulation function of the human body, causes disturbance of the vasomotor center, and finally leads to the disorder of lipid metabolism (Cooney, 2012).

Interviewer: Do you think it is quiet here?

Respondent 1: "Yes, it's usually like this. It's very quiet. (没有啥噪声。)"

Respondent 2: "There are also some walking sounds. (就是穿皮鞋来回走有影响有干扰)"

Interviewer: What do you think of the sound insulation of this room? It's the sound insulation in your room.

Respondent: Very good. (隔音效果还行。)

Interviewer: If you are in the activity hall, can you hear other voices, that is, the voices of other people's activities.

Respondent 1:"In my opinion, the stereo is not very good. (隔音效果不好)"

Respondent 2: "I feel like the decibel is quite high. (就都能听见，干扰挺大的)"

Respondent 3: "Yes, you can hear it from this room. (要是房间门没关严就有影响，能听见)"

Respondent 4: "Yes, because the old man doesn't sleep well, and he doesn't rest well when it's too noisy at night. (我睡觉轻，要是这个屋里有别的声音，我容易醒。)"

The requirements of sound in the daily life of the elderly are simple and direct. In the survey, the elderly generally prefer a quieter environment. Therefore, the acoustic environment is an important factor influencing the living environment of RACFs. Moderate and non-noisy sound is conducive to the lives of the elderly. At the same time, the elderly have a lot of feedback on sound, which shows that the elderly attach great importance to the acoustic environment. In the coding process, the physical environment has been classified under the 'living environment'.

5.3.3.2 The Influence of the Light Environment on the Elderly

The impact of lighting on the elderly was classified under 'living environment' in the coding process. The following are samples from interviews selected from all surveys in three types of homes about their perception towards lighting in their living environment.

"The sunlight is important (阳光重要)";

"The light is alright; I do not feel much about it (光线还可以，没什么感觉)";

"No, I do not feel it very well in the room. (没有，室内其实我用不太上)"

"If there is a light in the corridor, I can turn it on. (走廊有灯，用就打开了)"

"The brightness is OK when reading during the daytime, but not at night. (白天看书的时候亮度还可以，晚上的时候这光线不行)"

"If it is not bright enough, I just turn on the TV. (不够亮，就看个电视还行)"

"I usually wear glasses when I look at things. It's more than 500 degrees. (平时看东西就带眼镜，都 500 多度了)"

"It's too bright. (太亮了也不好)"

"I think it's OK now. (在这个光线我觉得还行)"

"I like this building, it's all very good. The light distribution is quite even. There's light in the front building. (像这个楼，就都挺好的，光线分布还挺均匀的都这样，前面那个楼就有啊)"

"It's dark. It's not very good. (暗的，不是很好)";

"It's OK. There's a little sunshine in the afternoon. Two or three hours a day, I think it's enough. (还可以吧,下午的时候能有点儿阳光，每天两三个小时，我觉得就够了)";

Light environment has always been among the main factors that influence the safety of elderly at home. Old people need adequate lighting to meet the basic needs to conduct a various of activities. With the process of aging, the visual system of the elderly will undergo various degradation changes. The degradation of the visual system reduces the perception and cognition of the outside world, such as the weakening of night vision, the ability to adapt to the light and dark, and lack of color perception. It is found that the pupil diameter of the elderly decreases with the increase of age, and the pupil's sensitivity to light also decreases (Telek et al., 2018). In addition, there are more eye diseases in the elderly, such as cataract, glaucoma and macular degeneration.

At the same time, the intensity of light will affect the reading activities of the elderly. Many elderly people like reading or newspapers, but the surrounding light is too strong or too dark will cause obstacles to reading activities. Therefore, the lighting environment is also one of the important needs of the elderly. It can be seen that the lighting environment usually affects activities outside the daily lives of the elderly.

The light environment also affects the mental health of the elderly. According to the Byrne and Maclean’s (1997) research, the light environment can affect the incidence of depression and cardiovascular diseases in elderly people, by affecting the physiological rhythms. The elderly with poor sleep quality are not as healthy as those with good sleep quality. They suffer more likely from cardiovascular diseases and endocrine system disorders, and their sleep quality can be negatively affected if it is too bright in the room. Negative emotions affect the risk of increased heart rate and blood pressure in the elderly, which may lead to stroke in serious cases. Therefore, in the environment of home-based elderly care, it is necessary to ensure sufficient indoor natural and artificial light to make up for the decline of the visual systems of the elderly.

Overall, the elderly investigated in this research were satisfied with their lighting conditions, and so in the investigation and analysis illumination conditions were not taken as a principal component.

5.3.3.3 The Influence of Thermal Environment on the Elderly

Appropriate temperature is essential for the living conditions of the elderly. Old people's choice of buildings is often closely related to heating and air conditioning. The environment temperature is significant in the coding process for this research. Based on a previous study of Wu et al. (2019) regarding thermal and sound impacts on comfort of patients in eight Chinese hospitals, the researched hospitals are inadequately ventilated, which leads to negative impacts on patients and increase challenges for hospital designers.

However, this research has found that the temperature requirements of the elderly in China are often related to the seasons. The following are samples from interviews regarding the elderly’s perception towards temperature.

"It's a little cold in the room before heating, so we should heat it earlier or add some measures. (就是没供暖之前这段室内有点冷，应该给我们供暖早一点或者增加一些措施)"

"In addition to the spring and autumn period, when the frost period finishes and begins, the heating is cool. In addition to this, the normal temperature is very good. (温度除了春秋就是开霜和关霜以后，就是暖气凉了，这两个节点，除了这个以外就是正常温度挺好的)"

"It's warm in winter. (冬天挺暖和的)"

As an important factor of concern to building users, thermal environment has been studied for many years. In many scholars' research on TC in dynamic environments, it is pointed out that the temperature range that is acceptable of non-air-conditioned areas is larger than that of air-conditioned areas under the same rating of thermal condition satisfaction (Flores et al., 2010). Thermal condition is affected by air velocity, intensity and frequency of air flow pulsation. ASHARE 55 defines thermal condition as people's satisfaction and subjective perception towards thermal environment (ASHRAE, 2017). (Referred to as "the standard") defines thermal condition as the level of subjective acceptance and satisfaction of human towards humidity and thermal environment. The adaptive average thermal feeling index is used to predict the average thermal perception of people in a building, but it does not specifically include thermal condition rating of the elderly. In addition, under the same level of dress as the young, the elderly need higher temperature environments to achieve satisfied thermal condition. In winter, it is easy to for the elderly to catch cold, and in summer, they are prone to heatstroke, and their adaptability to the thermal environment is weakened. Metabolism affects the exchange of heat among the body and the environment by maintaining the energy needed for activity. Due to declining metabolic rate, old people have different adaptive reactions to the thermal environment.

Elderly people have poor physique and are prone to get sick. Indoor temperature conditions have a great impact on the health of the elderly. Especially in Northeast China, where winters are long and the temperature is very low. If the indoor heating is insufficient and the temperature is not high, the elderly can easily catch a cold and even cause other diseases. Therefore, the thermal environment determines the health of the elderly, and a good and appropriate temperature can effectively ensure the quality of life of the elderly in RACFs.

To sum up, research shows that physical environment factors (including sound, light and heat) in the home environment have important effects on the elderly. The physical environmental aspects of buildings not only affect the physical function of the elderly, but also affect their psychological health.

All the words and sentences were recoded from the 152 seniors for subsequent data analysis, and the interview transcripts and notes of 40 responses were also sorted. The key words and important points in the text were marked. After recoding, the formation category of the axial code is shown in Table 5-12, which illustrates what factors are involved regarding the deeper insight of the needs of the elderly.

Table 5-12. Category formed by axial coding

Number	Main category	Relationship category	Initial category
1	Why needs: the deep reason of the needs of the elderly	Old people's own reasons	Age
			Occupation
			Education level
			Physical fitness
			Character
			Living environment
			Living habits and hobbies
		Children factor	Number of children
			Child care
		Residence factor	Living environment

5.3.4 Factors affecting Needs for the Living Environment

Through the model constructed by three-level coding, it can be concluded that individual factors, family factors and social factors are the main aspects that influence the living environment needs of the elderly. The individual factors include age, gender, and personalities. The family factors include children and their filial piety. The social factors include the number, quality and attitudes of those community workers from government services. The three factors have their own connotations, constitute the corresponding dimensions, and have different effects.

(a)Individual factors

The needs for adequate material and cultural conditions can be attributed to individual factors. The culture needs refer to the seniors' spiritual pursuit, which affects their mental state. Among the 305 responses, happiness in old age is often satisfied by individual factors, and can get more value in family and social factors.

(b)Family factors:

A positive correlation between the happiness of the elderly and number of children exist. Yet, sometimes older people with many children can also be negatively affected when they shirk responsibility for the support of the old people. However, the high degree of children's care and the high rating of living environment of the elderly can make up for it. The more the children take care of the elderly, the more of the elderly are willing to stay at home, which directly affects the happiness of the elderly.

(c)Social factors:

The number, quality and attitudes of community workers in government services will directly affect the happiness of the elderly with their living environment. Some respondents said that the happiness of the elderly is the result of the joint action of local RACFs and community service staff. At present, there are two main sources of RACFs: one is state-run RACFs and services, which are small in number with excellent accommodation; the other is community service, mainly composed of community staff and residents' committee staff with general quality accommodation comparing with the ones run by the state. But generally speaking, the lack of state-owned RACFs and the unstable community services make it difficult to insure the quality of the living environment of the elderly.

In addition, the physical environment is the most important factor for the elderly. The elderly living in RACFs are usually affected by factors such as sound, light, and heat. Any defect or change may greatly change the quality of life and state of the elderly. Therefore, solving the problem of the physical environment can effectively guarantee the quality of life of the elderly in RACFs.

5.4 Discussion

Through the model constructed by three-level coding, it can be concluded that "what needs", "why needs" and "why choice" are the main aspects affecting the elderly'. The three factors have their own connotations, constitute the corresponding dimensions, and have different effects. The 'What' and 'Why' include furniture and appliances, service personnel, freedom, sanitation, privacy, dietary, medical facilities, entertainment needs, companionship needs, and convenience of traffic facilities.

(a) Physical environment:

The residential environment, including the acoustic environment, thermal environment and light environment, has a bigger influence on elderly's life. Combined with the life characteristics of the elderly and the special requirements of the living environment, specialist acoustic measurement and research for different requirements have become another important part of acoustic environment research. There is a complementary relationship between the elderly's physical health and quiet environments, because the needs of the physical environment of the elderly team are contained in multiple demand categories.

Based on this, it is not difficult to see that the elderly's need for quiet and the need for private living space are complementary. The following are samples of interviews regarding the elderly's perception towards quietness and privacy:

"It's not good if the noise is too loud, it will affect the chat, and it's easy to cause conflicts between us.（噪音大了不好，噪音大了影响聊天，容易引起我们人之间的矛盾）"

"And it's better to have more single rooms, the elderly have different personalities, and it's better to live alone. （最好有更多的单人房，老年人有不同的个性，最好独自生活。）" [R3][R5][A6] (see table 5-3 for the meaning of these notations)。

The respondents were worried about the cold, especially in the northeast of China. It should be noted that many elderly people declared that the heating system will be turned off for a period of time before and after the heating. For community-based and home-based elderly care, the elderly's degree of acceptance and recognition of the need for warmth is generally higher than in the past. Some elderly people who still live in their home and community have moved to the few aged care facilities because their children are too busy to look after them, but their economic conditions are restricted. Because of the superiority of living conditions, the elderly in aged care facilities do not have to worry about the temperature. "In this climate environment in the north, it is essential to keep the indoor environment warm (北方这样的气候，必须保持室内的温暖。)." [R1].

Furniture and appliances Furniture and equipment like air conditioning, television and some electrical appliances are also very important. Many old people prefer wooden, not iron, furniture because the iron furnishing can be very cold. The needs of the elderly equipment can often be linked to the seasons. "Although there are fans in the room in summer, they are not enough. Without air conditioning, I still feel very stuffy and hot（夏天房间里虽然有风扇，但还是不够。 没有空调，我还是觉得很闷很热）." [A3] [R13].

The physical environment is the most important for the elderly. The elderly living in RACFs are usually affected by factors such as sound, light, and heat. If these factors change, or there are defects, it may greatly change the quality of life and status of the elderly. Through interviews, we know that factors such as sound, light, and heat are the most concerned by the elderly. Therefore, solving the problem of the physical environment can effectively guarantee the quality of life of the elderly in RACFs.

(b) Service personnel.

The comfort level of the elderly in RACFs is affected by the service personnel. The number, quality and service attitude of the staff in elderly care institutions directly affects the elderly's judgment of the quality of life. Some respondents said that the lack of excellent service personnel is a major obstacle for local aged care institutions. At present, there are two kinds of service personnel: one is employing people with few qualifications, in fewer numbers and very likely to move on; the other type is college graduation, mainly composed of newly-graduated college students, who often participate in the work out of love, or because the need for a job for economic reasons, and have little work experience. But generally speaking, the lack of excellent service personnel and the high levels of staff turn-over make it difficult to guarantee the quality of elderly care services, which will undoubtedly have effects on the willingness of the elderly to consider care home accommodation.

"In addition, I think a group of leaders and staff who can be considerate and close to the elderly and care for the elderly should be trained in the aged care facilities (另外，我认为应该对导干部进行培训，让他们学会体贴老人，照顾老人。)." [A4] [A5] [A9].

(c) Freedom.

In interviews it was found that one of the main reasons why the elderly at home do not want to go to aged care facilities is their worry about loss of freedom. Respondents were unwilling to be constrained by the activities of residential aged care facilities.

"We fell free living here. There's no activity organized. It means that you can go out if you want; lay down if you want, play if you want, and do whatever you want（我们在这里很自由。 没有人组织活动。 想出去就出去； 想躺下就躺下，想玩就玩，想做什么就做什么）". [R8][R14][A7].

(d) Sanitation.

Sanitary conditions are significant in investigating the elderly's QoL. If the sanitation is poor, there will be bacteria make the seniors get sick. Excellent sanitation conditions can guarantee the health level of the elderly. "It's sanitary, especially clean, and very bright. (卫生，特别干净，还挺敞亮的)".[R16]. Floor, lighting, natural lighting, elevators, and barrier -free facility are also important factors in the elderly's living quality. The needs of the elderly for living are also closely related to the local climate. The previous sections of this chapter analyzed the impact of the physical conditions of sound, light and heat on the elderly. The elderly will generally have a need about which level they live on. A higher apartment floor is not good for the elderly without an elevator. In the study, it was also found that there was a relationship between the light conditions and the floor level of the apartments. The following are sample responses from the interviews:

"I think the living area should be arranged on the second floor or above, because the first floor can be humid （我觉得客厅应该在二楼以上，因为一楼有点潮湿）".

"In terms of physical environment, it would be good to add a desk lamp in this room, so it is convenient to read books （在环境上，最好增加一个台灯，方便读书。）".

"I think it's very dark to read such a book now （读这样的书，光有点暗）".

"It's not good without an elevator. It's really not good for the elderly without an elevator. If there's no elevator in this place, I can't come to live [here] （没有电梯不行。这对老人不好。 如果没有电梯，我就不能住在这里）".

"Regarding the stairs in the aged care facilities, they might need to consider to have some of the barrier-free equipment to help residents who have mobility issues to climb the stairs （关于老年护理设施中的楼梯，他们可能需要考虑使用一些无障碍设备来帮助行动不便的居民爬楼梯）".

"The stairs here are too steep, which is not very convenient for the elderly to use (这的楼梯还是比较陡的，老人用起来不太方便)". [R15][R6][A7].

(e) Private toilets.

The elderly generally have needs for private toilets. Compared with home-based elderly care and RACFs, it mainly depends on whether it is convenient to use the toilets. Convenience in daily life is vital in the choices of the elderly.

"The main problem now is that there is no private bathroom. All the bathrooms are centralized on the second floor. They are open once a week on Wednesday. Everyone has complained a lot about this. You see, we also have bathrooms on this floor, but they don't open them. They said it's wasteful. We have to go to the second floor which only opens one day a week and can be very crowded（现在的主要问题是没有独卫。 所有的浴室都集中在二楼。 每周三开放一次。 每个人都不满意。 你看，我们这一层也有浴室，但他们不开。 他们说这是浪费。 我们必须去二楼，那里一周只开放一天，可能会很拥挤）". [A1].

(f) Dietary variety.

Satisfactory life for the elderly is closely related to their diet. The standardized meals in aged care facilities cannot be easily arranged according to personal needs or preferences of the residents. In addition, the elderly know little about nutrition and can't understand the dietary arrangement of aged care facilities. This is also one of the reasons for the elderly to be provided at home.

"They supplied 7 to 12 different type of meals today; they have two of their own vegetable cultivation rooms." "Elderly can easily lack protein, and the staff dealt with it very well, the food here is very good for health despite some people don't understand this and complain about the flavor of the food (今天这里有 7 到 12 种不同的菜。 他们有两个自己种蔬菜的地方。老年人很容易缺蛋白质，他们的蛋白质处理得很好，有些老年人不了解，抱怨食物的不好吃，但这里的食物还是挺健康的。)".[A8], [R7], [R9].

(g) Medical facilities.

For most elderly people, medical conditions are a core consideration. In the course of this investigation, it was found that many old people are reluctant to leave their hometown, and the reason for their children to move to larger cities is for better and more advanced medical treatment. It is a necessary condition for aged care facilities to provide complete medical and health care facilities.

"There's a physiotherapy device in our medical room. I'll do it in the morning after breakfast and have a foot massage every day (医疗室里有一个理疗设备。 我会在早餐后做足底按摩。)." [A2] [R6] [R7]

(h) Entertainment needs.

The recreational and sports facilities mentioned by the elderly include mahjong, outdoor sports and indoor sports facilities and cultural facilities. Among these activities, many elderly people mention the need for indoor sports facilities, because although the external environment has a great effect on elderly, and sun and rain will affect their outdoor activities, and indoor sports facilities are very necessary. The organizers of sports and entertainment, and the children of these elderly residents, mentioned in interviews that the sports facilities are generally very good, - "There are many places around for exercise（周围有很多锻炼的地方）" [A1] [R7]; but no one helps the residents to use them. It is essential for the managers of aged care facilities or the old people themselves to select organizers for sports and entertainment.

(i) Newspapers and the Internet.

The entertainment needs of the elderly interviewed are fairly traditional. It mainly depends on big print newspapers.

"I normally read newspaper and news on the internet. Computers provide more content than that of newspaper, but computers are not available here now, and they don't have any elderly newspapers. Besides, the font on the papers is very small, which we usually adjust to much larger size when we read news on computers at home（我主要是看报纸，上网看新闻，一直保持阅读习惯。电脑新闻比报纸丰富。在这现在不能上网，看报纸也不是特别方便，这没有老年报。而且这些报纸还是字体小。我在家看新闻电脑字体都调的比较大）."[R11] [R17].

(j) Peer companionship.

Peer companionship is an important part of the elderly's life and is one of the factors influencing the elderly's choice of aged care facilities.

"A few days ago, my son took me home to live for few days, but I just want to come back here only one day after, it is not that I don't like my son's place, I just prefer spending time with people of my age (前几天我儿子带我回家住了几天，但我第二天就想回来了，不是说我不喜欢他家，我只是喜欢和跟我差不多年纪的人在一块。)".[A1]

(k) The companionship of young people.

Most elderly people think of themselves as getting younger inside and are very willing to get along with younger people.

"I know someone in the gym. She's in her 60s. She's willing to get along with me, not with her peers. She is talking with me about dressing and having fun. When she is with younger people, her heart can be younger. So it can't be divided by age, by body, by level of care（我在健身房认识一个人。她已经 60 多岁了。她不想和同龄人相处，而

是和我相处。 她和我谈穿衣和玩的事。 她和年轻人在一起时心态会更年轻。 所以不能按年龄、身体、护理水平来划分）".

(l) Pet companionship.

Having a pet for company is an increasingly popular way for the aged to find companionship.

"I told them I like little animals. I went to Beisandao, and I bought two little animals, but they wouldn't let me so I had to give them up (我告诉他们我喜欢小动物，然后去北三道买了两只小动物，结果他们不让带。)." [R11] [R15]

(m) Religious facilities.

The elderly lack may spiritual sustenance in their later life and can turn to religion to recognize themselves. Interviews for this research found that many of the respondents had tended to become devout in their later years.

"A lot of elderly residents suddenly have faith when they get old to support themselves to move forward. The aged care facilities should take this phenomenon into consideration, such as a Buddha Hall or a church (很多老人老后突然有了信仰，以此支持自己继续前行。养老机构应该考虑到这种现象，比如佛堂或教堂)". [A8] [R19]

(n) Gardens and green spaces.

The elderly thrive on the discussion of gardening. "It's a hobby for old people to care for flowers and plants. Excellent green spaces can make the elderly feel comfortable (花草是老人的爱好之一。好的绿地能让老人感到舒服)".

"More green plants, like a garden (有很多绿色植物，像花园一样)". [R4] [R20]

(o) Convenient transportation.

The elderly tend to have more leisure time and people choose to travel so there is a need for particular forms of transportation. The elderly also need to go shopping. Therefore, convenient transportation is also an indispensable part of the living environment for the elderly.

"It's convenient when I want to go out and do something by myself. There are markets, squares and parks around. It's very convenient（一个人出去的时候很方便。 周围有市场、广场和公园。这很方便。）." [R16]

In summary, we can draw a ranking of the importance of the needs of the elderly: the physical environment, peer companionship and freedom are most important to the elderly at present, because these will affect their quality of life and psychological state; secondly, the elderly will also pay attention to hardware facilities that directly affect the living environment of the elderly, such as independent toilets, gardens, and medical equipment. Finally, they also focus on living elements such as dietary diversity and convenient transportation.

Based on the research in this chapter, we can know that the needs of the elderly in the physical environment are more and different. The difference of the physical environment is very easy to affect the satisfaction of the elderly with RACFs, so the physical environment is very important for the elderly. If these factors change, or there are defects, it may greatly change the quality of life and status of the elderly. Through interviews, we know that factors such as sound, light, and heat are the most concerned by the elderly. Therefore, solving the problem of the physical environment can effectively guarantee the quality of life of the elderly in RACFs. However, people often ignore the views of the elderly in this regard, and there are very few domestic related studies. Therefore, this paper will do a more in-depth exploration of this. In the next chapter, sound, light, and heat conditions will be measured to determine the acceptability of the elderly in these aspects.

5.5 Summary

Influences on elderly people's QoL can be identified as three main categories of "what needs, why needs, and what choice" through grounded theoretical research and analysis.

Compared with previous research, this chapter has carried out the following innovation and expansion. First, in the research content: previous literature on the elderly's quality of life of has been general, scattered, and lacking focus. With the help of the hierarchical coding of grounded theory, the systematic elements affecting the QoL of the elderly are obtained. It was found that the elderly have significant needs for the acoustic environment, lighting environment (illuminance and brightness), thermal environment (heating and warmth), quietness, furniture, sanitation, dietary, medical facility, recreational facilities, and barrier-free facilities, etc. But many of these needs are poorly satisfied in RACFs in China.

Second, in terms of research methods, there is few empirical researches of the quality of life of the elderly, especially from qualitative perspectives. This chapter adopts a grounded theory and qualitative research method, with semi-structured interviews for the main collection research data.

From the research above, we can know that: first of all, the acoustic environment will affect the activities and psychology of the elderly at the same time. Some elderly people believe that if the environment sound is too loud, it will affect their communication, which will cause them to feel irritable, and even lead to conflicts. Second, thermal conditions will affect the health of the elderly. The climate in the Northeast is cold, so indoor heating or air conditioning is necessary, and the heating time must meet the needs of the elderly. The elderly are more sensitive to cold due to their poor health. Sufficient heating time and heat can effectively ensure their health. Finally, the light environment must also be appropriate. Too weak light will indirectly affect the mood of the elderly, leading to depression, and too strong light will also make the elderly feel uncomfortable in life.

At this stage, although China's elderly care institutions can meet the hardware standards, there are still some problems in meeting the needs of the elderly. In fact, in most current RACFs, the elderly are not satisfied in these aspects. Therefore, the elderly are not satisfied with the quality of life of RACFs. Moreover, although RACFs have been working hard to improve various facilities, there will always be some omissions in factors such as sound, light, and heat, which will affect the lives of the elderly. In the next chapter, we will conduct measurements and research based on the problems found in this chapter to explore the indoor environment of Chinese elderly care institutions.

6. Indoor Environmental Quality of RACFs in Northern China

6.1 Introduction

Indoor Environmental Quality (IEQ) stands for a building's indoor environment performance in the aspect of occupants' health, well-being, and productivity. Physical environment parameters comprise temperature, light, visual and auditory comfort, each of which differs in the degree of comfort and impact on users' physical health. This study explores the relationships between the elderly people's perceptions of RACFs and the indoor environment. Based on a physical environment survey, the acoustic, light, and thermal environments of five RACFs were measured in different seasons and different spaces, and a questionnaire was administered to evaluate aspects of the environment, including indoor air quality (IAQ). The results demonstrate that season affects the measured values of the physical environment, but not the elderly's rating of that environment. Participants were more satisfied with bedroom environments than activity room environments. As the physical environment changes, so do the elderly's rating. Factors affecting the environmental ratings include participants' age, education level, pension level, marital status, residence time, and former residence.

With the increasing number of "empty nest elderly", an increasing number of seniors choose to live in RACFs. At the same time, due to the physical health of the elderly, the physical environment is very important to them, and the elderly also have higher requirements for the physical environment. Therefore, it is increasingly significant to discuss the IEQ of RACFs.

IEQ factors (e.g. acoustic environment and indoor air quality) comprise temperature, light, visual, and auditory comfort, which differ in terms of the degree of comfort and impact on users' physical health (Giuli et al., 2013). A previous study has observed that the IEQ environment greatly influences patients' and elderly mental and physical health (Huang et al., 2013), and improve users' health and efficiency.

The acoustic environment is one of the IEQ factors having significant effects on the health of the elderly. Excessive noise can damage health and hinder the hearing recovery of the elderly in RACFs (Schiff, 1990). Some studies have pointed out that long-term exposure to an environment above 65 dB(A) can cause serious health problems. For many elderly people, background noise and lighting can interfere with their sleep, causing them to lose concentration, feel tired, and have trouble with normal communication during the day. Older people need more lighting than young people, and insufficient light in corridors or stairs can cause them to fall. Providing proper lighting for the elderly in care homes can help reduce damage to visual functions and promote mental health (Haanes et al., 2015). In addition, because the elderly have high sensitivity to temperature, it is very significant to keep a constant and appropriate temperature in the living environment. Some scholars have found that when the temperature drops under 15°C, the blood pressure of the elderly rise. Therefore, it is recommended that rooms for the elderly should be heated in winter.

Elderly care facilities in China still focus on satisfying the most basic living needs of the elderly (Lee et al., 2002). Studies (Mui et al., 2008) have attempted to associate indoor environmental conditions with the feelings and perceptions of senior occupants in RACFs. However, such studies have focused on only one or a few parameters, or a short sampling period, or a few sampling sites, while IEQ is seldom integrated. To address this, research for this thesis involved a large scale systematic approach to the indoor environment in RACFs in China, to explore the relationships between indoor environments and older people's perception in those facilities.

The study focuses on five research questions in relation to the physical environment:

1) What are the objective physical environments in the RACFs?
2) What is the impact of the physical environment on elderly people's ratings of the RACFs?
3) What is the threshold range of physical environment parameters acceptable to the elderly rating?
4) What is the relationship between different physical environmental factors and overall IEQ rating?
5) What are the ratings of elderly people with different demographic and social backgrounds?

In this chapter, the research methodology is presented with sites, participants, and research methods. The research results and analysis are illustrated according to the elderly's rating of the four environmental parameters, which are acoustic environment, thermal environment, and lighting environment, as well as IAQ. The Correlation between IEQ indicators rating and physical environment and the effects of the demographic factors are also demonstrated respectively.

6.2 Methodology

In this study, the sound pressure level (SPL), humidity, illuminance, brightness, and temperature of the activity rooms and bedrooms of five RACFs were measured. A questionnaire was administered to gain participants' ratings of the facilities' physical environment factors. In total 885 valid questionnaires were obtained.

6.2.1 Sites

A field survey was implemented in five RACFs from summer to winter of 2016-2017 in Harbin, Changchun, and Shenyang, the capital cities of China's three northeast provinces, which have long winters and a cold climate. In Harbin, for example, the average temperature in July is 22 °C and maximum temperature 38 °C. The winters are long, cold, and dry, with occasional snowstorms. January has an average temperature of -15 – -30 °C with the lowest temperature being -37.7 °C.

The samples were selected using probability (stratified) sampling and while the RACFs differed from each other in many important ways (RACF see Table 6-1 and Figure. 6-1), all sites provide meals, accommodation, laundry, activity rooms, and medical services for the elderly. Among them, small RACFs are defined as facilities with less than 150 bed; medium RACFs are defined as facilities with between 151 and 300 beds; large RACFs are defined as facilities with between 301 and 500 beds; and super-large RACFs are defined as facilities with over 500 beds (50867-2013, 2013). The summer-winter transition refers to the period from summer to winter, which includes later summer, autumn, and early winter.

Table 6-1 Profiles of the five facilities

	Hongdongda Care Home (HGD)	Guoxin Qinqin Residential Care Home (GX)	Shenhe District Care Facility(SHQ)	Aida Residential Care Facility (AD)	Ankang Residential Care Facility (AK)
City	Harbin	Changchun	Shenyang	Shenyang	Harbin
Season	Summer Winter Transition	Summer Winter Transition	Summer Winter Transition	Summer Winter Transition	Summer Winter Transition
Number of beds	50	200	180	350	1500
Number of activity rooms	2	10	4	3	＞10
Street facing	√				
Reconstruction	√	√		√	
Location	City center	City center	Suburb	New district	Suburb
Scale	Small	Medium	Medium	Large	Super large

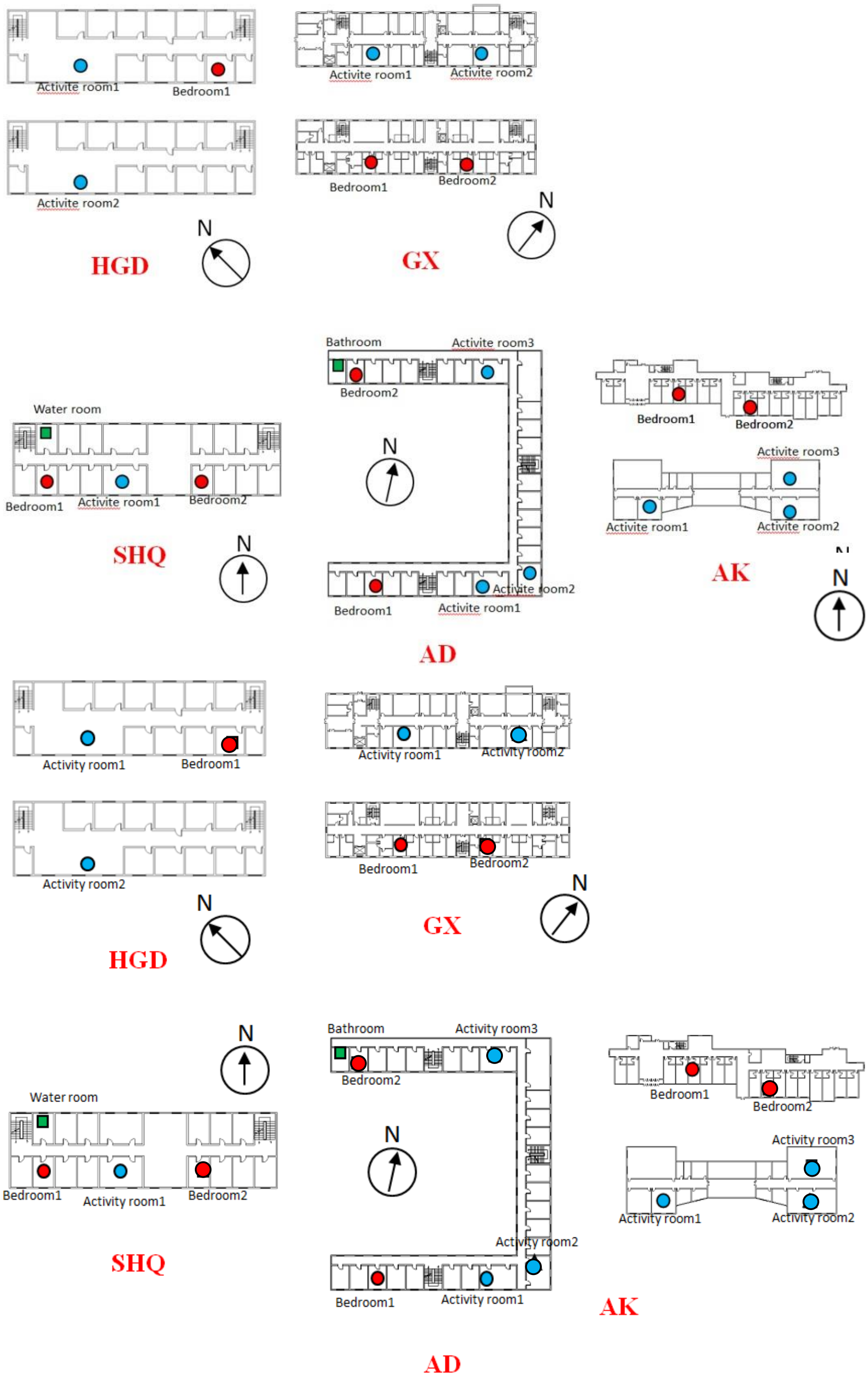


Figure. 6-1. Floor plan of five RACFs. (The red dot represents the bedrooms , the blue dot activity rooms and the green square represents bathroom and water room)

Note: HGD, GX, SHQ, AD, and AK are abbreviations for the five RACFs that were measured in this study. HGD and AK, the RACFs in Harbin; GX, the residential aged care facilities in Changchun; SHQ and AD, the residential aged care facilities in Shenyang.

6.2.2 Participants

The elderly participants were invited to participate in a survey about their age, gender, education, background, etc. To better characterize the IEQ of the five selected RACFs, the final analysis only included responses from residents who had lived in these facilities for six months or more. Applying the Frailty Scales of Rockwood et al.'s (2005), older persons who scored 1–4 qualified as participants, meaning that their physiological and psychological status was sufficient to join the study. This study collected a total of 885 questionnaires, 94 in summer, 126 in winter, and 665 in the transition period. There were 408 responses from men and 477 from women. In addition, the study included statistics on age, education, retirement, marriage status, residence time, and former residence. (Figure. 6-2)

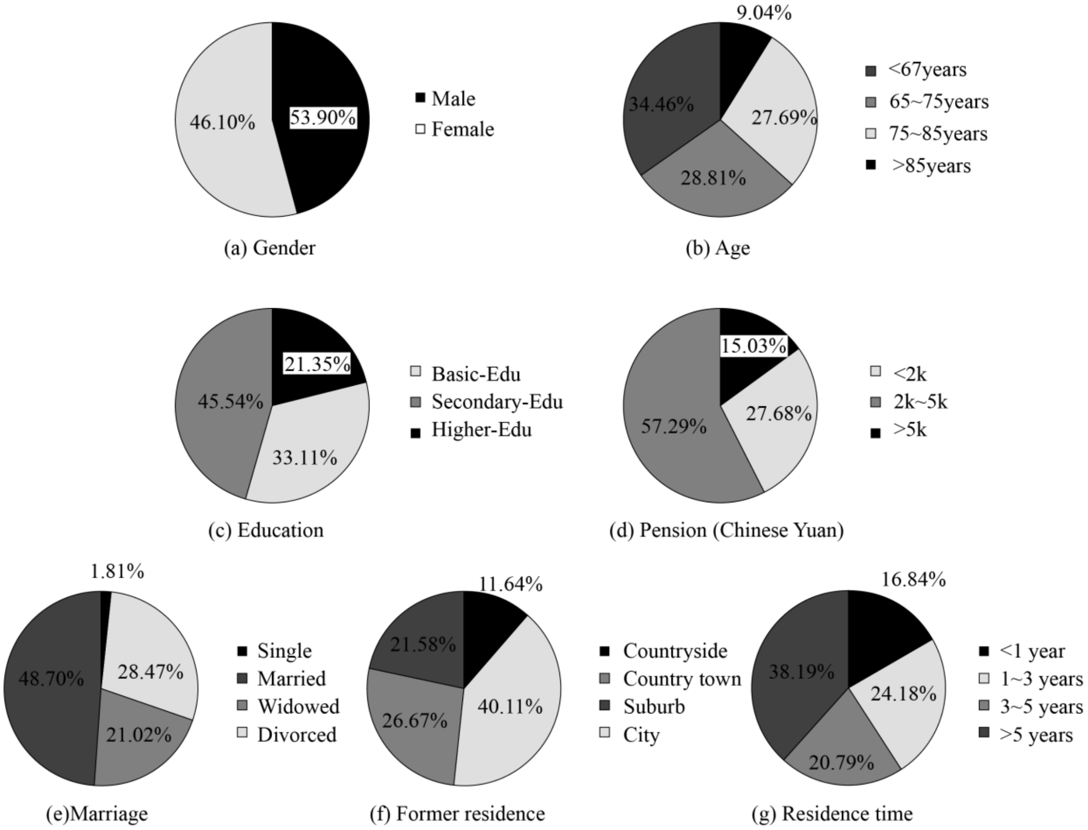


Figure. 6-2. Background Information of participants

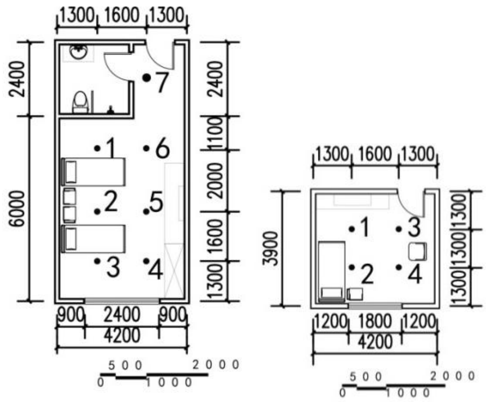
6.2.3 Measured Indoor Environment

Nine bedrooms and eleven activity rooms were sampled in the five RACFs, with sample measurements including five major indoor environmental parameters: sound pressure levels, brightness and illuminance levels, air temperature, and relative humidity (RH). For each of these measurements, a multi-point method was adopted; that is, each room was arranged with four to sixteen measurement points. Each measurement point was 1.2 m from the floor and at least 1.0 m from walls and windows (Figure. 6-3). The SPL and lighting environment was measured for 18 consecutive hours (working hours) and the thermal environment was measured for 24 consecutive hours

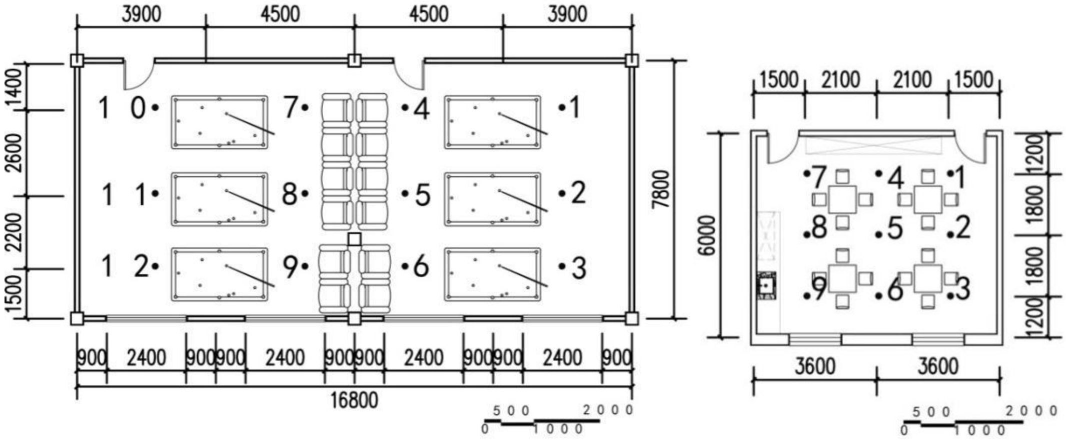
The measurement time of each room was measured at intervals of 1 hour each day because one person had to measure 10-15 measurement points in a facility and made sure that each room can be measured at least once at an hour’s interval.

In addition to the current long-term measurement, there is also a description of the short-term measurement, which is to measure a set of corresponding physical environment indicators after each questionnaire.

The summer measurement was conducted between July 20 and August 15, 2016. The autumn measurement was conducted between October 13 and November 9, 2016. Winter measurement was conducted between January 5 and 15, and between January 28 and February 8, 2017. During this period, the physical environments of the five RACFs were measured and the questionnaire survey was conducted. It should be noted here that in each small room, SPL is only measured at one measurement point, BSAB801 Sound Level Meters was set to record three successive sets of measurements at each measuremnt point, and 10 SPL readings automatically recorded in each set.



(A)Double bedroom (B) Single bedroom



(C) Activity room (D) Special activity room

Figure. 6-3. Examples of measurement points distribution diagram

Table 6-2 Measurement and instrument

Measurement	Instrument	Measurement Range/Accuracy
Sound	BSAB801 Sound Level Meters	19 dB(A) ~ 137 dB(A) (±0.1 dB(A))
Illumination	T-10A Illuminance Meters	0.01 - 299,000 lux (±5%)
Brightness	GPH-1001 brightness Maters	20 cd/m^2~2000 kcd/m^2
Temperature	K-type thermocouple (Centre 314 Temperature/Humidity Datalogger, Centre Tech, Taipei, Taiwan)	−40–80 °C (±0.1 °C);
Relative humidity (RH)	RH sensor (Centre 314 Datalogger)	0–99% (±3%)

For each specific measured parameter, multiple measurement sites were chosen in relation to the size and layout of the RACF, with equipment positioned in selected areas with various but representative environmental settings. The measured process and results followed the norms and standards (National Standard GB 50867–2013, GB 50034-2019, GB 3096–2008, GB 22337 -2008, GB 50867–2013, T18883–2002, ISO 7730 and ASHRAE 55).

6.2.4 Questionnaire Survey

In the present study, the utilized questionnaire survey aims to investigate the satisfaction and subjective perception of occupants of aging residential facilities on the building's acoustics environment, thermal condition, lighting condition, IAQ, and overall IEQ. The survey was conducted in five RACFs. Interviews were carried out face-to-face with voluntary participants to improve the rate of questionnaire return. The survey locations, including bedrooms and activity rooms, were chosen in each facility. As summarized in Table 3, the survey information was separated into two main categories: information on background and satisfaction with IEQ. The different aspects of the category ‘Satisfaction with IEQ’ - acoustic, visual, and TC, IAQ, and overall comfort - were analyzed with a seven-point Likert scale based on the participant’s reported perceptions. For example, satisfaction with the thermal environment was evaluated by responses to the following question:

‘To what extent are you satisfied with the thermal environment in this room?

□Strongly dissatisfied □Dissatisfied □Somewhat dissatisfied □Neutral □ Somewhat satisfied □Satisfied □Strongly satisfied’

Table 6-3 Categorical information collected from the questionnaire

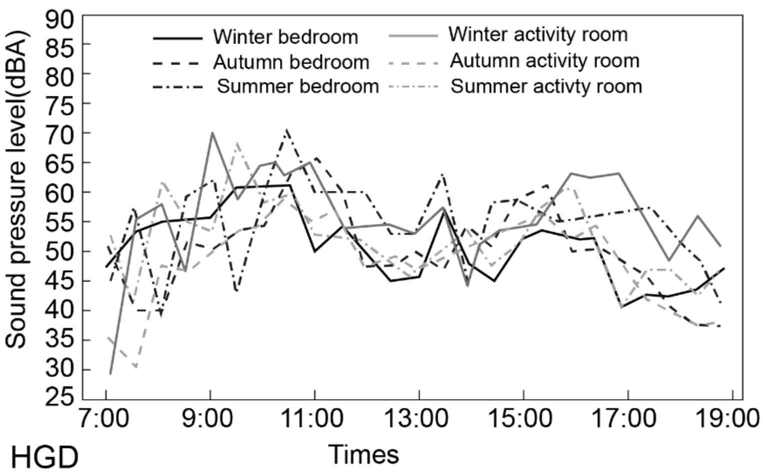
Category	Question
Background information	Gender; Age; Education level; Pension; Marriage; Place of residence; Length of stay
Satisfaction with IEQ	Acoustic, Loudness, Noise level, Intelligibility, Preference degree; Lighting, Lighting equipment, Light distribution, Interior lighting; Thermal-Env, Temperature, Relative Humidity, Ventilation; IAQ, Odor, Freshness, Cleanliness

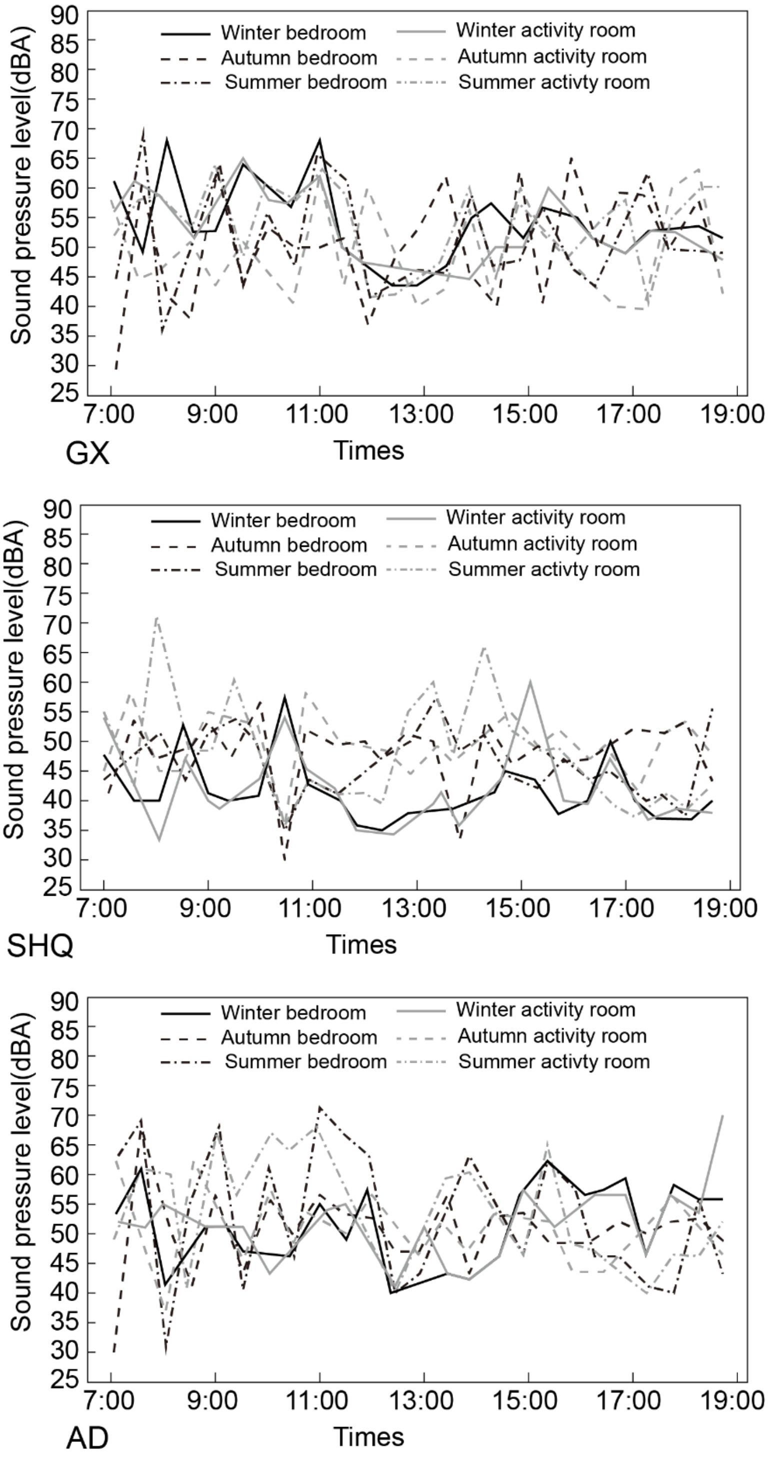
6.3 Results and Analysis

6.3.1 Rating of the Acoustic Environment

6.3.1.1 Sound Pressure Level

People's sensitivity to noise in the living environment changes with the frequency of the sound. The acoustic environment is a complex concept and its perception is related to sound pressure level, the sound itself, subjective experience, and personalities, such as social factors, cultural factors, personal preferences, and emotions (Belojevic et al., 2003).




Winter bedroom
Autumn bedroom
Summer bedroom
Winter activity room
Autumn activity room
Summer activty room
Sound pressure level(dBA)
Times
GX
SHQ
AD

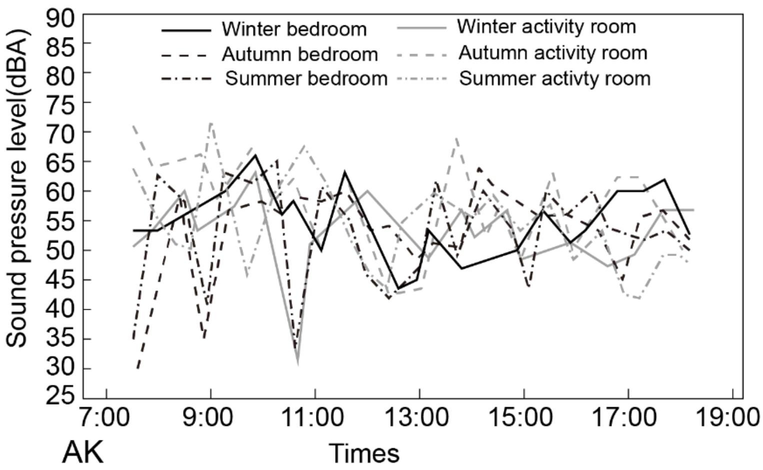


Figure. 6-4. Sound pressure level measurement in different rooms in different seasons

The highest SPL in the bedrooms exceeded 65 dB(A) in winter (see Figure. 6-4). In the activity room, the sound pressure level were different among five RACFs in winter, but the highest SPL of 5 RACFs were all reaches 60 dB(A). Although the fluctuation of sound pressure level in summer is small, its minimum value is higher than that in winter and autumn. Compared with winter, open windows, higher temperature, lower wind speed and more frequent people's activities in summer will interfere with the indoor acoustic environment, which may make the level of sound pressure level relatively stable. The SPL fluctuates greatly in the morning (07.00–12.00 a.m.), with peak noise between 10.00–11.00 a.m. In HGD, the sound pressure level gradually decreases at lunch and siesta time and into the evening, with similar results for the other RACFs studied. In AK, the levels of sound pressure of the bedroom is similar in summer and autumn bedroom, which begin at around 30 dB(A) in the morning at 7 am, while the SPLs in winter bedroom and activity rooms are similar that begins at roughly 50 dB(A) at 7 am, and the SPLs begin at almost 70 dB(A) in summer and autumn activity rooms. All SPLs end is around 50 to 55 dB(A) at 7 pm. Overall, the sound pressure level increases as winter approaches, with the main activity time of elderly people in the morning or before lunch.

According to WHO regulations, 55 dB(A) is the threshold value that affects health. In Europe, areas where the noise exceeds 75 dB(A) will be included in the highest level. The Nation code of China stipulates that the highest limit of noise in areas dominated by residential, cultural and educational institutions is 55 dB(A) during the day and 45 dB(A) at night. Noise can affect human blood pressure and heart, leading to heart attack and death from cardiovascular disease. In China, the noise in the living environment should be less than 45 dB(A), the insulation of air sound should not be less than 50 dB(A), and the impact sound should not be more than 75 dB(A) ("Harbin University of Architecture and Architecture. Design Code for the Elderly," 1999). The maximum sound of recreational and fitness rooms shall not exceed 45 dB, and the maximum sound of rehabilitation and medical rooms shall not exceed 40 dB. In addition, there are different regulations for different room types. China divides the room types into three categories, namely category I, category II, and category III. The noise transmitted by the partition wall or floor between category Ⅰ and category Ⅰ should not exceed 50 dB, between category Ⅰ and category Ⅱ should not exceed 50 dB, between category Ⅱ and category Ⅱ 45 dB, and between category Ⅱ and category Ⅲ 45 dB.

In terms of lighting, relevant departments have strict regulations on the ratio of window to floor area of RACFs. That ratio of the living room, the dining room, rest room, recreational and fitness room, rehabilitation and medical room and other rooms used by the elderly should be higher than 1:6, while that of the public toilet should be more than 1:6. Higher than 1:9. In addition, when the windows of the elderly's room are east-west, effective shading measures should be taken.

In terms of heating, RACFs without heating facilities should install safe and reliable heating equipment in the bathroom according to the local climate characteristics. The radiator and hot water radiant heating manifold must be installed with protection measures against burns. In the living room, bathroom, entertainment and fitness room, rehabilitation and medical room, and office, the design temperature should be 20 °C, public toilets, stairwells, and corridors should be 18 °C, and the bathroom should be 25 °C.

From this point of view, the surveyed residential aged care facilities need to further improve noise control.

6.3.1.2 Rating of Acoustic Factors

Table 6-4 shows correlation coefficients between subjective responses of overall IEQ and acoustic environment factors. It could be found that the correlation coefficients of acoustic comfort, noise level, loudness, preference degree, and overall acoustic rating are significantly positive (P <0.001). In the rating of the AE, the ratings of the four RACFs basically exceed 3 points, except for the Intelligibility and Preference degree ratings of SHQD, which are 2.83 and 2.82 respectively, and the Preference Degree of

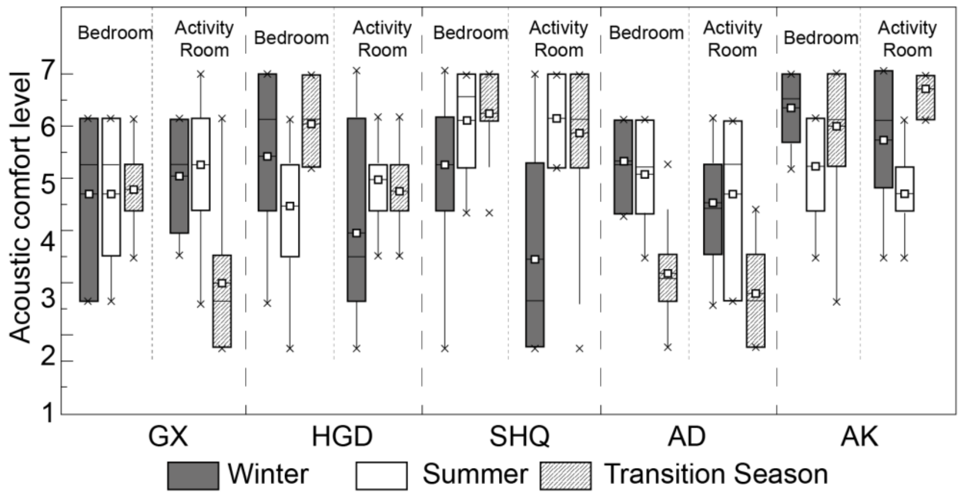
AK, which is 2.67. However, the intelligibility aspects of the sound environments of HGD, GX, AD and AK RACFs are either weakly correlated or uncorrelated, and the other indicators of AK are basically irrelevant, because the site is relatively far away and is an independent super large facility, and the activity room and the residential building are separated. It may be that elderly people, who often suffer from hearing disorders, have difficulties with sound clarity in general. Overall, the acoustic environment of the five RACFs was evaluated at a medium level (3.5–5 points).

It can be seen from the table that, except for AK, the correlation between Intelligibility and Acoustic Environment Rating is the lowest ($P>0.05$). Therefore, the intelligibility hardly affects the perception of the acoustic environment by the elderly. The Preference degree has a high correlation in the first four RACFs ($P<0.001$). The reason is also very simple. People will feel happy about the sounds they like, and hate those they don't like. Therefore, the degree of influence of preference is very high (0.749). In addition, the correlation coefficients of acoustic comfort, loudness, noise level, etc. are also very high, which are above 0.4 ($P<0.001$), which are all important factors that affect Acoustic Environment Rating. Finally, due to the remote location, the separation of the activity room and the residential building, etc., the correlation of AK is generally low ($P>0.05$).

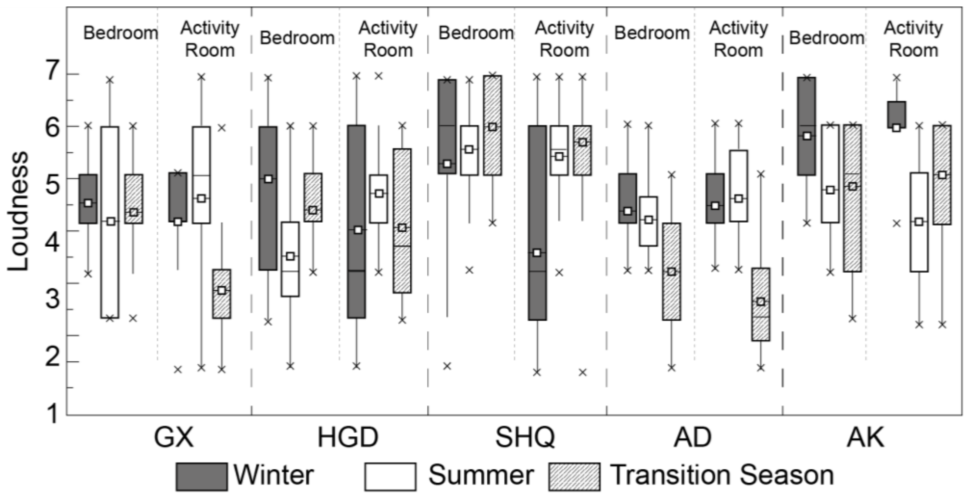
Table 6-4 Correlation analysis of acoustic environment rating

RACFs	Acoustic index	A	B
HGD (Small-scale)	acoustic comfort	4.32/2.096	0.757/0.000 (***)
	Loudness	3.89/1.695	0.618/0.000 (***)
	Noise level	4.36/2.122	0.405/0.000 (***)
	Intelligibility	4.73/1.473	0.103/0.393
	Preference degree	3.94/2.117	0.749/0.000 (***)
	Overall sound rating	4.23/1.845	0.668/0.000 (***)
GX (Medium-scale)	acoustic comfort	3.81/1.872	0.664/0.000 (***)
	Loudness	3.56/1.643	0.602/0.000 (***)
	Noise level	3.61/1.753	0.611/0.000 (***)
	Intelligibility	5.12/1.389	0.266/0.011 (*)
	Preference degree	4.39/2.065	0.622/0.000 (***)
	Overall sound rating	3.84/1.794	0.694/0.000 (***)
SHQ (Medium-scale)	acoustic comfort	5.15/1.939	0.734/0.000 (***)
	Loudness	5.18/1.813	0.693/0.000 (***)
	Noise level	4.55/1.665	0.749/0.000 (***)
	Intelligibility	2.83/1.635	0.698/0.000 (***)
	Preference degree	2.82/2.031	0.755/0.000 (***)
	Overall sound rating	5.18/1.992	0.715/0.000 (***)
AD (Large-scale)	acoustic comfort	3.54/1.742	0.726/0.000 (***)
	Loudness	3.41/1.298	0.683/0.000 (***)
	Noise level	3.42/1.706	0.611/0.000 (***)
	Intelligibility	5.45/1.062	0.009/0.458
	Preference degree	4.92/1.662	0.767/0.000 (***)
	Overall sound rating	3.55/1.798	0.801/0.000 (***)
AK (Super large-scale)	acoustic comfort	5.43/1.269	0.254/0.015
	Loudness	5.11/1.279	0.014/0.898
	Noise level	4.24/1.901	0.069/0.514

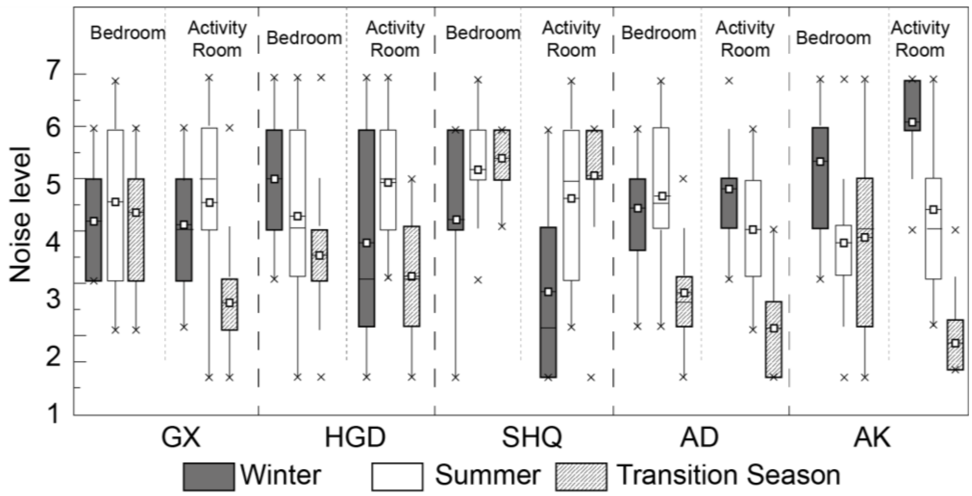
Intelligibility	5.07/1.459	0.007/0.946
Preference degree	2.67/1.563	0.184/0.079
Overall sound rating	5.41/1.156	0.116/0.271



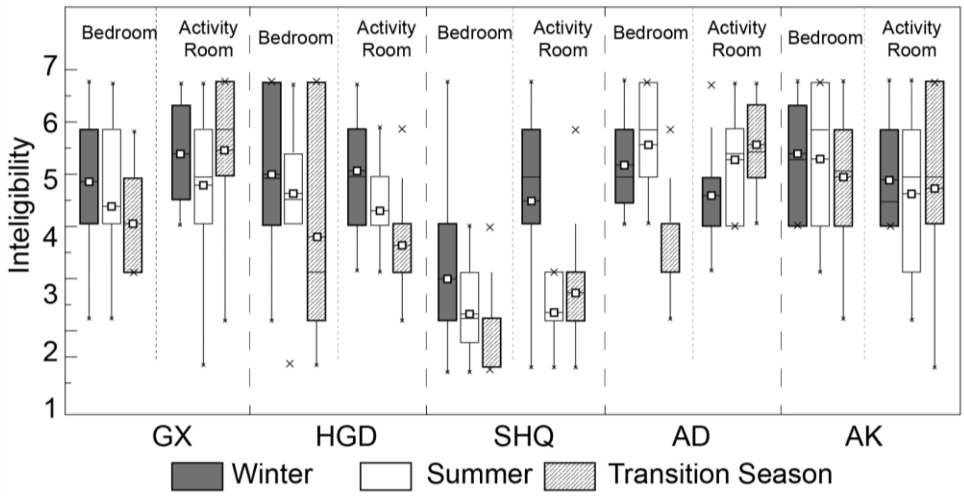
(A) Acoustic comfort



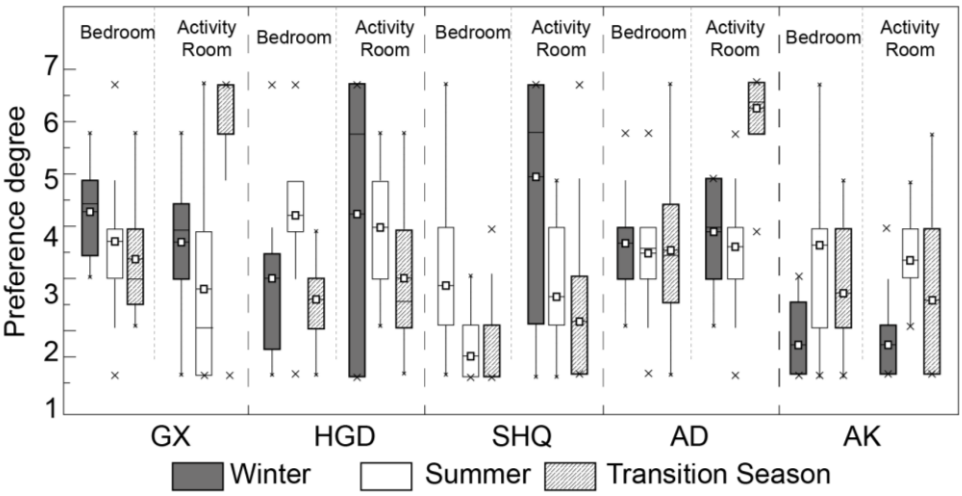
(B) Loudness



(C) Noise level



(D) Intelligibility



(E) Preference degree

Figure 6-5. Rating of acoustic indicators of five RACFs based on seasonal differences

The seasonal change survey RACF (Figure. 6-5) showed no obvious change in acoustic indicators, nor were the rating results in bedrooms and activity rooms affected by seasonal changes. However, it can be observed from the average value of AD that the acoustic comfort, loudness, and noise level of AD and AK were more affected by season than other RACFs, with rating values of the transition season more than 1 point lower than summer and winter. The preference degree and intelligibility are less affected by the season, and the five indicators of GX, HGD, and SHQ are the same. This was because the survey was conducted in autumn when surrounding buildings were under construction. The resulting noise affected the rating of the acoustic environment.

In GX, the acoustic comfort level in summer is the highest, and so is AD. In HGDI, the bedroom has the lowest acoustic comfort level in summer. The reason may be that the window needs to be opened for ventilation in summer, and the sound from outside the window will enter the room. The same is true for SHQ's bedroom. Among the AKs with the lowest correlation, the acoustic comfort level in winter is the highest.

Ratings of specific sound level and noise level by the elderly may need to take into account the hearing loss issues. Hearing loss associated with the elderly is a common disease of the elderly. Over the age of 65, approximately 40% of people have age-related hearing loss worldwide (Thomas, 2011). A Japanese laboratory study compared the scores of young and old in a speech recognition measurement and the results indicated that the older testers' scores were 25% lower compared to those of the young people. The influence of this difference equals to an increase of 5 dB(A) in environmental noise.

6.3.1.3 Relationship between SPL and Acoustic Rating

The linear relationship between SPL and the AE is shown in Figure. 6-6 (The analysis of AK is not included here, because AK is not significantly correlated in the previous analysis). Regardless of season or room, the rating of acoustic comfort decreased with increasing SPL. The SPL and AE of bedrooms have a direct linear relationship, and the R^2 of the five RACFs all exceed 0.6. An rating value exceeding 4 points indicates that the elderly are satisfied with the surrounding physical environment. In the summer, they generally express dissatisfaction with the acoustic environment when the SPL exceeds 70 dB(A). The highest rating for SPL was slightly higher in winter and exceeded 65 dB(A), which may cause the elderly express dissatisfaction. For bedrooms and activity rooms, the satisfactory SPL is between 65 and 70 dB(A). The

SPL rating of AD bedrooms is the highest, with participants generally expressing irritability when the SPL exceeds 56 dB(A). The analysis of linear aggression can reference to Meng et al. (2017b)'s study regarding relationship between sound pressure and crowd density in restaurants. The results showed that the R^2 fitting values of HGD and GX were higher in summer, exceeding 0.5, and the fitting values of GX and SHQ were higher, exceeding 0.5 in winter. In the transition season, the R^2 value did not exceed 0.5, which may be caused by seasonal changes. In addition, R^2 in the bedroom and activity room are higher, except for the GX in the activity room. Generally, changes in SPL are related to the schedule and behavior of the elderly. The SPL during nap time and meal time is lower than other times. In general, the SPL in winter is higher than that in summer and transition seasons, and its fluctuations are large. This is because it is too cold outside in winter and the elderly are more inclined to indoor activities, which can easily gather and cause the SPL to rise. In addition, the analyse of the percentage of sound evaluation in different intervals of 30-80 dB(A) (see Figure 6-7). The results show that with the increase of SPL, the proportion of scores exceeding 4 points shows a trend of first increasing and then decreasing. With the increase of SPL, there is no obvious trend in the percentage change of the score value of 1 point. We found that the elderly have a higher evaluation of sound, even if there is some noise, their acceptance is higher.

In addition, the satisfaction threshold of the elderly to the acoustic environment in summer is higher than that in winter and transition season. The reason may be that windows need to be opened in summer. When outside sounds enter the room, the indoor cause will inevitably increase, and thus the satisfaction threshold will increase accordingly. In the comparison between the bedroom and the activity room, it is not difficult to see that the satisfaction threshold of the activity room is higher than that of the bedroom. The reason is simple. The sound of the activity room will be louder when there are activities, which is generally acceptable to the elderly. The bedroom is a private space. For such a room, most elderly people like to be quiet.

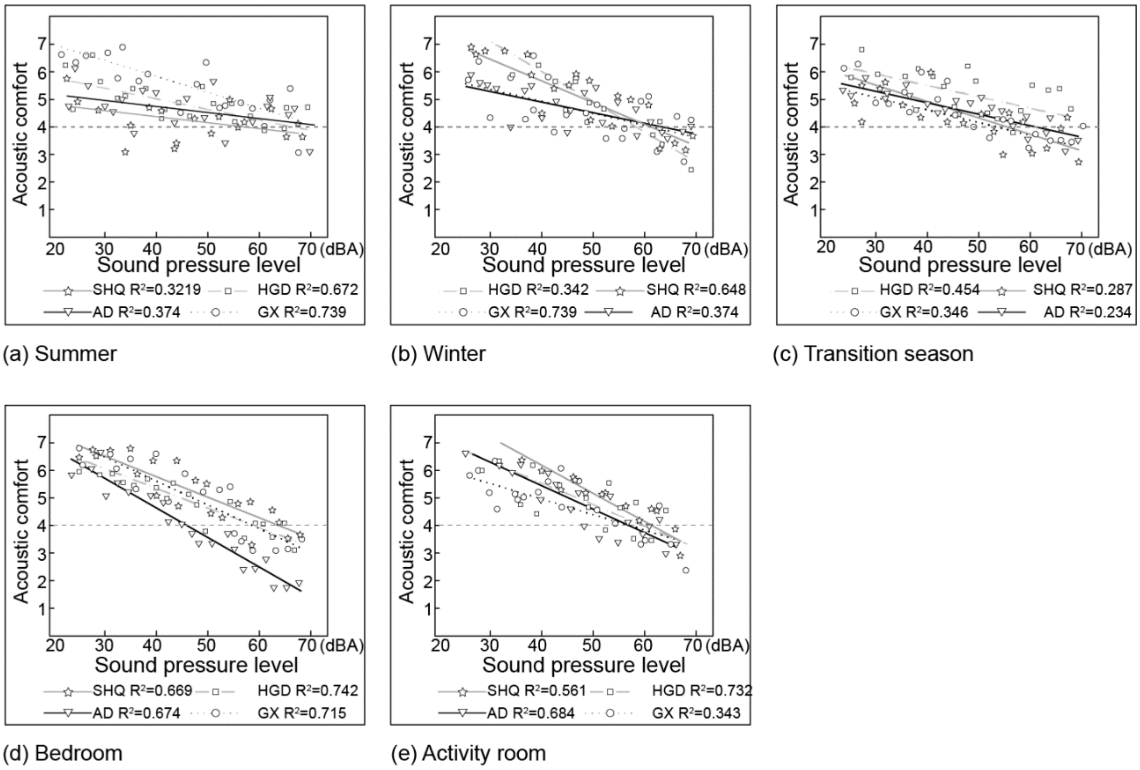


Figure.6-6. The fit between SPL and acoustic rating for five RACFs

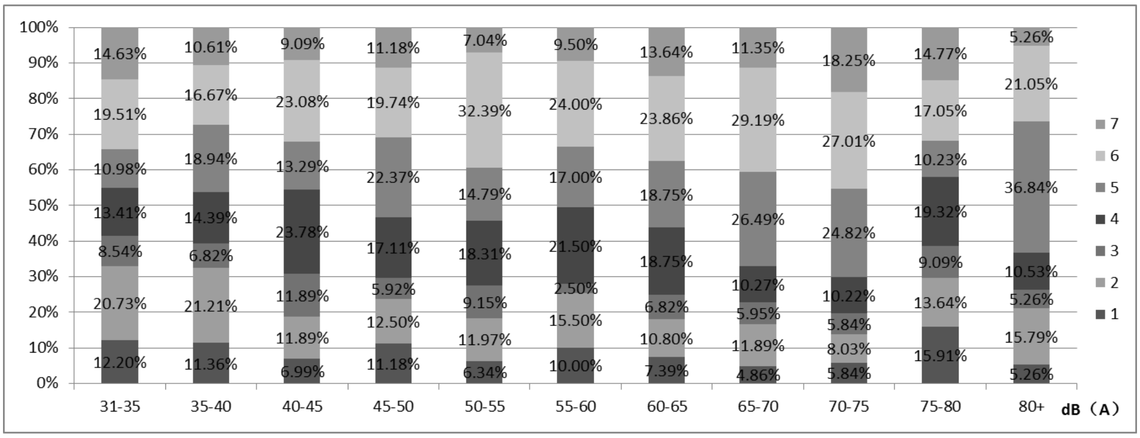


Figure 6-7.Comparison of different SPL evaluation values

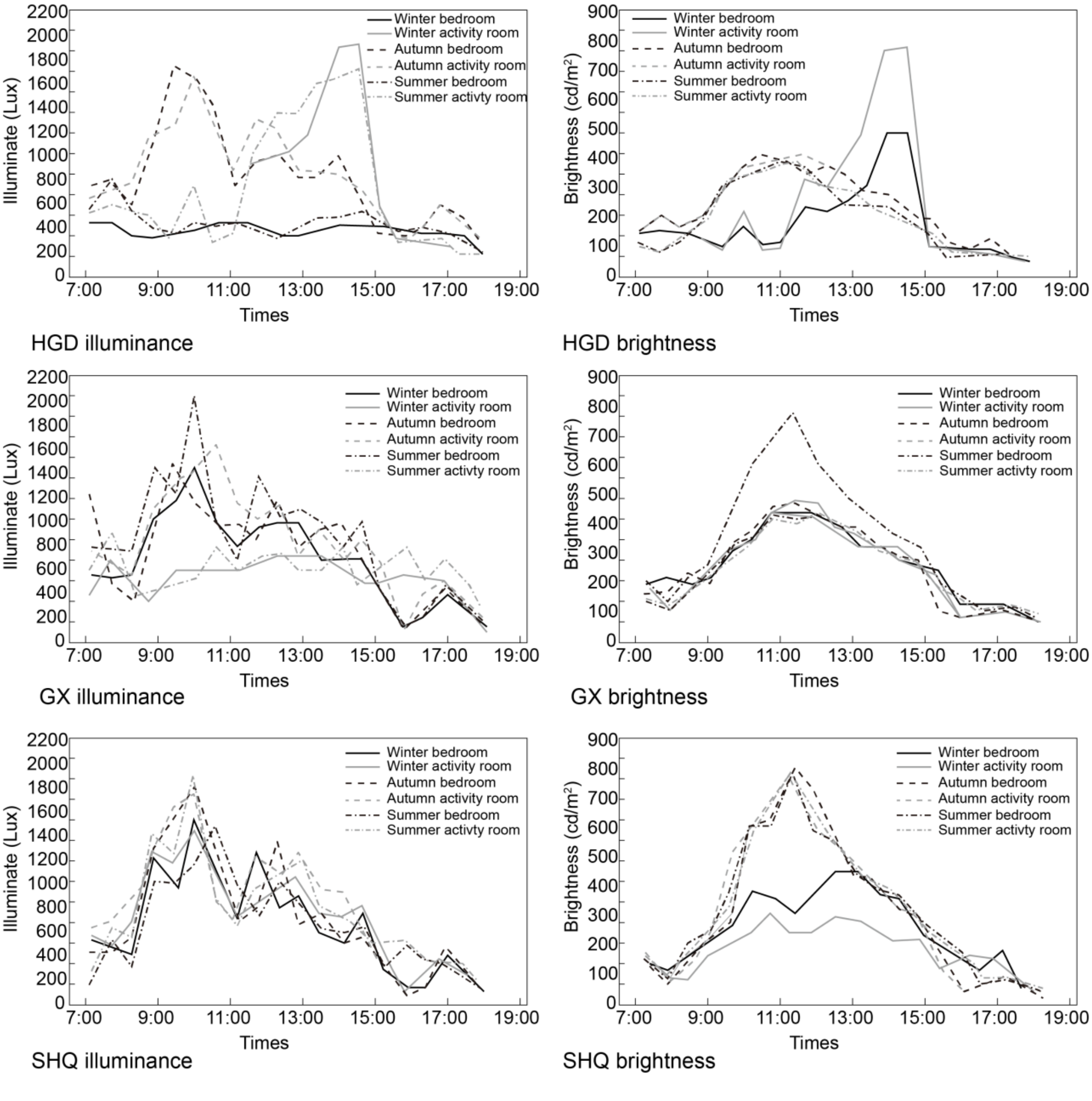
Lai et al. (2009a) reported that when the noise level exceeds 70 dB(A), noise acceptance is greatly reduced. Jeon et al. (2010b) reported dissatisfaction with 80% of drainage systems and air noise levels of 42 dB(A) and 43 dB(A), respectively.

As can be seen from the figure 6-7, Acoustic Comfort Level will drop linearly as the sound pressure increases. Between 20 dB(A) and 30 dB(A), Acoustic Comfort Level will reach its peak. For different seasons, the Acoustic Comfort Level in summer is basically the same as that in the transition season, and it is slightly lower in summer. In addition, the Acoustic Comfort Level of the bedroom and the activity room will also reach a peak value between 20 dB(A) and 30 dB(A), but the acoustic comfort Level of the bedroom corresponds to a slightly lower sound pressure level than the activity room, indicating that I am A relatively quiet environment is required.

6.3.2 Rating of the Lighting Environment

6.3.2.1 Illuminance and Brightness

Light measurement is based on illuminance and brightness, and is measured under natural light environment and indoor ordinary light environment. Internal levels of light can be affected by seasons, weather, building location, and orientation. For elderly people who like reading and indoor activities, lighting directly affects their QoL.



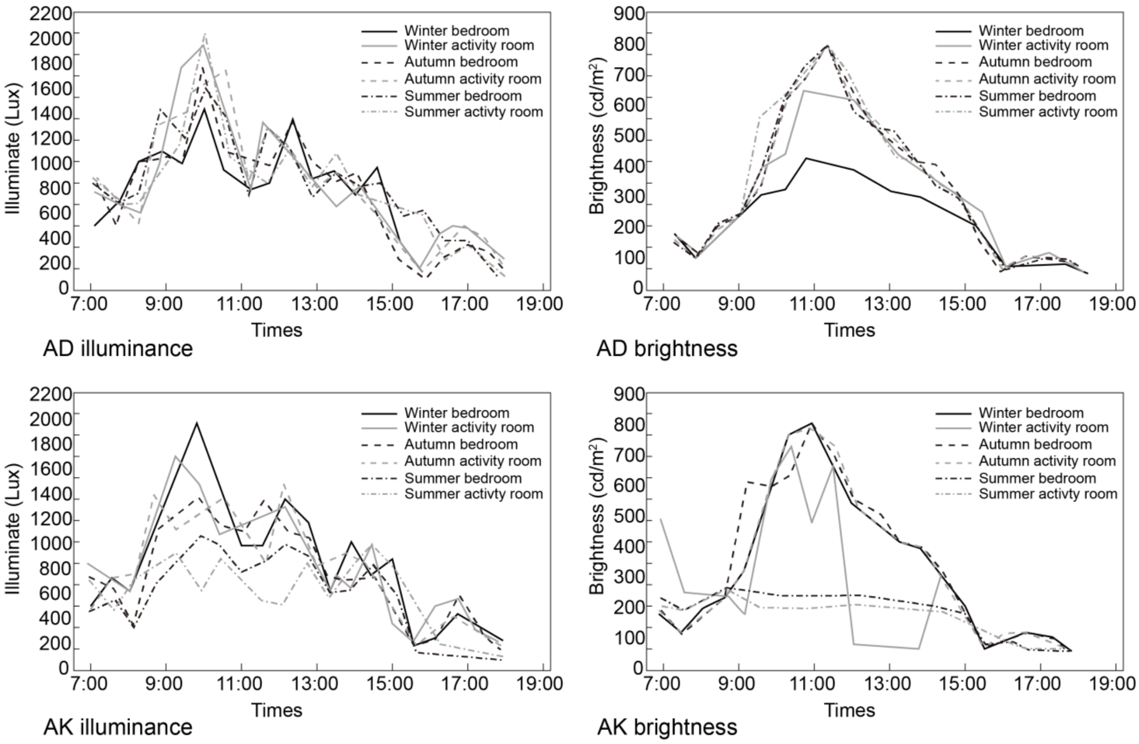


Figure. 6-8. Comparison of seasonal light in five RACFs

Daylight can provide a healthy and visually comfortable environment in the building, but seasonal influences cause differences in light in RACFs (see Figure. 6-8). Northeast China has higher latitudes, so winter daylight time is shorter, and indoor light measurements show that winter light levels are lower than that in summer and autumn. The small-scale RACF, HGD, differs from the other four, with winter light values higher than in summer and autumn. The highest brightness of activity rooms in HGD is 750 cd/m^2, in winter, while bedroom brightness is 450 cd/ m^2, also in winter. The illuminance and brightness peaks of the HGD also differ significantly from the other four. HGD has the best lighting conditions at around 3 p.m., because it has more west-facing windows, so afternoon light conditions are better. In GX, SHQ, and AD, most windows face east and the morning light is better. In HGD, the highest value of brightness in winter appears between 2-3 pm, the peak value of the activity room reaches 750 cd/m^2, the bedroom is 450 cd/m^2, and it generally appears at 11 am in summer. The peak value is only about 400 cd/m^2. In AK, the best lighting condition occurs at around 10 to 11 am, and in the summer bedroom and activity room, the index of brightness remains stable from 9 am to 4 pm. As the sun moves westward, the illuminance and brightness show a downward trend. The most direct environmental factor that affects the comfort of the elderly is the light intensity of the room.

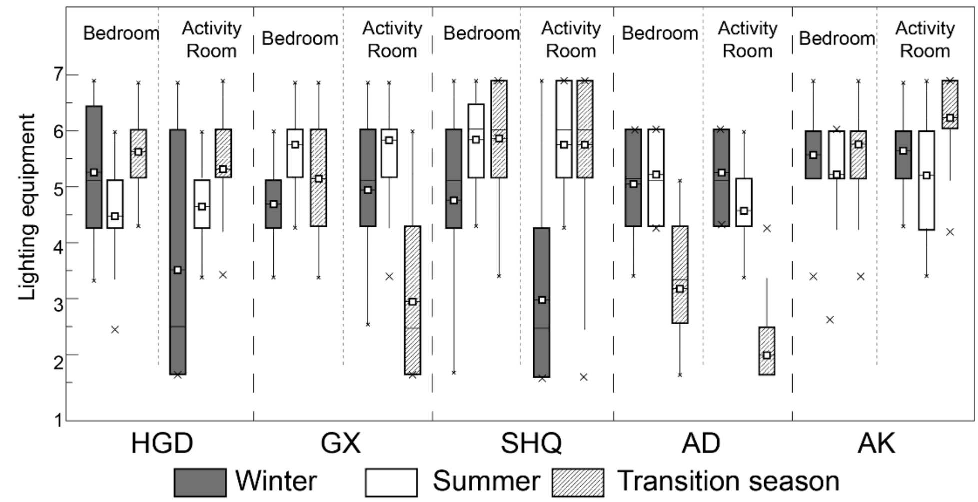
6.3.2.2 Rating of Lighting Factors

The indicators involved in the light rating include lighting equipment, light distribution, and interior lighting. The light ratings of the five RACFs and their correlations with IEQ rating are shown in Table 6-5. The three lighting rating indicators for SHQ are higher than the other three RACFs, except AK, and the average score is close to 5 points. AK's light distribution and interior lighting scores are very high, both exceeding 5 points. The light ratings of AD and AK are the lowest, with indicators between 3–3.5 points. In addition to SHQ and AK, the other three RACFs all show low interior lighting rating, which may be a building design flaw.

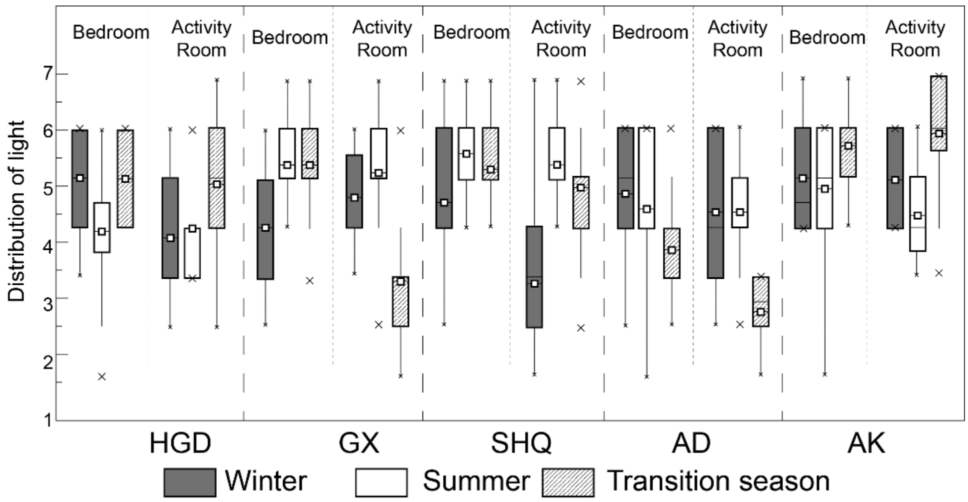
In addition, column B is the correlation between each indicator and Light Environment Rating. The lower the value to the right of the slash, the higher the correlation. Among all five RACFs, lighting equipment has the highest correlation. It can be seen from this that lighting equipment directly affects the indoor lighting, which in turn determines how you feel about the lighting conditions. Interior lighting has the lowest correlation, which is ranged from 0.131 to 0.692, especially in AK (0.131). The reason may be because it can be adjusted freely. When this condition cannot meet the needs of the elderly, people can make up for it through adjustment. The RACFs did not fully consider elderly people’s needs for indoor lighting during the initial construction or renovation. Due to the pervasive poor lighting in these RACFs, elderly people refer to other factors when evaluating IEQ, factors such as IAQ, ventilation, noise, music, and heating, etc. So the correlations between interior lighting and IEQ rating are weak for HGD and AD, at 0.399 and 0.412 (p-value <0.01). In addition, the correlation between AK's light distribution, indoor lighting, and IEQ rating is weak, with values of 0.240 and 0.131 (p-value < 0.01), because the site is relatively far away and is an independent super large facility, and the activity room and the residential building are separated.

Table 6-5. Correlation analysis of light environment rating

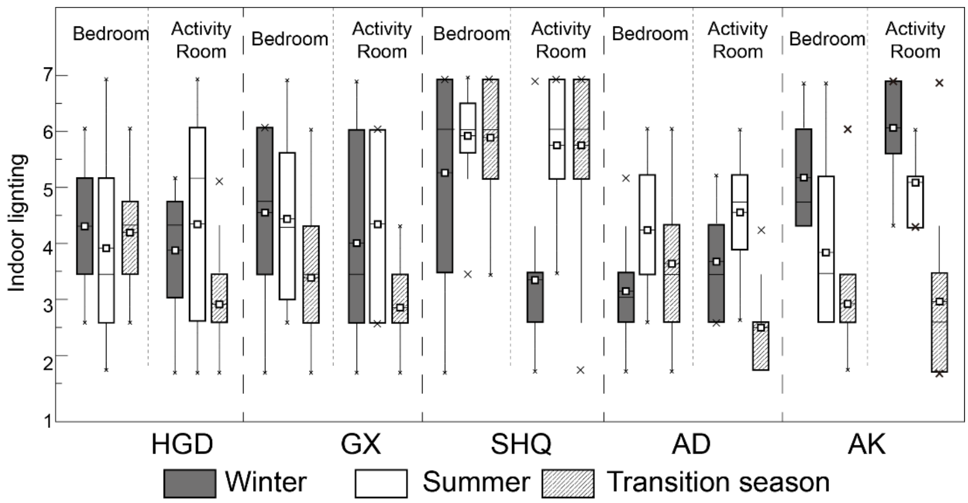
RACFs	Light index	A	B
HGD (Small-scale)	Lighting equipment	4.08/1.888	0.736/0.000 (***)
	Light distribution	4.11/1.260	0.646/0.000 (***)
	Interior lighting	3.77/1.891	0.399/0.001 (**)
GX (Medium-scale)	Lighting equipment	4.24/2.002	0.684/0.000 (***)
	Light distribution	4.14/1.481	0.624/0.000 (***)
	Interior lighting	3.18/1.739	0.553/0.000 (***)
SHQ (Medium-scale)	Lighting equipment	4.84/2.084	0.754/0.000 (***)
	Light distribution	4.48/1.458	0.657/0.000 (***)
	Interior lighting	4.98/1.998	0.692/0.000 (***)
AD (Large-scale)	Lighting equipment	3.40/1.964	0.762/0.000 (***)
	Light distribution	3.52/1.547	0.612/0.000 (***)
	Interior lighting	2.78/1.325	0.412/0.001 (**)
AK (Super Large-scale)	Lighting equipment	3.40/1.946	0.669/0.000 (***)
	Light distribution	5.57/1.041	0.240/0.021 (*)
	Interior lighting	5.14/1.173	0.131/0.215 (*)



(A) Lighting equipment



(B) Light distribution



(C) Interior lighting

Figure. 6-9. Rating of lighting indicators of five RACFs based on seasonal differences

As shown in Figure 6-9, generally speaking, the difference between the highest value and the lowest value of each rating value in winter is the largest. In SHQ, the rating value of the activity room is at the lowest value in winter (2-4.5). In GX, except for the indoor lighting rating value, the highest values of the other two rating values are the same in summer and transition season (maximum value is 6). In HGD, all three values reach their maximum in winter (5-6.5). Among them, the indoor lighting rating value also reached the maximum in summer, which was the same as that in winter (5). In AK, the difference of indoor lighting rating value in each season is relatively large.

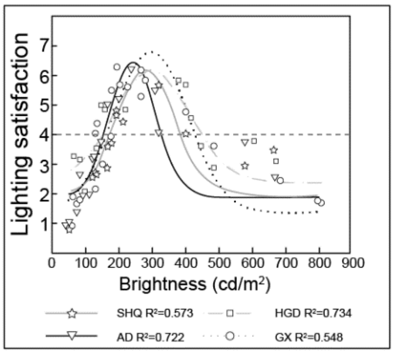
As a high-altitude region, Harbin has a late sunset and long days in Summer (Zhao et al., 2013), with sufficient sunlight in summer to meet the needs of the light that illuminates interiors and making up for poor lighting equipment and lack of artificial illumination. However, unlike the other RACFs which are suburban, HGD is located in the city center, surrounded by tall buildings that interfere with daylight illumination. In all five RACFs, the lighting ratings for bedrooms were higher than for activity rooms. Ratings of lighting equipment and light distribution in bedrooms are superior to activity rooms because participants can control the bedroom lighting themselves. Based on the seasonal variation of the light environment, it can be learnt from the mean that the light environment rating in summer is normally higher compared to that in winter and transitional seasons, which is consistent with the seasonal characteristics of northern China. Occupants can adapt bedroom lighting to their needs, which may increase the elderly’s happiness index and overcome the lack of bright daylight in winter.

The decline in elderly people’s visual function and psychological sensitivity determines their special requirements for the light environment (Cui & Ji, 2017). The changes in vision associated with aging are one of the most important physical changes in the aging process. Thus, it is significant to ensure the interior lighting conditions so that the elderly residents' vision would not be chronically damaged by poor lighting.

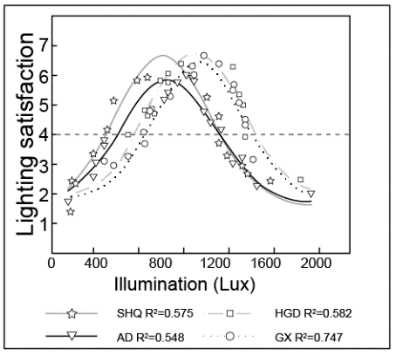
6.3.2.3 Relationship between Lighting Environment and Lighting Rating

Lighting can affect people's perceptions and reflect people's responses to the environment (Loe, 2017). In addition, indoor lighting environments can have significant effects on the daily life and mood of residents. The generally accepted brightness range for the elderly is between 100-400cd/m^2. The lighting indices for this study include brightness and illuminance, which have a non-linear relationship to light rating (see Figure 6-9. The analysis of AK is not included here, because AK is not significantly correlated in the previous analysis). As for brightness and illuminance increase, light ratings in all cases show a trend of first rising and then declining. As the seasons change, peaks of brightness differ. As shown in Figure 6-10, once brightness exceeds 250 cd/m^2 in Summer, light rating begins to decline rapidly. Taking the AD with a better fitting effect as an example, once the AD summer brightness exceeds 250 cd/m^2, the light rating begins to decline rapidly. The brightness threshold for winter and transitional seasons is 450 cd/m^2. In addition, as the brightness changes, the light assessment of the bedroom and the activity room will not be very different. The brightness threshold for Winter and the transition season is 450cd/㎡, and the light rating of bedrooms and activity rooms do not differ greatly. In addition, I also analyzed the brightness rating percentages in different intervals between 0-400 cd/m^2 and above 400 cd/m^2 （figure 6-11）.The results showed that the brightness of 300-400 cd/m^2 was the highest in the high evaluation, and this brightness was the most satisfactory to the elderly. As the brightness increases, the percentage of more than 4 points begins to decrease. At the same time, some elderly people have a certain proportion of low rating of insufficient brightness, which shows that the elderly have a certain demand for high brightness, which may be related to their declining vision.

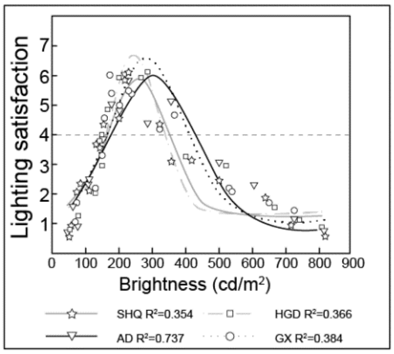
The percentage of illuminance perception in different intervals was analyzed in figure 6-11. The results show that the illuminance of 800-900 lx accounts for the highest proportion in the 7-point, and the illuminance is the most satisfactory for the elderly. As the illuminance increases, the percentage of rating exceeding 4 points first increases and then decreases. The perception of illuminance among 400-500 lx has the highest percentage of more than 4 points.



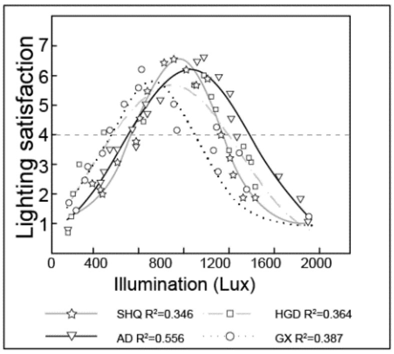
(a) Brightness summer



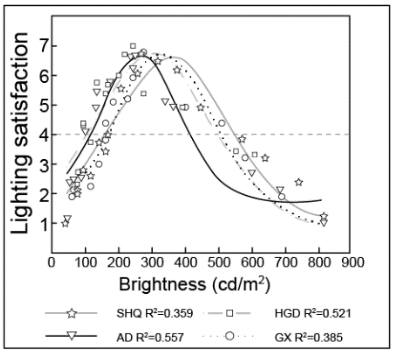
(b) Illumination summer



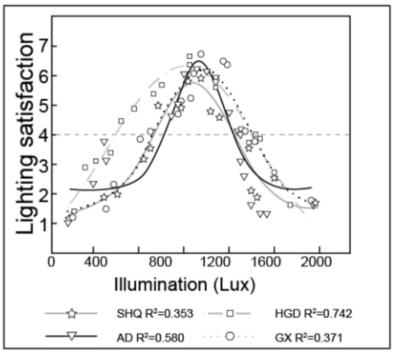
(c) Brightness in winter



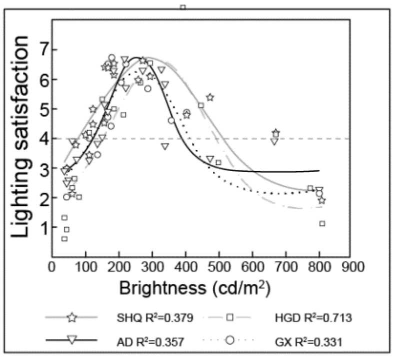
(d) Illumination in winter



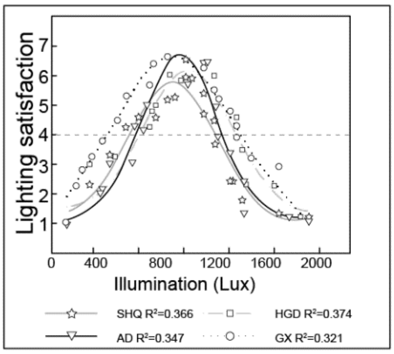
(e) Brightness in the transition season



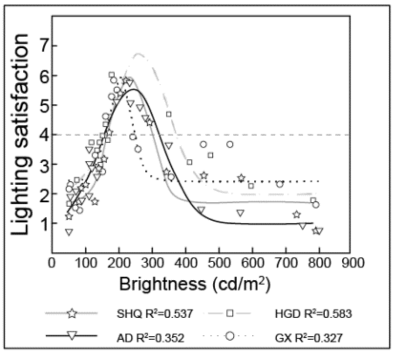
(f) Illumination in the transition season



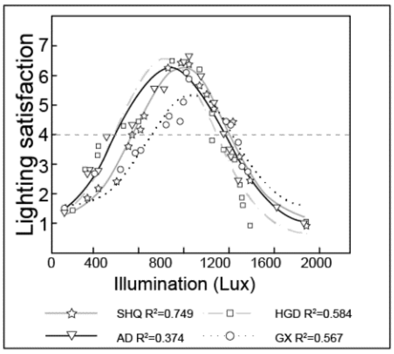
(g) Brightness in bedroom



(h) Illumination in bedroom

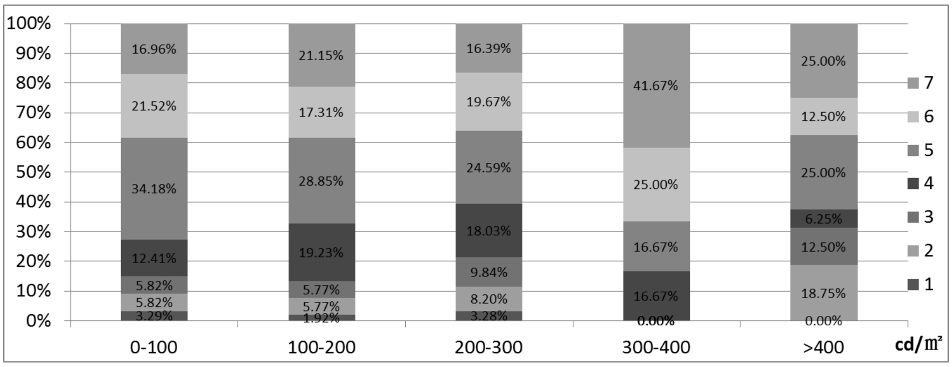


(i) Brightness in activity room

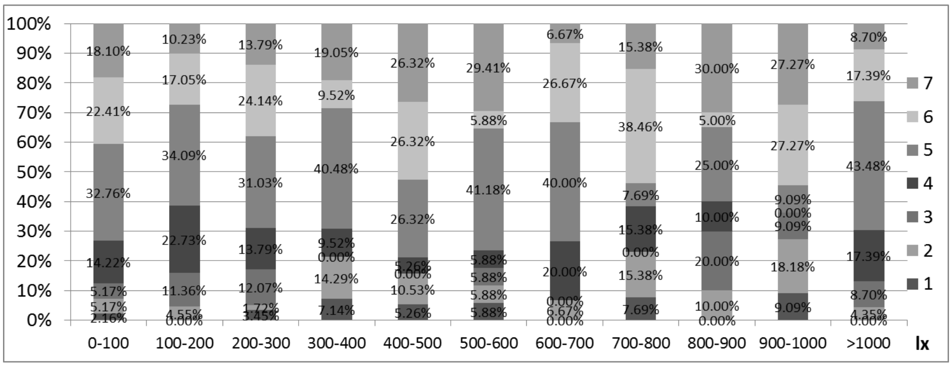


(j) Illumination in bedroom

Figure. 6-10. The fit between lighting Indices and lighting rating for five RACFs



(A) Comparison of different brightness rating values



(A) Comparison of different illuminance e rating values

Figure. 6-11 Comparison of lighting environemnt rating values

HGD has the best brightness linear regression, with R^2 of 0.713 in bedroom and 0.583 in activity room. While for illuminance, the SH has the best linear regression, with R^2 of 0.386 in bedroom and 0.749 in activity room.

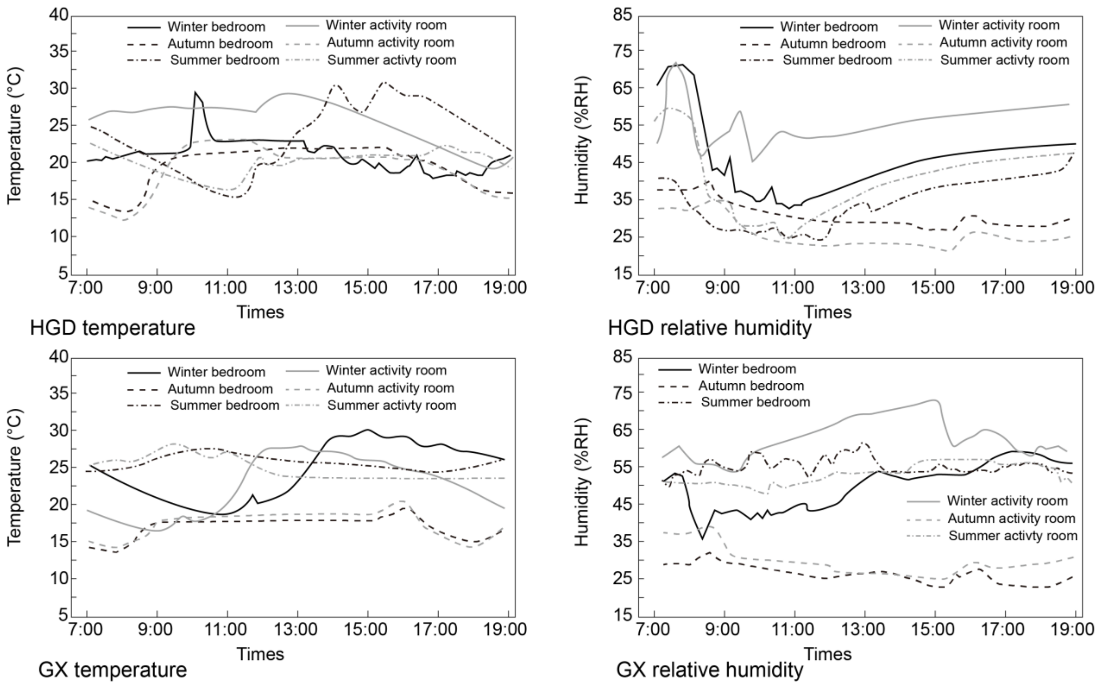
With the increase of illuminance, the lighting rating also showed a trend of first rising and then falling. The threshold values of the illuminance of various RACFs also differ greatly. In summer, the thresholds of AD and SHQ are similar, approximately 800 Lux, with the thresholds of HGD and GX at approximately 1100 Lux. It is interesting, however, that the light rating of GX drops in winter when illuminance exceeds 800 Lux, while the HGD threshold is 900 Lux in winter. In the transition season, the rating of all RACFs drops when the illuminance exceeds 1200 Lux. The thresholds of bedrooms and activity rooms are similar, with elderly people satisfied with the illumination of below 1000 Lux. In general, the brightness corresponding to the peak of the Lighting Comfort level in summer and transition seasons is lower than that in winter, and the brightness range corresponding to the Lighting Comfort level higher than the standard value in summer is also smaller than that in winter.

Sinoo et al. (2011) measured the horizontal and vertical illuminance and color temperature of Dutch residential aged care facilities. They found that the illuminance in the window area was significantly higher than the vertical illuminance, which leads to the significance of windows in the RACFs that ensure adequate natural lighting in all seasons.

6.3.3 Rating of the Thermal Environment

6.3.3.1 Temperature and Humidity

The measurement of the thermal environment is based on temperature and RH, and is measured in a natural indoor environment. The thermal environment is affected by many conditions. In addition to natural weather, ventilation, air conditioning, heating, indoor humidifiers and human activities will also affect the changes in temperature and humidity (Geng et al., 2017). The temperature measurement displayed in the Figure 6-12 shows no obvious differences between activity rooms and bedrooms. The indoor temperature in winter is generally higher compared to that in summer and autumn except for HGD afternoon temperature and SHQ morning temperature which are lower than that of summer.



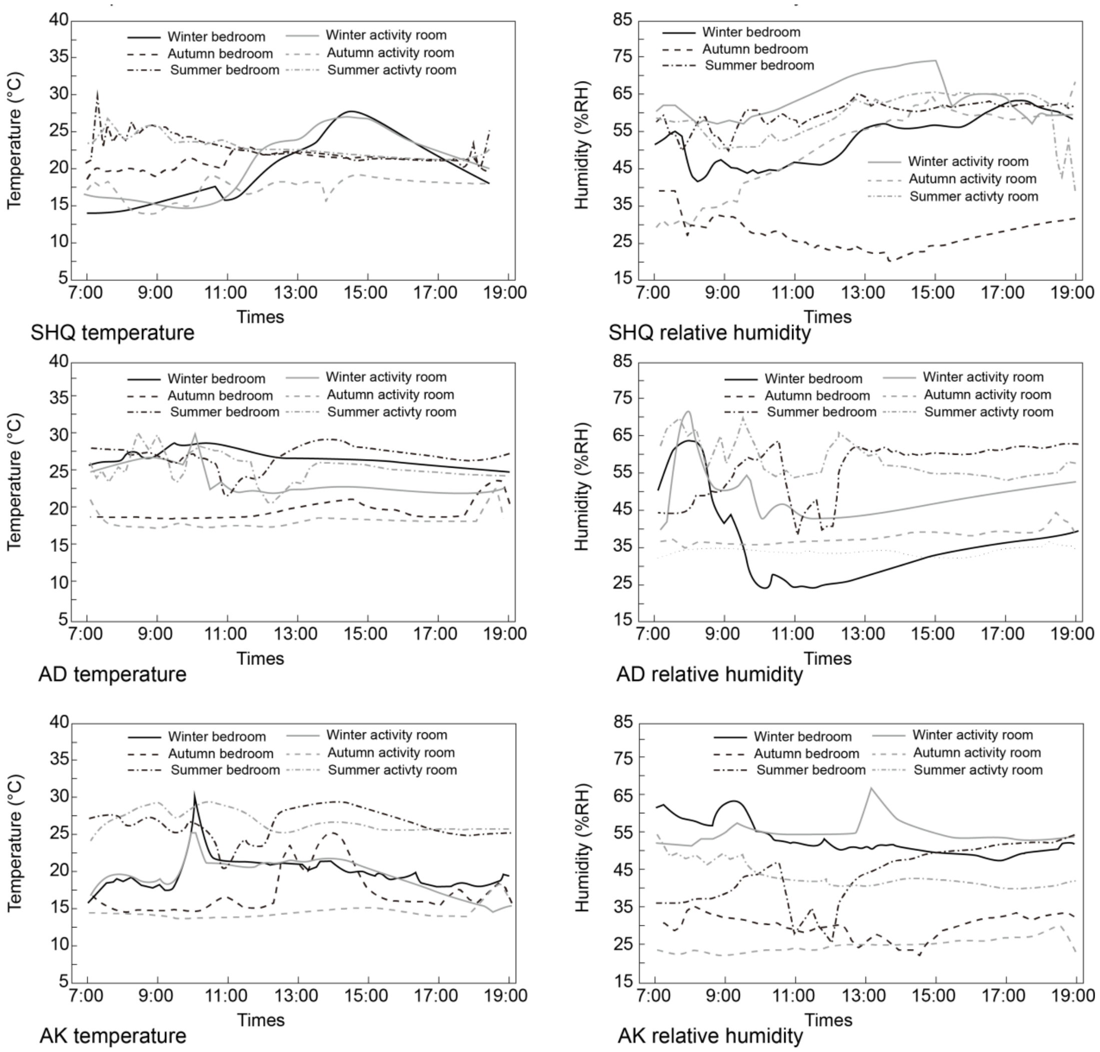


Figure 6-12. Comparison of thermal environment in five RACFs

In winter, the indoor temperature varies dramatically during the day （see Figure 6-12）. For example, the winter morning temperature of SHQ is around 14 °C, which rises to over 25 °C in the afternoon and drops to around 22 °C in the evening. Bedroom temperatures in autumn are similar to those in summer, with temperatures in the morning and evening are relatively low, increasing slightly during the day and stabilizing at approximately 20 °C. The indoor temperature control of AD is the most stable of the five RACFs, at 20-30 °C in summer, and the GX at 23-26°C and AK 20-30 °C, while the air temperature ranges from 15-23 °C ranges from in autumn and 25-30 °C in winter. A stable indoor temperature can prevent the elderly from frequent clothing changes and reduce the risk of illness. The indoor temperature of AK is quite stable in the Summer bedroom and activity room, as well as in the Autumn activity room, while the temperature in the Autumn bedroom rises rapidly at 1 pm from 15 °C to 25 °C, and drops to 16 °C at 3 pm. In winter, the temperature of both the bedroom and the activity room rise rapidly at around 9:30 am from 16 °C to 30 °C at around 10:30 am, and drop back to 22 °C at 11 am.

The RH of small-sized RACFs in winter is higher compared to summer and autumn, and particularly in the morning, the RH peaks at 67.5%. This sultry weather may affect sleep. The RH in autumn is lower compared to summer and winter, at approximately 45%. The indoor RH of medium- RACF and large-sized RACFs in Summer is higher compared to Winter and Autumn, perhaps because there are fewer opportunities for window ventilation in Summer, and the large temperature difference between outdoors and indoors causes the formation of water vapor indoors, increasing indoor humidity. But the humidity of AK in winter is higher than in summer and autumn. Furthermore, factors such as floor level and room location in the building affect humidity measurement. For example, the humidity is significantly higher in rooms near water rooms or public bathrooms. The RACF RH in autumn is lower than in summer and winter, at approximately 35%. Temperature and humidity are key indicators for assessing a room’s comfort, so they are highly valued by residents. The overall RH in autumn of all five RACFs is lower compared to winter and summer, perhaps because in autumn, the indoor temperature is lower compared to summer and winter as the heating system is not on. Thus we can say that the air can be less acceptable with the rise of temperature and humidity.

6.3.3.2 Rating of Thermal Environment Factors

There are three rating indicators for the thermal environment: air temperature, RH, and Ventilation. However, in the structural equations in Chapter 7, the temperature, humidity, and ventilation are evaluated separately. The reason is that we found in our analysis that air temperature, RH, and Ventilation are all strongly correlated and significant with IEQ. Therefore, in the analysis of structural equations later, they will be analyzed as independent variables.

Table 6-6 presents the rating of the three thermal environment indicators and their correlations with the IEQ rating. The thermal environment analysis here specifically analyzes three indicators: air temperature, RH, and Ventilation. These three indicators are the three evaluation indicators of the thermal environment. In this analysis, air temperature, RH, and Ventilation all have a strong correlation and significance with IEQ. Therefore, in the analysis of structural equations later, they are analyzed as independent variables.

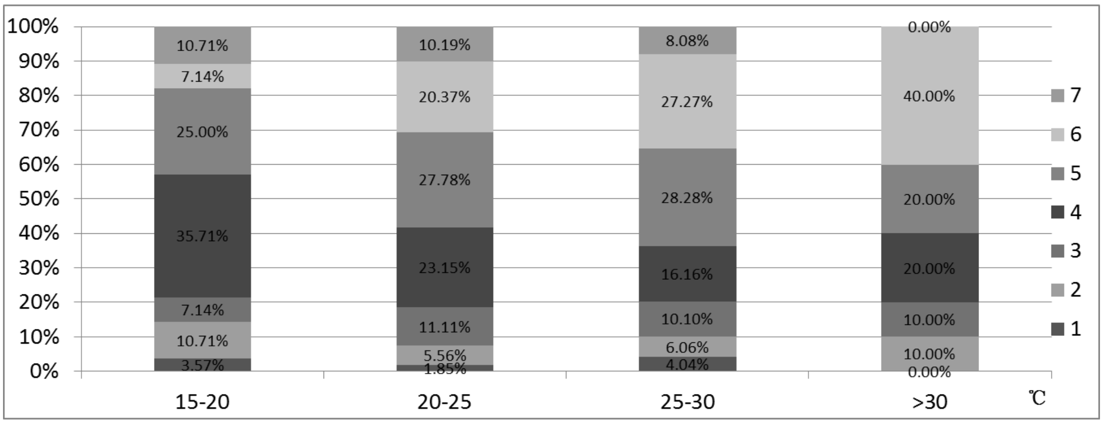
Elderly people are satisfied with their RACFs' thermal environments, and almost all ratings of temperature and ventilation exceed 4 points. The humidity rating of SHQ is the lowest, at only 2.87 points. In terms of correlation, temperature has a high correlation with the overall thermal environment. HGD, GX, SHQ and AD are 0.713, 0.762, 0.703 and 0.813 respectively ($p < 0.001$). The RH has a low correlation with the overall thermal environment, especially HGD, GX and AD are 0.258 ($p < 0.05$), 0.369 ($p < 0.001$) and 0.177 respectively. The ratings of temperature, humidity, and ventilation are positively correlated with IEQ rating. The ratings of temperature and ventilation are highly positively correlated, with a correlation coefficient close to or above 0.7 ($p < 0.001$). The RH ratings of HGD, GX, and AD are weakly correlated with IEQ rating.

Among all the five RACFs, air temperature has the highest correlation, so we can know that air temperature has the greatest impact on the thermal environment index. Among HGD and AD, RH has the lowest correlation, which are 0.258 and 0.177 ($p > 0.05$). In addition, the correlation of ventilation is in the middle, and the corresponding value is relatively high, ranging from 0.386 to 0.772. Therefore, although the influence of ventilation on the thermal environment index is not as good as the air temperature, the degree of influence is also large. In addition, there is no obvious correlation between AK's rating of various indicators and IEQ rating ($p > 0.05$), because the site is relatively far away and is an independent super large facility, and the activity room and the residential building are separated.

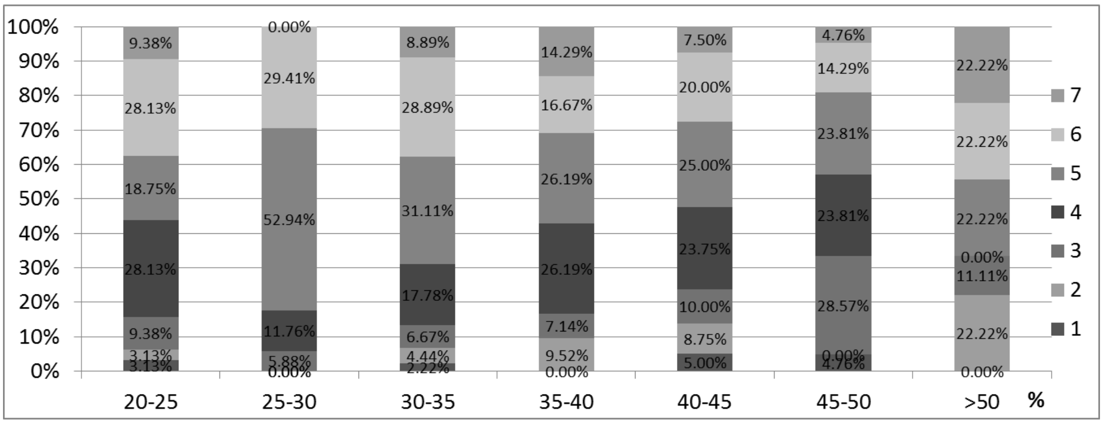
On this basis, the indoor thermal environment needs of the elderly are analyzed (see Figure 6-13). The overall evaluation of temperature by the elderly is relatively high, and the percentage of rating exceeding 4 points first increases and then decreases. In the range of 25-30 °C, the percentage of rating exceeding 4 points is the highest. Above the 30 °C range, the proportions of low rating (1 point) and high rating (7 points) are both 0.00%. This shows that the elderly need higher indoor air temperature, but too high temperature can also cause discomfort for the elderly. Changes in temperature will cause changes in indoor humidity. Tthe percentage of humidity perception was analyzed in different intervals. The percentage of rating were exceeding 4 points showed a tendency to increase first, then decrease and then increase. Most of the elderly did not give high or low rating under 25-30% humidity, and most of them concentrated on 5 or 6 points. At the same time, the percentage of the elderly's low rating of different humidity (1 point) is very low, not exceeding 5%.

Table 6-6. Correlation analysis of thermal environment rating

RACFs	Thermal-Environment index	A	B
HGD (Small-scale)	Air Temperature	4.24/1.793	0.713/0.000 (***)
	RH	4.17/2.042	0.258/0.031 (*)
	Ventilation	4.20/1.924	0.386/0.001 (**)
GX (Medium-scale)	Air Temperature	4.31/2.015	0.762/0.000 (***)
	RH	5.33/1.955	0.369/0.000 (***)
	Ventilation	4.20/2.137	0.732/0.000 (***)
SHQ (Medium-scale)	Air Temperature	4.73/1.827	0.703/0.000 (***)
	RH	2.78/1.769	0.707/0.000 (***)
	Ventilation	4.89/1.808	0.726/0.000 (***)
AD (Large-scale)	Air Temperature	3.86/1.896	0.813/0.000 (***)
	RH	6.17/1.126	0.177/0.183
	Ventilation	4.41/2.392	0.772/0.000 (***)
AK (Super Large-scale)	Air Temperature	5.52/1.181	0.199/0.057
	RH	5.07/2.106	0.095/0.368
	Ventilation	5.67/1.513	0.071/0.512

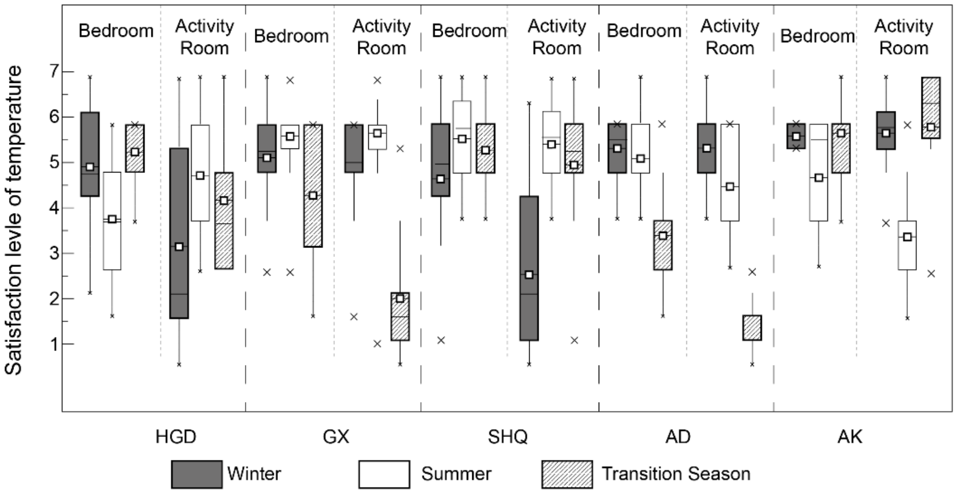


(A) Comparison of different temperature rating values

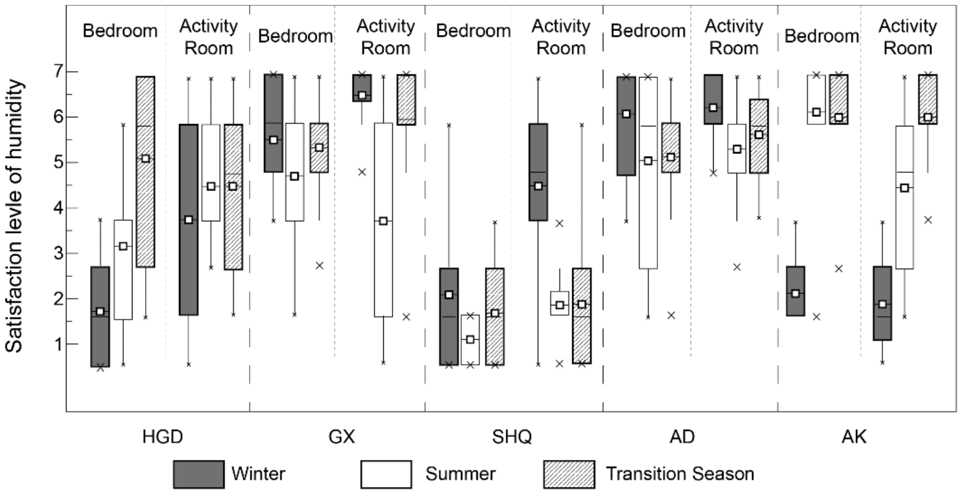


(B) Comparison of different humidity erating values

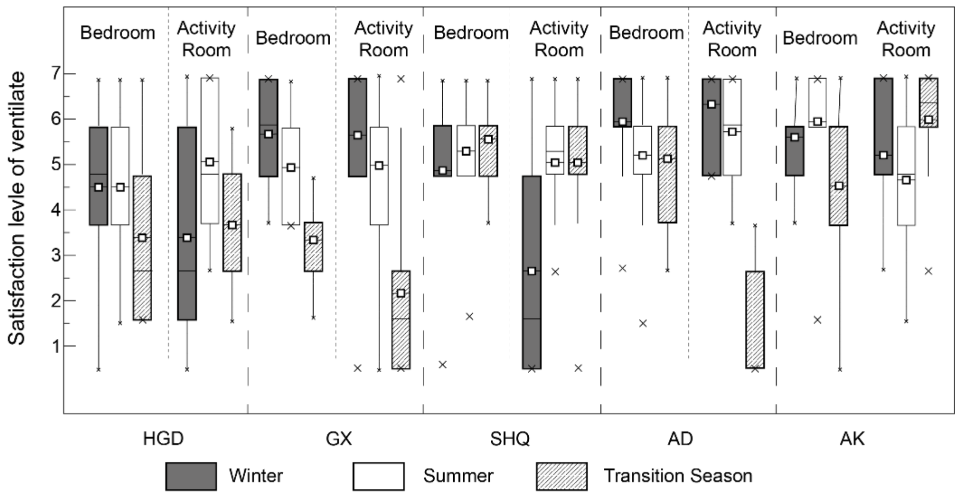
Figure 6-13. Comparison of thermal environment rating values



(A) Air Temperature



(B) Relative Humidity



(C) Ventilation

Figure. 6-14. Rating of thermal environment indicators of Five RACFs based on seasonal

It is shown in Figure. 6-14 that no systematic or regular changes in temperature ratings with seasonal changes and elderly people are normally satisfied with the indoor temperature in transition seasons. For different rooms, the rating values of the three indicators of the bedroom are generally slightly higher than that of the activity room. The reason is that the bedroom area is small and it is the personal space of the elderly. Therefore, the bedroom is better than the activity room in terms of the control of various elements. In contrast, the activity room has a large area and a large number of people, and factor control is difficult to meet the needs of everyone. In HGD, the range of the three values of the activity room is the largest in winter. The same is true in SHQ, except for the humidity level rating value, which reaches the highest value in winter (The value of bedroom is 2.5 and that of activity room is 6). In AD, the temperature rating value and ventilation level rating value of the activity room are the lowest in the transitional season, which are 1.5 and 2.5 while the humidity level rating value is very high in the three seasons. The temperature rating values of the bedrooms of GX and AK remained the same in the three seasons. The humidity level rating value of the SHQ bedroom is the lowest overall. Finally, the rating value of GX's activity room (except for humidity level) is the lowest in the transition season. The reason may be that the ventilation facilities are not complete, which causes the ventilation and air temperature to fail to meet the needs of the elderly.

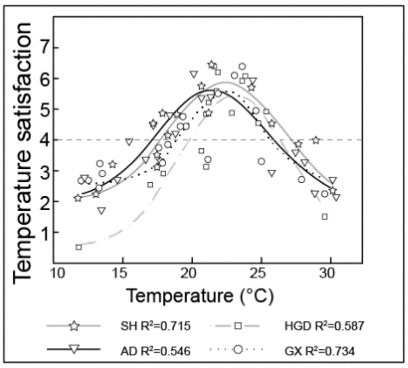
A field survey of the thermal environment in RACFs also demonstrated that the elderly prefer a neutral thermal environment, but that they are less sensitive to thermal environment than that of young people and they were not sensitive to temperature changes (Guergova & Dufour, 2011). In winter, clothing had no obvious effect on TC, nor did opening or closing windows affect the indoor thermal environment, therefore, it is necessary for the staff of RACFs to especially ensure the heating system in winter, as well as the ventilation, to maintain the indoor humidity and temperature and prevent the elderly from getting cold. Also, a previous study investigated the indoor thermal environment of 12 RACFs in Niigata Prefecture, Japan, and discovered that the indoor thermal environment is affected by heating equipment operating conditions and room layout, as well as by house insulation and airtightness, with most residents neutral or satisfied (Iino et al., 2005), which not only emphasize the importance of the heating equipment, as well as the room layout, that when designing the aged care facilities, the architectures should ensure the rooms that have no heating system can also be heated in Winter.

As shown in Figure. 6-14(B), winter humidity satisfaction in the RACFs is higher than that in summer and the transition season, except for HGD and AK. According to the measured humidity data of SHQ in figure 6-10, the RH was between 30–70%RH, except for bedroom humidity in autumn which was below 35%RH. According to previous research (Taleghani et al., 2013), this is an ideal RH. However, as shown in Table 6-7, the humidity rating of SHQ is the lowest, at only 2.87 points. It remains unexplained why elderly people have underestimated the humidity of SHQ in this instance.

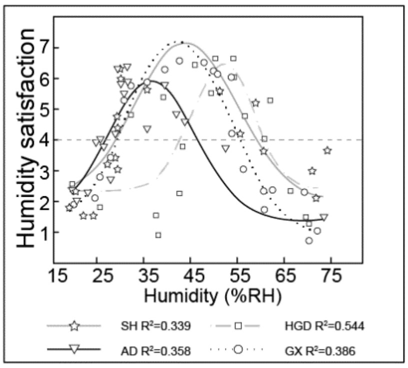
As shown in Figure. 6-14 (C), the bedroom ventilation rating is relatively high because elderly people can open windows or doors at will. The ventilation of activity rooms cannot meet everyone’s needs, so there are differences between RACFs. However, several RACFs evaluated ventilation in the transition season as low. One study found that elderly facilities in Hokkaido have adequate ventilation when windows are open (Noriko, 2017). In that case, the RACFs should initially ensure the number and facing of windows are adequate, that the elderly can open at their will when they feel the ventilation is poor.

6.3.3.3 Relationship between Thermal Environment and Thermal Rating

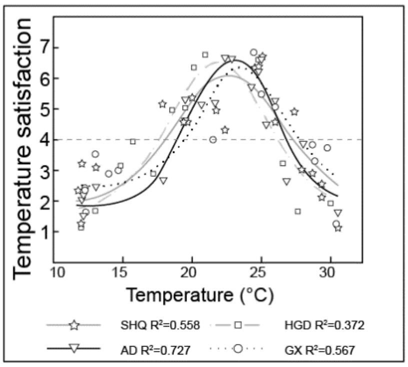
A previous study conducted in Korea showed that in summer, the indoor thermal environment has a higher humidity ration and temperature compared to the standard comfort zone, and the majority of indoor thermal environments in winter and autumn are in the comfort zone (Bae & Chun, 2009). Figure 6-15 (The analysis of AK is not included here, because AK is not significantly correlated in the previous analysis.) shows that a good fit exist between seasonal temperature and thermal environment rating, with R-squared all above 0.5, showing a significant nonlinear relationship between them. For all RACFs, the threshold does not change much based on season or room, and elderly people are satisfied with temperatures of between 20–27 °C.



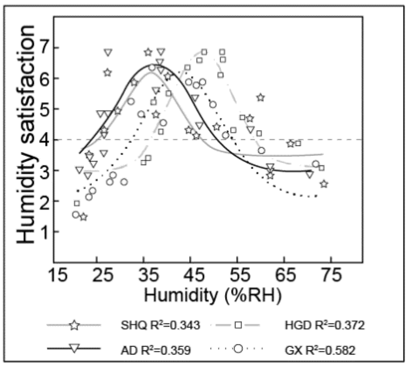
(a) Temperature in summer



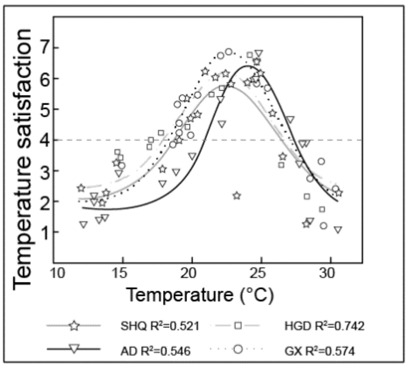
(b) Humidity in summer



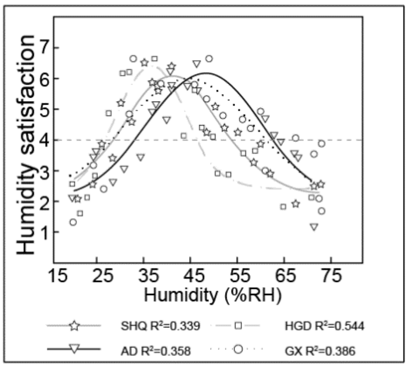
(c) Temperature in winter



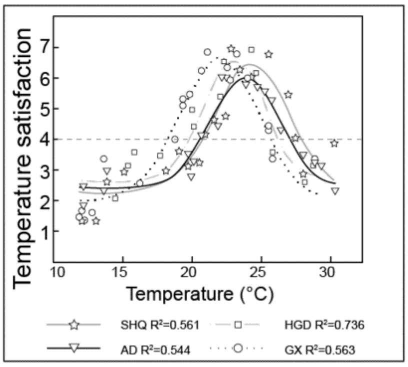
(d) Humidity in winter



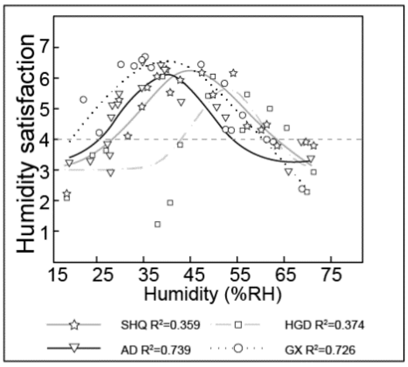
(e) Temperature in the transition season



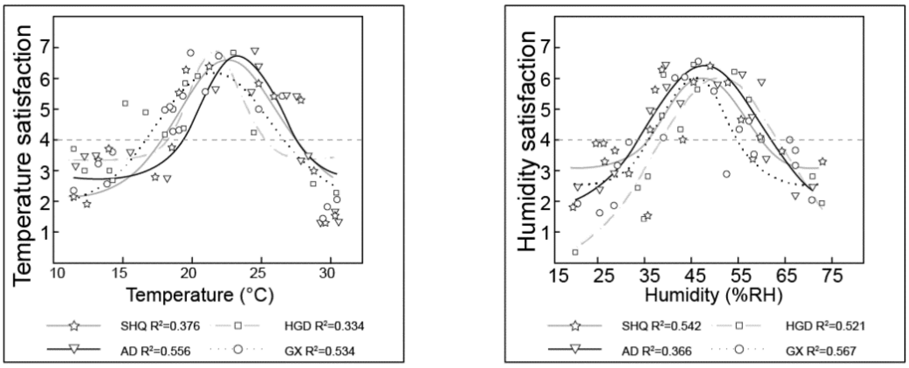
(f) Humidity in the transition season



(g) Temperature in bedroom



(h) Humidity in bedroom



(i) Temperature in activity room (j) Humidity in activity room

Figure 6-15. The fit between lighting indices and lighting rating for five RACFs

With regard to temperature, the elderly are more satisfied with temperature in winter and transition seasons than in summer. It can be seen that the elderly do not like hot weather. Similarly, satisfaction with humidity is also lower in summer, because summer is rainy and humid. For different rooms, the elderly are more satisfied with the temperature and humidity in the activity room than in the bedroom. The reason may be that the elderly have higher requirements for their own private space, so their needs are relatively difficult to meet. The thermal comfort level of the bedroom peaks when the humidity is between 35%-45% RH, and the activity room is between 45%-55% RH, indicating that a bedroom with a dry environment is more suitable for the elderly to live, while the activity room The humidity can be increased appropriately. In addition, the humidity corresponding to the peak value of Thermal Comfort Level in summer and winter is lower than that in the transition season.

In terms of humidity, there are differences between RACFs, reflecting the same trend based on good fitting results with R-squared exceeding 0.3. The threshold of thermal satisfaction and humidity change is 35–47% RH. Unlike the results of research by Taleghani et al. (2013) that showed that comfortable humidity is 55–70% RH, the results of the existing research indicate that elderly people prefer a drier environment, with some respondents stating that high humidity makes them feel breathless, hot, and stuffy.

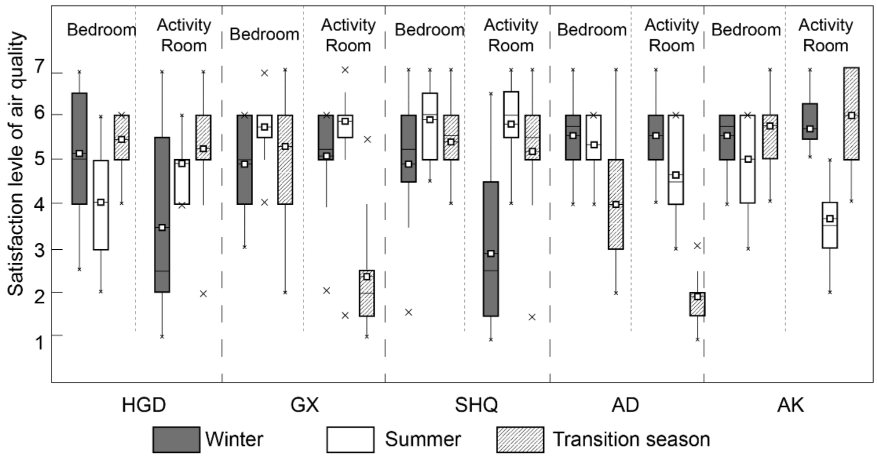
The survey also found that consistent with other research (Jiao et al., 2017), opening windows and changing clothes are usual ways for the elderly to adjust the thermal environment. Jiao et al. (2017) believe that ventilation improves the thermal environment more than clothing change in summer. In our survey, the RACF bedrooms were not equipped with air conditioning, and although electric fans were installed, participants were unwilling to use them, which further emphasize the significance of windows and natural airflows for the elderly residents to adjust thermal environment.

6.3.4 Rating of IAQ

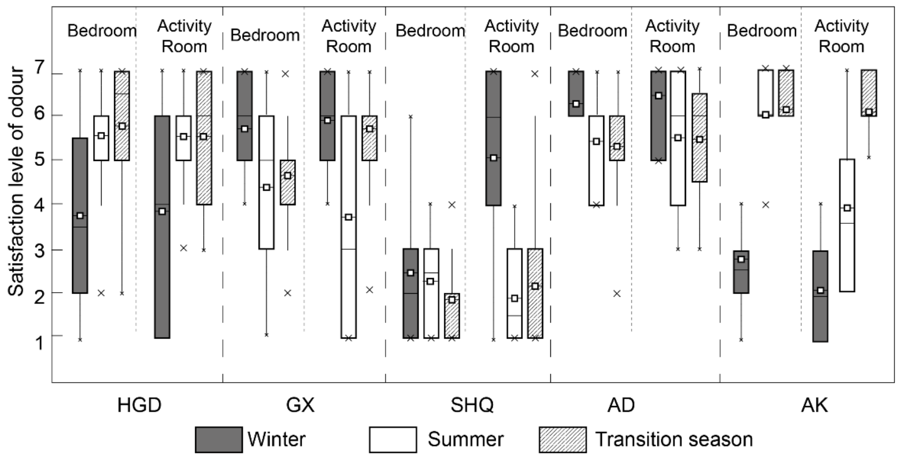
Column A in Table 6-7, the IAQ rating of SHQ is the lowest, with all indicators below 3 points. However, it has a high correlation with IEQ rating, showing that IAQ issues affect the elderly's IEQ rating of SHQ. The IAQ rating of the other four RACFs is almost 4 points or more. However, some of these indicators are weakly related or unrelated to the overall IEQ rating. For example, indicators of AK are basically irrelevant, because the site is relatively far away and is an independent super large facility, and the activity room and the residential building are separated. Column B is listed as correlation. The higher the value, the higher the correlation. The correlation coefficients of odor rating of HGD and GX are 0.389 and 0.366 ($p<0.001$), which are weakly correlated with the overall IEQ rating. The odor and cleanliness of AD are not related to the overall IEQ rating, and the correlation coefficients are only 0.283 and 0.186 ($p<0.05$). Thus, elderly people are less sensitive to odor, and odor rating is poorly correlated with overall IEQ rating. The odor of the living environment is essential to elderly people's health. Being exposed to bad odors could lead to health effects from mild discomfort to serious symptoms.

Table 6-7. Correlation analysis of IAQ rating

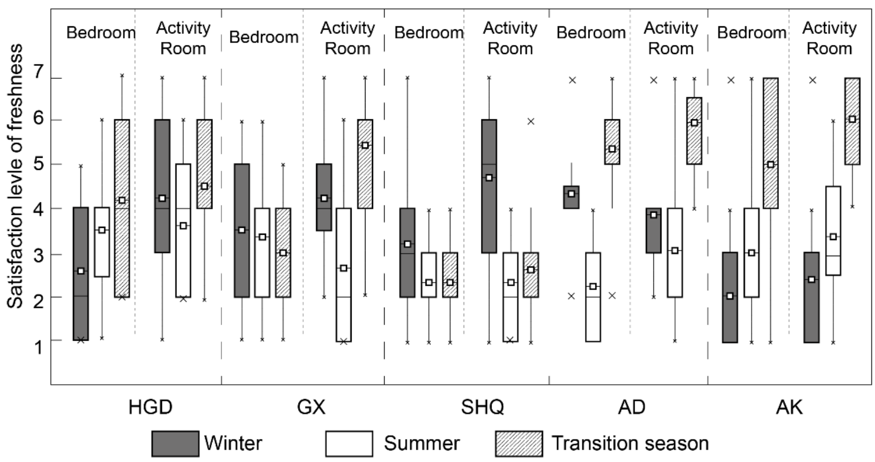
RACFs	IAQ	A	B
HGD (Small-scale)	Odor	5.06/2.144	0.389/0.001 (**)
	Freshness	3.83/1.805	0.387/0.001 (**)
	Cleanliness	4.35/2.043	0.420/0.000 (***)
GX (Medium-scale)	Odor	4.93/1.965	0.366/0.000 (***)
	Freshness	4.08/1.886	0.599/0.000 (***)
	Cleanliness	4.57/1.696	0.564/0.000 (***)
SHQ (Medium-scale)	Odor	2.76/1.997	0.732/0.000 (***)
	Freshness	3.09/1.701	0.723/0.000 (***)
	Cleanliness	2.67/1.901	0.757/0.000 (***)
AD (Large-scale)	Odor	5.901.224	0.283/0.034 (*)
	Freshness	4.57/1.846	0.508/0.000 (***)
	Cleanliness	5.09/1.478	0.186/0.163
AK (Super Large-scale)	Odor	4.89/2.146	0.059/0.579
	Freshness	3.48/2.089	0.154/0.144
	Cleanliness	4.66/2.056	0.091/0.391


Satisfaction levle of air quality
Bedroom
Activity Room
HGD
GX
SHQ
AD
AK
Winter
Summer
Transition season

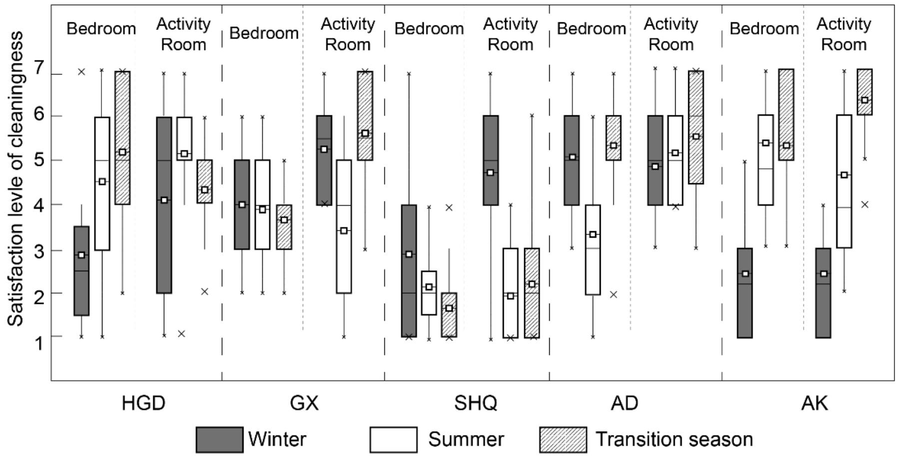
(A)


Satisfaction levle of odour
Bedroom
Activity Room
HGD
GX
SHQ
AD
AK
Winter
Summer
Transition season

(B)


Satisfaction levle of freshness
Bedroom
Activity Room
HGD
GX
SHQ
AD
AK
Winter
Summer
Transition season

(C)



(D)

Figure.6-16. Rating of Five RACFs based on IAQ factors

Figure 16(A), the IAQ score of bedrooms is higher than that of activity rooms, except for AK in transition season. As shown in Figure 16(B), the IAQ rating of SHQ is the lowest, with all indicators, apart from that of activity room in winter, below 3 points. IAQ assessment is highly correlated with IEQ assessment. The IAQ rating of the other three RACFs is almost 4 points or more. However, some of these indicators are weakly related or unrelated to the overall IEQ rating. At the same time, for the rating of freshness and cleanliness, the rating of SHQ is also low overall.

In HGD, the air quality rating value in winter is lower than that of the bedroom, while the rating values of the other three indicators are the opposite. In GX, the freshness of the activity room in the transition season is higher than that of the bedroom, and the rest is roughly the same. The air quality rating value in the transition season of AD activity room is the lowest, and the highest value is only 2. Moreover, the freshness rating value of the activity room in summer and winter is not high. Other indicators are acceptable. AK's odour, freshness and cleanliness rating values are generally more regular, the lowest in winter, the middle in summer, and the highest in transition season. In terms of AK's air quality rating value, the bedroom is basically the same in the three seasons, the activity room is the lowest in summer, and the motivation and transition seasons are higher.

Nowadays, the key responsibilities of RACF in many countries are to prevent chronic diseases among the elderly, and to achieve this it is significant to understand the impact of IAQ has on elderly health, and respiratory health issues can also attribute to indoor temperature and RH (Fraga et al., 2008).

6.3.5 Relationship between Physical Environmental Factors and Overall IEQ

6.3.5.1 Correlation between IEQ Indicators Rating and Physical Environment

Elderly people in the RACFs studied gave good overall IEQ mean ratings of the four physical environmental parameters, all of which exceed 4.5 points (out of 7). The four selected physical environment parameters shown in table 6-8 have a strong positive correlation with the overall IEQ mean rating and a strong influence on IEQ, with all correlation coefficients close to or above 0.7 (p<0.001).

Table 6-8. Correlations between IEQ and four environmental parameters

Overall IEQ	Acoustic	Lighting	Thermal-Env	IAQ
Mean rating	4.43	4.34	4.49	4.58
Correlation coefficient	0.730	0.686	0.731	0.691
p-value	0.001***	0.001***	0.001***	0.001***

***P<0.001, ** P＜0.01, * P＜0.05.

Table 6-9. Descriptive statistics

	Mean	Std. Deviation	N
Lighting	4.4544	1.93067	1457
Acoustic	4.4152	1.84379	1457
Thermal	4.35	1.680	1457
IAQ	4.35	1.690	1457

Among Lighting, Acoustic, Thermal, and IAQ, Lighting has the highest value at 4.4544, and Thermal and IAQ have the lowest value at 4.35（see Table 6-9）.

Table 6-10. Relevance and significance of physical environmental factors

Correlations					
		Lighting	Acoustic	Thermal	IAQ
Lighting	Pearson Correlation	1	.491***	.391***	.377***
	Sig. (2-tailed)		.000	.000	.000
	N	1457	1457	1457	1457
Acoustic	Pearson Correlation	.491***	1	.369***	.376***
	Sig. (2-tailed)	.000		.000	.000
	N	1457	1457	1457	1457
Thermal	Pearson Correlation	.391***	.369***	1	.783***
	Sig. (2-tailed)	.000	.000		.000
	N	1457	1457	1457	1457
IAQ	Pearson Correlation	.377***	.376***	.783***	1

	Sig. (2-tailed)	.000	.000	.000	
	N	1457	1457	1457	1457

According to the table 6-10, lighting is positively correlated with acoustics, thermals, and IAQ (P <0.001). Acoustics was positively correlated with lighting, thermal and IAQ (P <0.001). Thermal is positively correlated with lighting, acoustics, and IAQ (P <0.001), and the correlation with IAQ is relatively high, with a value of 0.783 (P <0.001). IAQ was positively correlated with lighting, acoustics and thermals (P <0.001).

Table 6-11. Significance of perception of physical environment and measurement data

		SPL
Acoustic environment assessment	Pearson Correlation	.34**
	Sig. (2-tailed)	.002
		Temperature
Thermal environment assessment	Pearson Correlation	.43**
	Sig. (2-tailed)	.003
		Humidity
Thermal environment assessment	Pearson Correlation	.43**
	Sig. (2-tailed)	.003
		Brightness
Lighting environment assessment	Pearson Correlation	.28*
	Sig. (2-tailed)	.006
		illuminance
Lighting environment assessment	Pearson Correlation	.35**
	Sig. (2-tailed)	.003

Acoustic environment assessment is positively correlated with SPL (P <0.01). Thermal environment assessment is positively correlated with Temperature (P <0.01). Thermal environment assessment is positively correlated with Humidity (P <0.01). Lighting environment assessment is positively correlated with Brightness, however the correlation is weak (P <0.1). Lighting environment assessment and illuminance are also positively correlated (P <0.01)（see Table 6-11）.

Table 6-12 shows the overall mean rating of the four IEQ factors as physical environment parameters of the RACFs. Column A represents the mean rating and standard deviation of four factors rated by the aged in the different RACFs. Of note, SHQ and AK have the highest ratings, with close to or at 5 points. GX, which is also medium-scale, has a lower score than SHQ. For AD, a large-scale RACF, the scores of various parameters are lower than 4 points. In Column B, which indicates the correlation between various indicators and thermal environment rating (The higher the value, the greater the correlation), the lower AD rating may be due to the poor acoustic and thermal environment because their correlation with the IEQ mean rating is as high as 0.826 and 0.849 (p<0.001). Because AD's lighting and the correlation between IAQ and IEQ are also higher than the other four RACFs, the values of these two factors are also very low. Besides, AD's sound insulation facilities are poor, the lighting and heating systems and other equipment are relatively old, the mean rating values of the four indicators of AD are all low. The results in Column B are similar to Table 6-6 and Table 6-7. The IEQ mean ratings of the other four RACFs have a high correlation with the four physical parameters, with correlation coefficients of between 0.66–0.85 ($p<0.001$). In addition, indicators of AK are basically irrelevant, because the site is relatively far away and is an independent super large facility, and the activity room and the residential building are separated.

Table 6-12 Mean rating and correlation of five RACFs

RACFs	Factors	A	B
HGD (Small-scale)	Acoustic	4.23/1.845	0.719/0.000 (***)
	Lighting	4.03/2.042	0.707/0.000 (***)
	Thermal-Env	4.17/1.816	0.694/0.000 (***)
	IAQ	4.41/2.004	0.736/0.000 (***)
GX (Medium-scale)	Acoustic	3.80/1.794	0.695/0.000 (***)
	Lighting	3.96/1.965	0.740/0.000 (***)
	Thermal-Env	4.27/1.959	0.849/0.000 (***)
	IAQ	4.12/2.060	0.715/0.000 (***)
SHQ (Medium-scale)	Acoustic	5.18/1.992	0.780/0.000 (***)
	Lighting	4.90/1.988	0.666/0.000 (***)
	Thermal-Env	4.81/1.747	0.694/0.000 (***)
	IAQ	5.16/1.812	0.698/0.000 (***)
AD (Large-scale)	Acoustic	3.55/1.798	0.826/0.000 (***)
	Lighting	3.40/1.946	0.704/0.000 (***)
	Thermal-Env	3.80/1.935	0.849/0.000 (***)
	IAQ	3.55/1.837	0.684/0.000 (***)
AK (Mega-scale)	Acoustic	5.41/1.150	0.152/0.148
	Lighting	5.41/1.197	0.104/0.323
	Thermal-Env	5.39/1.241	0.139/0.186
	IAQ	5.66/1.312	0.087/0.408

6.3.5.2 Mean rating of IEQ Factors by Season

Table 6-13 shows that the transition season (autumn) has the highest IEQ mean rating, with all four factors close to 5 points. The data used in this table is the rating of the thermal environment, and the previous analysis is the rating of the three indicators of the thermal conditions, so the results of the previous two times are different. It may be that the thermal environment in the transition season is appropriate, with warming in spring and the end of hot summer in the autumn. Spring and autumn scenery may also affect the elderly’s overall feelings. Light levels may also have effects: a Dutch study (Sinoo et al., 2011) found that in seven RACFs, at least three-quarters of the measurements showed corridor brightness significantly below the 200lx threshold. Poor lighting can produce disorganized circadian rhythms (Mishima et al., 2001), and therefore, in Winter or when there is insufficient light, the lighting of RACFs may need to be improved.

Table 6-13 Mean rating IEQ factors based on seasonal differences

Factors	Winter	Summer	Transition	F	P	η_p^2
Acoustic	4.059	3.790	**4.909**	32.732	0.000	0.069
Lighting	3.946	3.687	**4.909**	34.923	0.000	0.073
Thermal-Env	4.188	3.987	**4.955**	24.794	0.000	0.053
IAQ	4.113	4.179	**5.071**	22.746	0.000	0.049

It can be seen from the table that the various ratings of the transition season are the highest (4.909-5.071), and the summer is the lowest (3.687-4.719). The reason may be that the window needs to be opened in summer to cause noise to spread into the room. However, the summer IAQ has the highest rating, and the reason may also be that the windows are open for ventilation. In winter, the mean rating of each index is between summer and transition season (3.946-4.188). Among them, lighting has the lowest rating, which is 3.946, and the reason has been analyzed before. The indicators of the transition season are the highest (4.909), because the temperature and light in the transition season are moderate, and the air quality is also in the best condition. In addition, the high rating of AK and SHQ during the transition season are also an important reason for that of the transition season.

Participants generally indicated that bedrooms were more comfortable than activity rooms (see Table 6-14), perhaps because bedrooms are private spaces and they have more freedom to open windows, close doors, or pull the curtains according to their preferences. Particularly in the IAQ rating, the bedroom rating (5.14) was significantly higher than the activity room rating (4.708). Generally speaking, the mean rating value of the activity room is lower than that of the bedroom, because the bedroom is a private space in which people can move freely without interference from the outside. However, when the activity is implemented in a public space, various conditions may be affected when the number of people is large. So it gets worse. Among the various indicators of the bedroom, the IAQ's mean rating value is the highest, reaching 5.140 points. In the activity room, the thermal environment has the highest rating value of 4.798 points. The reason may be that institutions pay more attention to the temperature control of public spaces. The relative advantages and costs of private and shared bedrooms are controversial, particularly considering the current commitment to establishing cost-effective and people-centric care facilities. Similar to the findings of this study, another study also found that private rooms are better than shared rooms in RACFs (Calkins & Cassella, 2007), but other research showed that, despite having home-like private rooms, elderly residents in RACFs preferred spend most of the day in common areas (Hauge & Kristin, 2008)

Table 6-14. Mean rating of IEQ factors based on location differences

Factors	Bedroom	Activity room	F	P	η_p^2
Acoustic	**4.791**	4.613	37.732	0.000	0.146
Lighting	**4.677**	4.640	35.483	0.000	0.139
Thermal-Env	**4.803**	4.798	32.504	0.000	0.129
IAQ	**5.140**	4.708	38.415	0.000	0.149

6.3.6 Effects of Personal Factors

Table 6-15 shows seven personal and social factors that may affect the rating of IEQ factors. Overall, gender difference has no significant effect on IEQ factor mean ratings ($P>0.05$). The mean rating value of men is slightly higher than that of women, but the difference is not much, basically no more than 10%. However, the length of residence and marital status do ($P<0.001$). In terms of acoustics, lighting and IAQ, the longer the residence time, the higher the evaluation value. In terms of temperature, humidity and odor, the rating index within five years will increase over time, but after more than five years, the rating value will decrease significantly. Age and education have a significant effect on all IEQ factors, except the temperature indicator. In terms of acoustics, lighting and IAQ, the longer the residence time, the higher the rating value. In terms of temperature, humidity and odor, the evaluation index within five years will increase over time, but after more than five years, the mean rating value will decrease significantly. Generally speaking, the older the age, the higher the mean rating value of various indicators, except humidity and odor. The rating value of various indicators will rise with the improvement of the education level of the elderly. Temperature, humidity, IAQ and odor evaluation were affected by former residence. The following sub-sections discuss the impact on IEQ mean rating of personal and social factors. Since the elderly spend most of their time inside the house, IEQ has a vital effect on their health. The comprehensive building performance has an essential impact on the wellbeing and health of residents who spend most of the time indoors.

Table 6-15. Relationship between IEQ mean rating values and residents' backgrounds

		Mean ratings					
		Acoustics	Lighting	Temperature	Humidity	Odor	IAQ
Gender	Male	4.71	4.6	5.34	5.11	4.83	4.83
	Female	4.34	4.22	5.12	4.62	4.52	4.5
	F	4.945	5.076	3.927	9.879	6.932	5.395
	P	0.345	0.939	0.531	0.424	0.352	0.693
	η_p^2	3.661	4.154	2.141	5.718	4.715	3.885
Age	<65	5.12	5	4.92	3.04	3.14	5.16
	65-75	4.13	3.98	4.94	4.71	4.56	4.37
	75-85	4.24	4.21	5.06	5.24	5.04	4.54

	>85	5.31	5.54	5.04	3	2.08	6.32
	F	9.848	9.301	1.18	34.711	25.278	6.949
	P	0	0	0.086	0	0	0
	η_p^2	3.554	4.036	1.147	4.232	4.355	3.804
Education	Basic-Edu	3.56	3.43	5.07	4.8	4.58	3.68
	Secondary-Edu	4.55	4.53	4.98	4.28	4.25	4.82
	Higher-Edu	4.61	4.53	4.74	5.19	4.94	4.99
	F	28.965	30.405	2.579	12.699	6.706	39.926
	P	0	0	0.077	0	0.001	0
	η_p^2	3.443	3.89	2.119	4.594	4.654	3.567
Pension	<2K	2.52	2.51	4.64	5.54	5.52	2.61
	2K-5K	5.03	4.92	4.94	4.22	4.12	5.22
	>5K	4.84	5.03	4.92	4.73	4.34	5.24
	F	109.697	109.458	1.234	17.677	28.344	101.611
	P	0	0	0.094	0	0	0
	η_p^2	2.938	3.332	2.145	4.544	4.439	3.161
Residence time	<1year	3.92	3.82	4.84	4.51	4.21	4
	1-3years	4.22	4.21	4.86	4.83	4.74	4.52
	3-5years	4.86	4.83	5.13	4.93	4.92	5.21
	>5years	5.31	5.12	4.55	4	4.04	6.1
	F	13.398	13.103	4.741	13.96	14.586	27.762
	P	0	0	0.04	0	0	0
	η_p^2	3.513	3.985	3.142	4.517	4.506	5.672
Former residence	Countryside	4.23	4.12	3.92	3.64	3.47	4.44
	Country town	4.05	4.05	4.65	3.84	3.76	4.20
	Suburb	3.94	3.74	4.78	4.72	4.64	4.23
	City	4.63	4.53	5.02	5.54	5.46	4.96
	F	1.942	2.619	64.626	80.480	84.905	4.974
	P	0.164	0.106	0.000	0.010	0.000	0.026
	η_p^2	3.593	4.055	1.176	4.156	4.171	3.790
Marital status	Single	5.52	5.42	4.02	2.45	2.23	5.93
	Married	4.83	4.75	4.95	3.94	3.84	5.1
	Widowed	3.04	2.94	4.68	5.24	5.01	3.13
	Divorced	4.53	4.63	5.02	6.17	5.62	4.86
	F	12.106	9.307	13.903	58.512	53.677	14.945
	P	0.001	0.002	0	0	0	0
	η_p^2	3	3.454	1.245	3.959	4.008	3.19

*Basic Education includes Primary school; Secondary Education includes junior or senior school; Higher Education includes college or higher.

6.3.6.1 Influence of physiological factors on the Rating of IEQ Factors

The ratings of the under-65 and over-85 groups were similar（see Figure 6-17）, with both rating the lighting environment, acoustic environment, and IAQ higher. However, the two 65 - 85 age groups rated humidity and odor higher, perhaps because the over-85s have poor physical functioning and relatively low sensitivity to the environment, making it difficult for them to perceive changes.

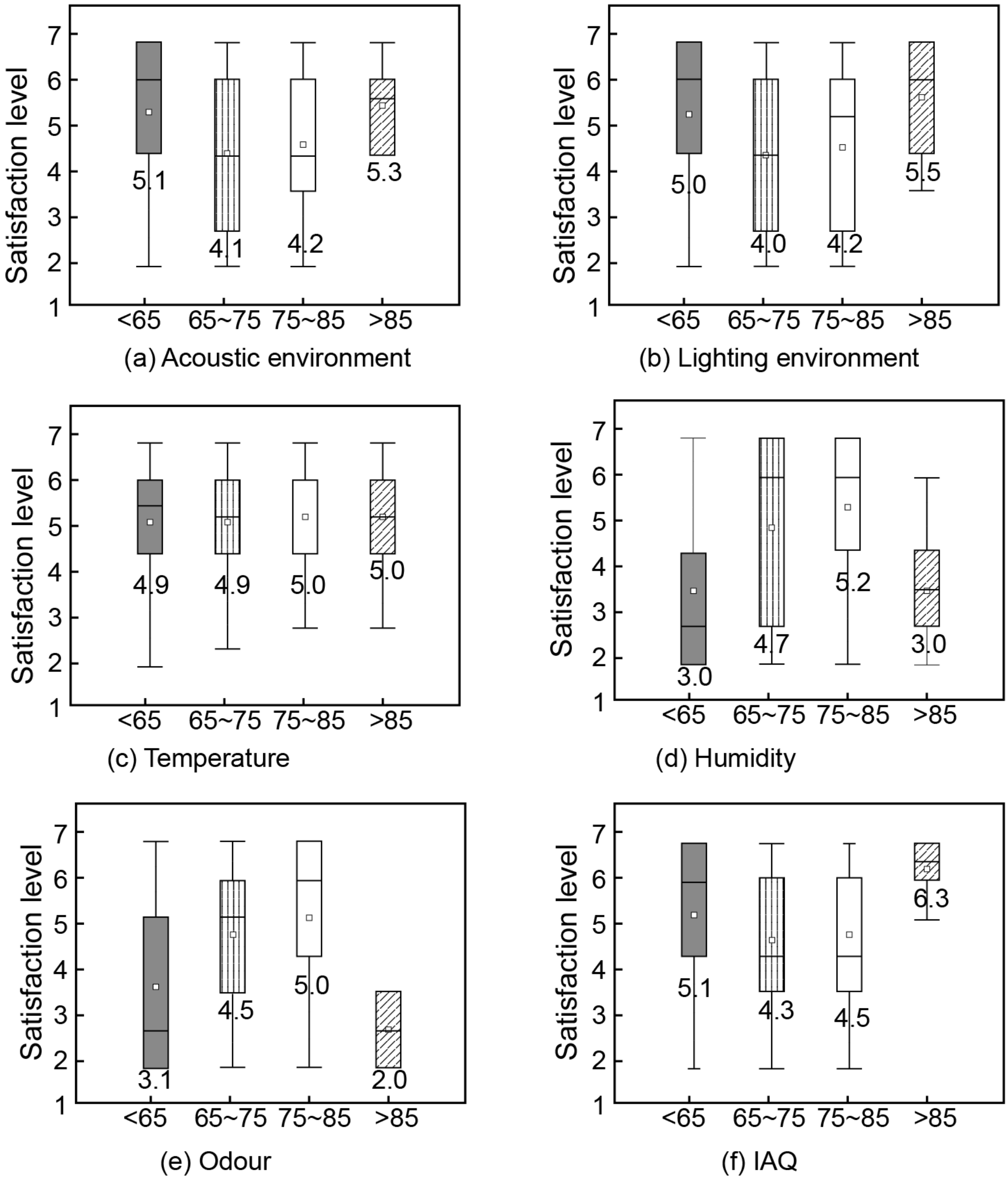


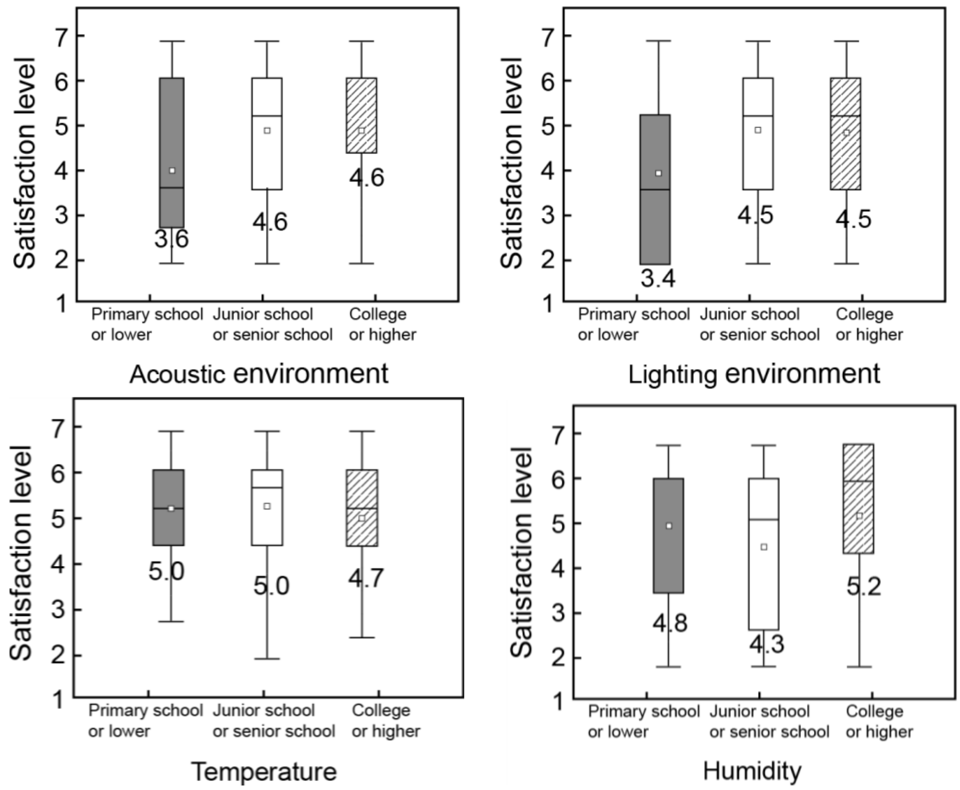
Figure 6-17. The IEQ factors rating based on age differences

As the level of light perceived by the retina decreases with age, elderly people need more light. After age 70, they have difficulty seeing some details, with some studies noting potential vision loss and increased light requirements after age 50 (Sinoo et al., 2011). In this study, the 66-85 year age group is also less satisfied with the level of lighting than those aged 60-65 years (see Figure. 6-17(b)). Falling is a huge problem for the majority of elderly people, and lack of light may contribute to falls.

Figure. 6-17(d) shows that the under-65s and over-85s in the study thought it was too humid, while the over-85s were satisfied with temperature and lighting. The odor was defined as a reference indicator of IAQ based on previous research (Saad et al., 2015), but both age groups gave diametrically opposite ratings. Based on these results, it is impossible to determine whether this difference stems from age, cognition, or questionnaire design.

6.3.6.2 Influence of Social Factors on the Rating of IEQ Factors

Elderly people with high levels of education usually give positive ratings (see Figure. 6-18.). Wu et al. (2020) also noted that in a quiet environment, people with higher education and pension levels have a higher rating regarding acoustic comfort. People with low education levels have stringent requirements for thermal environments, with some studies noting that more highly educated people prefer a low-temperature environment (approximately 25.3°C) (Yamtraipat et al., 2005), perhaps to aid concentration and contemplation. Elderly people with basic education have relatively low IAQ ratings comparing with that of the elderly with senior and higher education (below 4 points). According to Guo et al. (2016), this difference stems from respondents' different perceptions of IAQ, with more highly educated people evaluating IAQ more positively.



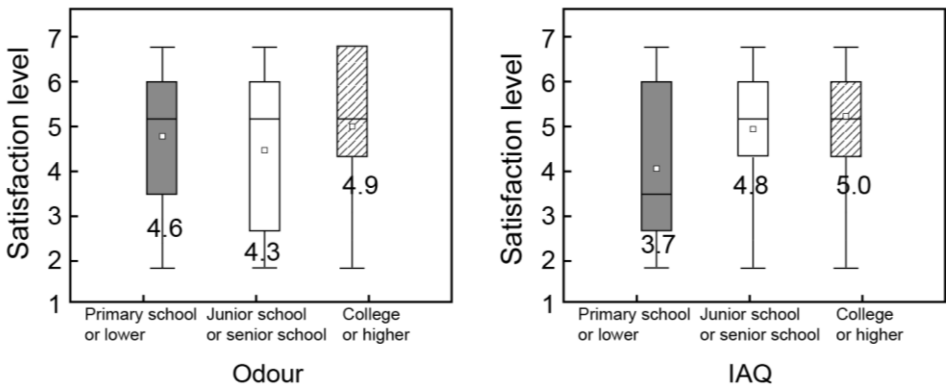


Figure 6-18. The IEQ Factor Ratings based on Differences in Education Level

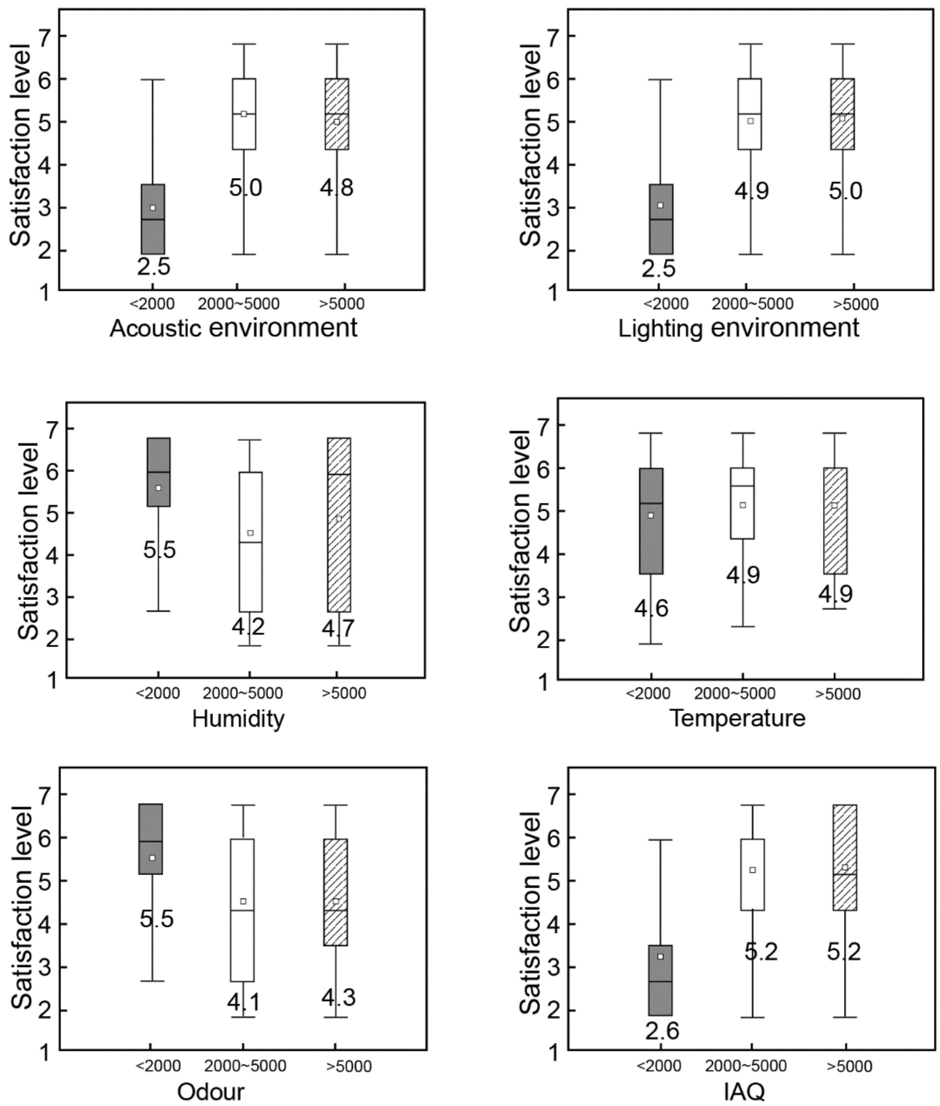


Figure. 6-19. The IEQ factor ratings based on differences in pension

As Figure. 6-19 shows, pensions have a similar impact on rating results as education level. In sum, basic education corresponds to low pensions (<2000), and higher education to higher pensions (>5000). Elderly people with low pensions and basic education are more critical with the living environment, and elderly people with higher pensions and higher education have a higher tolerance for the environment.

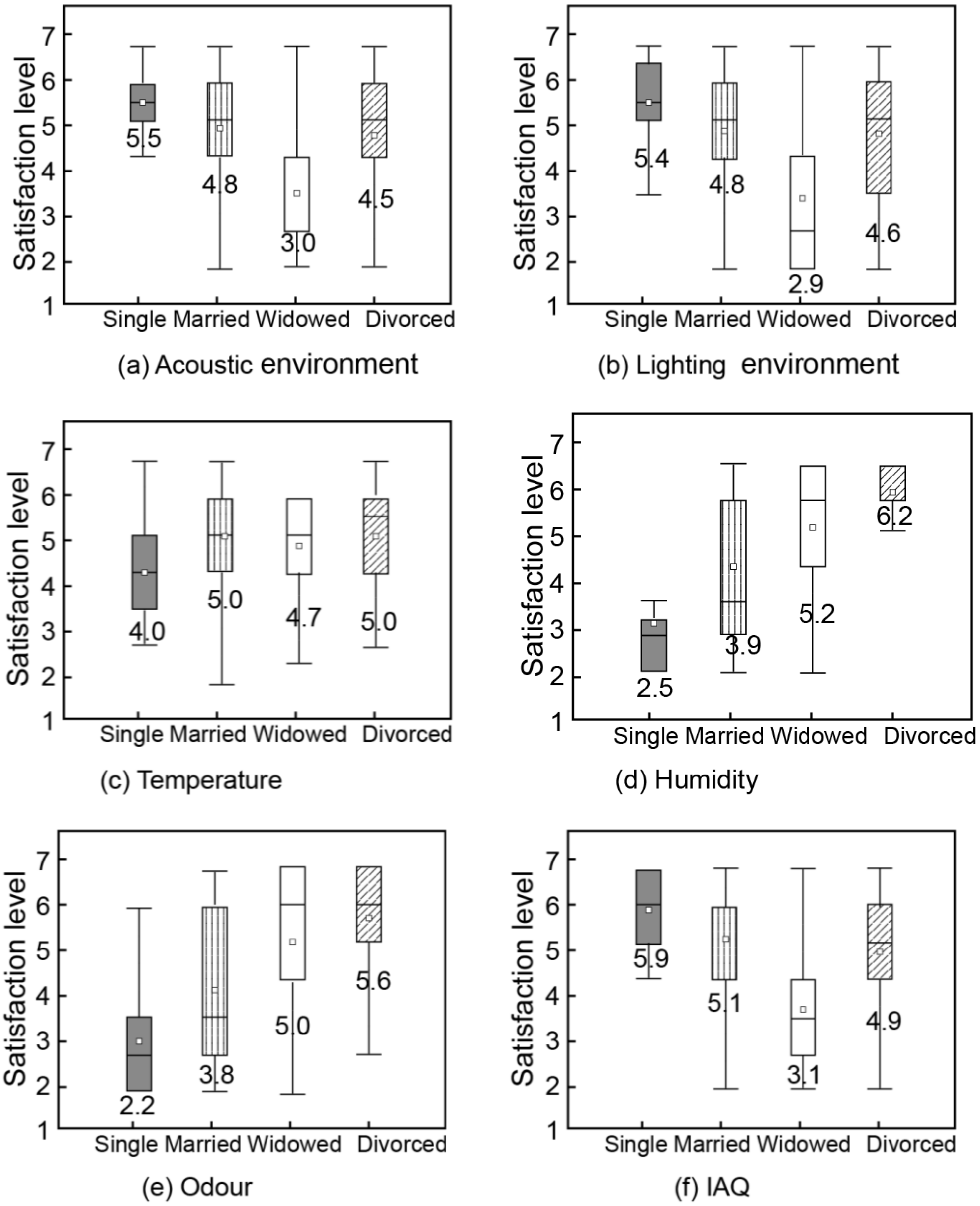
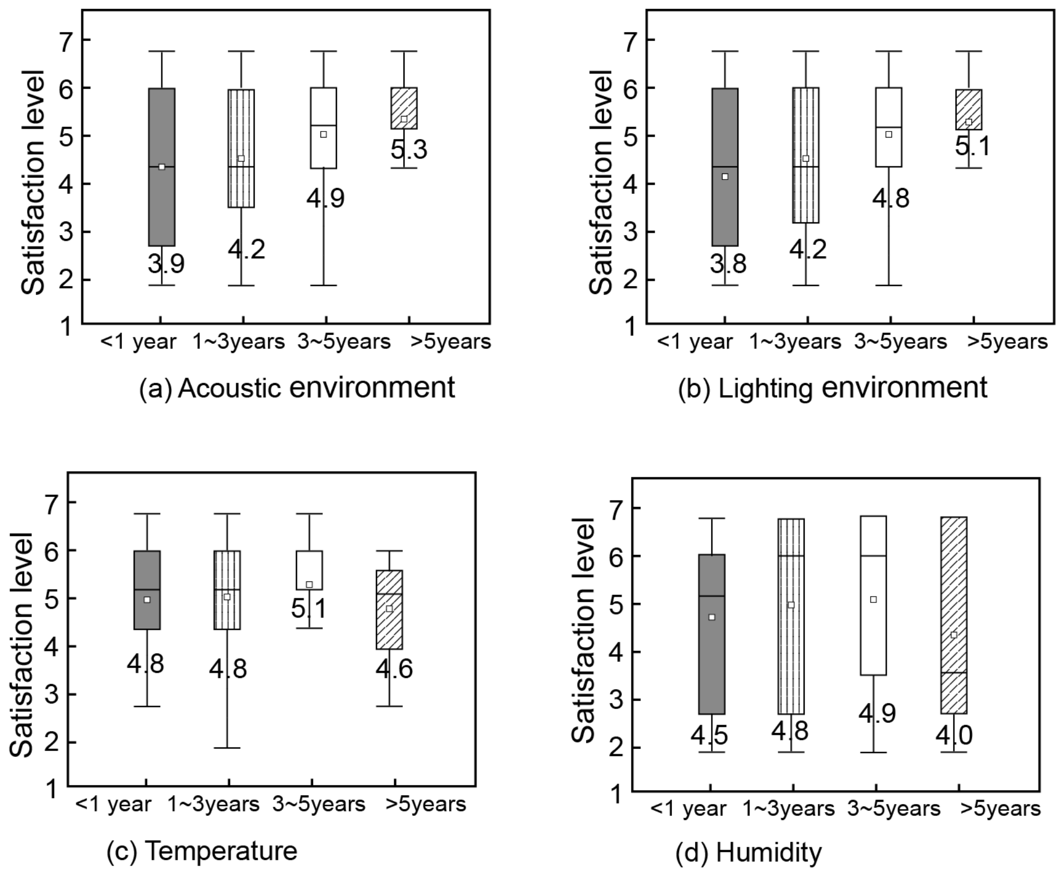


Figure. 6-20. The IEQ factor ratings based on differences in marital status

As shown in Figure. 6-20, marital status is related to large differences in IEQ rating, except for temperature rating. Overall, divorced elderly people have a higher IEQ rating than other groups; widowed elderly people have an average IEQ rating of fewer than 4 points; and married elderly people have a relatively stable rating of various factors, unlike the single group. Previous research shows that unmarried (single, divorced, and widowed) people are more likely to have cognitive impairment than married people (Håkansson et al., 2009), which can create uncertainty in the rating of the surrounding environment. However, the results of research for this thesis show that the divorced elderly are more satisfied with the RACF environment than the married elderly, perhaps because the former is more likely to be suffering emotionally and the social environment of the RACF makes up for the lack of a close relationship (Karp et al., 2006) and reduces cognitive impairment.

6.3.6.3 Influence of Lifestyle Factors on Rating of IEQ Factors

The length of residence also has a impact on the rating of IEQ. With increased time spent in RACFs, rating of IEQ also increases (see Figure. 6-21). Elderly people who have lived in RACFs for more than three years rated IEQ at 5 points on average, particularly the acoustic environment, light environment, and IAQ. Simultaneously, their long residence indicates that elderly people are happy with the RACF environment in terms of temperature, humidity, ventilation, and time spent in the shared area.



(a) Acoustic environment (b) Lighting environment

(c) Temperature (d) Humidity

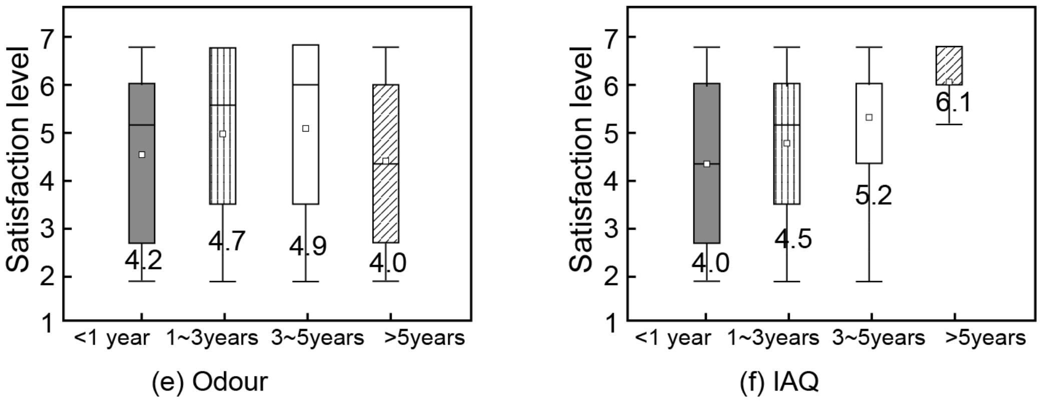


Figure. 6-21. The IEQ Factor ratings based on differences in Length of Residence

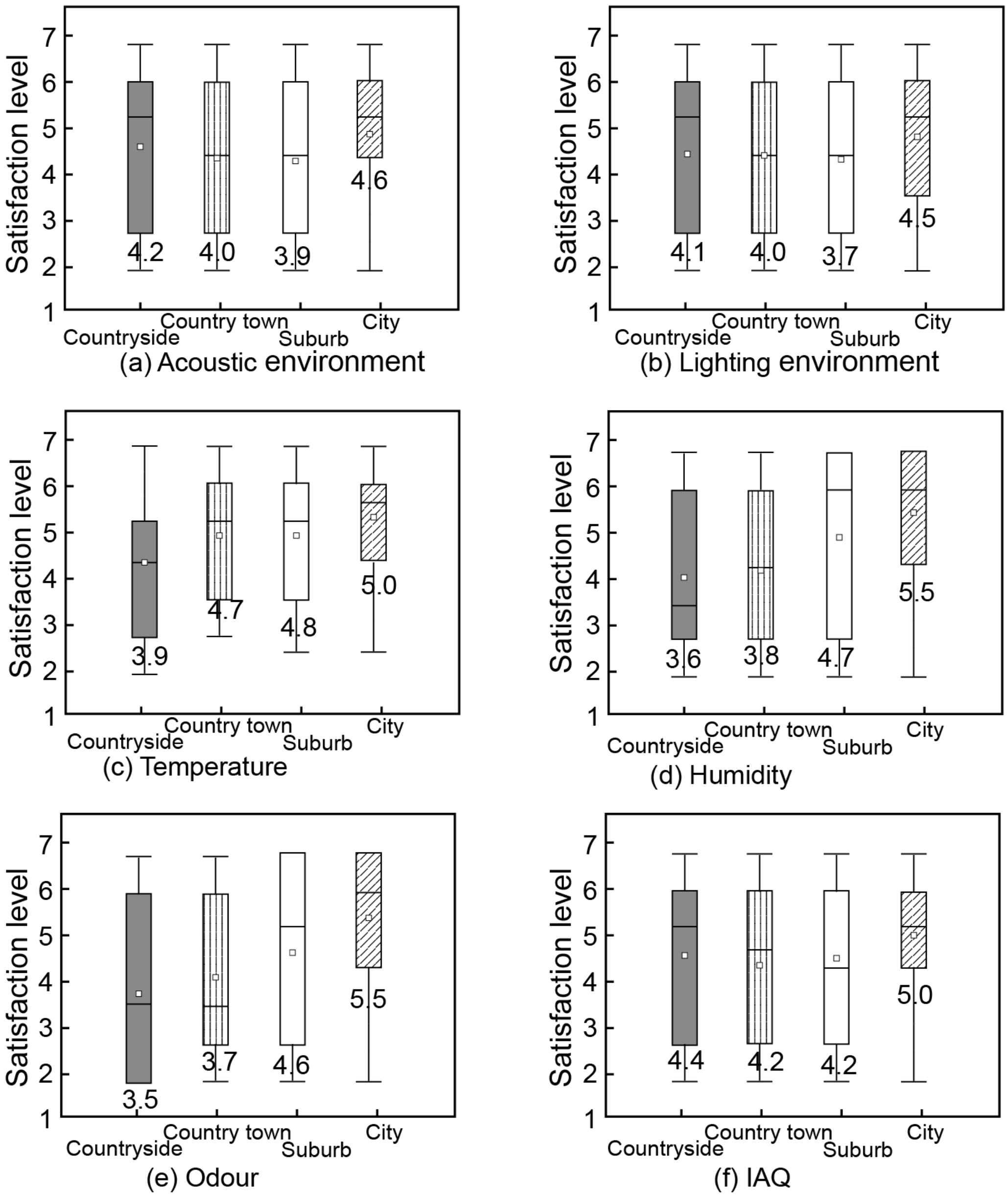


Figure 6-22. The IEQ factor ratings based on differences in former residence

As Figure 6-22 shows, elderly people who once lived in cities are more satisfied with life in RACFs, and rate IEQ higher than other groups. There is little difference between non-urban residents (countryside, country town, and suburb). People in these groups who previously had lived in natural environments, and found it difficult to adapt to city pollution. Some studies of indoor IAQ have shown that past living environment can affect IAQ rating. Previous rural dwellers can identify IAQ more accurately than urban dwellers, while urban dwellers rate IAQ more negatively (Guo et al., 2016). The results here show that former countryside and country town dwellers rated IAQ lower than former urban dwellers, because the latter have already adapted to this air environment, and evaluate it less accurately than rural people.

6.4 Summary

The results indicated that the physical environments of the five RACFs were significantly correlated with the IEQ rating, including acoustic, lighting, and thermal environment, and IAQ. The above research analyzes the threshold of various indicators, which will help people understand the degree of satisfaction and acceptable range of the elderly for a certain factor, and then set standards for various indicators and related facilities based on this.

The sound rating of the surveyed RACF is at an intermediate level, and the elderly have a weaker understanding of intelligibility. The rating of acoustics was not affected by season or room, while the light environment that depends on window orientation generally received higher ratings in summer than in winter and autumn. The acoustic rating has a linear relationship with the SPL. The summer sound pressure level threshold is 70 dB(A), and the winter and autumn sound pressure level threshold is 65 dB(A). Brightness and illuminance have a nonlinear relationship with lighting rating. The results of various RACFs show that the RH in autumn is lower compared to summer and winter, about 45% RH. The lighting ratings of bedrooms were generally higher than activity rooms. The temperature measurement shows similar trends between activity rooms and bedrooms, with indoor temperatures generally higher in winter than in summer and autumn, and morning and evening temperatures lower. The rating of RH is slightly higher for activity rooms than for bedrooms and is also affected by RACF size. Elderly people are less sensitive to odor, and odor rating is poorly correlated with overall IEQ rating.

The threshold value of SPL in summer is 70 dB(A) and 65 dB(A) in Winter and

Autumn. Brightness and illuminance have a non-linear relationship with lighting rating. Lighting rating is not affected by seasonality, with a generally accepted brightness range of between 100–400 cd/m^2, and a threshold of illuminance between 450–1400 lux. The IEQ ratings of all five RACFs are highly correlated with the four physical parameters and are affected by seasonal changes. The rating results generally indicated that bedrooms are thought to be more comfortable than activity rooms in all five RACFs. The results also show that elderly people’s rating of the physical environment in RACFs is not affected by gender, and effects by different age of the elderly are reflected in other physical environmental factors other than temperature. There are obvious differences based on education level, pension level, long-stay and newcomers, married and single, and urban and non-urban residents. Furthermore, because the survey results may have been affected by external elements, such as the inconsistent results of IAQ and odor, the humidity rating was lower than expected. Overall, elderly people are satisfied with the IEQ environment of their RACFs. However, their ratings remained low, which may explain their unclear descriptions, or perhaps simply abnormal data. The over-85s gave high IAQ ratings while giving low ratings for odor, freshness, and cleanliness.

The above research results are combined with many other research results. On this basis and through interviews, investigations and calculations, the understanding of the needs of the elderly and the pros and cons of RACFs has been further deepened. These results will help to further explore the living conditions of the elderly, and help the government, construction companies, and other relevant departments to improve the policies and environment of the elderly care institutions, so as to effectively improve the life of the elderly in their later years.

However, these alone are not enough. In addition to the research results of this chapter, there are other factors that need to be explored, such as AC, RS, etc. rating In the next chapter, the AC, RS, IEQ, and QoL of the elderly living in RACFs are discussed and the relationships among each other are examined.

7. Structural Equation Model of Factors Affecting the Quality of Life in RACFs

7.1 Introduction: Background and Hypothesis

Structural equation model is a statistical method to analyze the relationship between variables based on the covariance matrix of variables, and is an important tool for multivariate data analysis. Many concepts such as psychology, education, and society are difficult to measure directly and accurately. Such variables are called latent variables. Therefore, only some explicit indicators can be used to indirectly measure these latent variables. Traditional statistical methods cannot effectively deal with these latent variables, while structural equation models can deal with latent variables and their indicators at the same time.

Structural equations can handle multiple dependent variables at the same time, allow independent variables and dependent variables to contain measurement errors, and can be used to estimate the degree of fit of the entire model.

Based on the analysis in Chapter 5 and Chapter 6, it can be found that older people respond strongly to sounds, and they are different. For the acoustic environment of RACFs, the elderly gave different ratings. As for RS, IEQ, and QoL, the elderly also attach great importance to them. In addition, in Chapter 6, the old people's acceptance of the four categories of factors and their subdivision factors are studied. From these results, theAC, RS, IEQ, and QoL were found have greatly effect on the satisfaction of the elderly with RACFs. Therefore, AC, RS, IEQ, and QoL are selected as variables for the structural equations in this chapter.

This chapter aims to build a structural equation model to explore the relationships between the elements of Architectural Composition (AC), Residential Satisfaction (RS), Indoor Environmental Quality (IEQ), and their effects on the Quality of Life (QoL) of elderly people residing in RACFs of northeast China, which are Harbin, Changchun, Shenyang, Dalian. The difference analysis found that there were differences in the rating of various scales, various structural characteristics of buildings (with or without reconstruction) for RACFs. Where the AC of some RACFs is not due to the lack of renovation, managers can improve the QoL of the elderly by improving IEQ and RS. This study is the first time RS rating factors for RACFs in northeast China have been examined to reveal the relationship between RS, IEQ, AC, and QoL: it has verified that RS and IEQ play a certain mediating role in the rating of AC and QoL.

This study aimed to establish a model to examine the rating of the AC, IEQ, and RS on the QoL of the elderly in the RACFs through a large-scale questionnaire survey of RACFs.in the northeastern area of China. By applying validation and reliability measurements with confirmatory factor analysis, Pearson correlation coefficients and Cronbach's alpha, which will be discussed in detail in the following part, the collected data were organized into a set of structural equation models to evaluate the correlations between the AC IEQ, RS and QoL of the elderly to demonstrate the positive and intermediary effects among the latent variables. The following hypotheses were proposed and verified:

Hypothesis H1: AC has a significant positive impact on RS, IEQ, and QoL

Hypothesis H2: RS and Indoor Environmental Quality (IEQ) have a significant positive influence on QoL.

Hypothesis H3: RS and IEQ are the intermediary variables between AC and QoL.

A one-year field survey was conducted to examine the observed relationships in terms of different building types (renovated or non-renovated buildings), seasons, spatial functions, and scales, together with a cross-sectional study covering 34 RACFs selected from four major cities in three provinces. Taking into account considerations of income, marital status, education, age, and gender, the sampling size for each of these influencing factors was a minimum of 30 people.

In addition, this chapter also discusses the scale of the RACFs, the difference between the AC of RACFs with and without renovation, and the impact on the elderly RS, IEQ, and QoL rating.

The world is facing a rapid increase in the elderly population, in particular, the proportion of population aging in developed and transition countries (such as Bulgaria and Croatia) is much higher than in developing countries. Through the United Nations Department of Economics and Affairs and some scholars, 60 or 65 years is usually defined as the elderly (Melorose et al., 2015). Japan has the highest aging proportion in the world in recent years. According to the World Population Prospects of UN statistics, Japan’s population aged 60 or older in 2015 was 42 million, accounting for about 33.1% of its total population ("World population prospects: The 2015 revision," 2015). Followed by Italy and Germany, the elderly population accounted for 28.6% and 27.6%, respectively. Despite being a developing country, China has also quickly entered an aging society due to the rapid economic growth, science, and technology, and the impact of family planning policies. In 2013, China had more than 202 million seniors

(Wu & Dang, 2013). By 2016, the 60-year-old population reached 230 million, making up 16.7% of the total population, of which 150 million were over 65 years old and about 30 million were over 80 years old (Xinhua News Agency, 2017). Without a doubt, the proportion will continue to rise in the next several decades.

This chapter describes the analysis of different factors affecting the quality of life in RACFs. One of these is the AC which involves building quality, planning and design, location, neighborhood status, and related overall external environment of the building. Another is IEQ which is the performance of a building in meeting the expectations of occupants' health and well-being in terms of providing the occupants with an acceptable indoor environment.

Previous studies had pointed out that different AC such as activity space, decoration, and green surroundings influence mental health, physical health, and social relationships, living environment.

Indoor environmental quality is related to the health and comfort of the indoor occupants, while acoustic quality, lighting, TC, and IAQ have important impacts on the safety and activities of the occupants. As illustrated in previous studies, the elderly's QoL in the RACFs could be accurately predicted from the indoor environmental quality such as space, accessibility design, and other indoor facilities. At present, various local governments in northeast China are working to improve the heating problem, such as installing insulation layers on exterior walls, under floor heating (Cheng et al., 2011). Therefore, helping the seniors to use the indoor heating to build a good environment is essential for their physical and mental comfort.

Another factor affecting the QoL of the elderly is Residential Satisfaction (RS), which largely depends on the subjective feelings of the elderly, the feeling of the indoor environment, the rating of the surrounding shops and services, the familiarity with the residential care facilities, satisfaction with the residence, relationships with neighbors, and so on.

7.2 Development Status and Model of China's Elderly Care Facilities

In China, both government financial allocations and social private business investment provide supports for the endowment of funding and resources in regions for aged-care development. Fiscal expenditure in China on social elderly care services contributes to two major sectors: i) buildup of social welfare facilities and institutions;

and ii) development of residential care facilities for the elderly (Hu et al., 2011). Among various existing problems in the RACFs, like underinvestment from private business, rapidly aging of the population, and slow economic development, the features of RACFs in the northeast of China include: insufficient number of RACFs, unbalanced development of RACFs, and the difficulty of standardizing the construction of RACFs

First, there are too few RACFs. According to the objectives of civil affairs development in the 13th Five-year Plan for Economic and Social Development ("The 13th five year plan for national economic and social development," 2016), there should up to 35-40 elderly care beds per 1000 aged population by 2020. However, a statistical survey conducted in 2018 by local concerned authorities in the northeast, showed that the average number of beds per 1000 was 32 in Heilongjiang Province; 32 in Jilin province; and 24 in Liaoning province. It looks as if Heilongjiang Province has relatively more beds, only more than Liaoning and equal to Jilin. Scholars studying the development of RACFs in the northeast also demonstrate the inadequacy of residential care facilities for the elderly (HAO, 2018; SHEN, 2018).

Secondly, the development of RACFs in northeast China is unbalanced. Public RACFs are mainly based on welfare, while private RACFs only receive a small amount of welfare from the government. The early public RACFs are welfare institutions set up by the state, with government financial investment, mainly focused on security, aiming to provide basic welfare security. Size and services of public RACFs such as non-profit institutions, they charge relatively low fees. The occupancy rate is high, and there is a waiting list for admission. Private RACFs are market-oriented. High-end RACFs provide better living environments, services, and resources: they are higher priced and have occupancy rates. Private low-end RACFs are relatively backward regarding the facilities and services, small scale, generally attracting people with low fees (Zhao & Wang, 2000). Their services also do not meet government standards.

Third, it is difficult to standardize the construction of RACFs. Public RACFs funded by the government are guaranteed to meet certain construction standards, however, the construction standards for private RACFs are different as the standards are up to the owners of this private RACFs. Some high-end RACFs have high standards almost like luxury hotels. However, they fail to consider the needs of the elderly for services and fail to provide specific individual services resulting in a waste of investment as they are more likely to raise the luxury standard of these RACFs rather than really learn about the needs of the elderly. In order to cut costs, some low-end RACFs reduce environmental quality and only provide basic living conditions, without taking into account the effects on the psychological feelings of the elderly.

7.3. Methodology

In this study, by using a mixed-method, the items for analysis were selected through literature review and interviews, and a questionnaire was designed for the survey. The questionnaire includes the personal information of the residents of the old-age facilities, the RS of the residents on the living environment, the indoor IEQ of the old-age facilities, and the QoL rating of the elderly. In addition, the AC of the RACFs is measured and recorded. A sample of 34 RACFs in urban areas of northern China was selected for investigation, and 1457 valid questionnaires were collected. SPSS modeler is a text analytics and data mining software application from IBM that is utilized to establish predictive models and implement other analytic tasks, while AMOS is an added SPSS model that is utilized for confirmatory factor analysis, structural equation modeling, and path analysis. According to the previous assumptions, SPSS and Amos were utilized to analyze the results of the research results.

7.3.1 Collection and Acquisition of Sampling Data

The study was conducted in three provinces in the northeast area of China: Jilin Province, Heilongjiang Province, and Liaoning Province (the Northeast).

As the major causes for this research on RACFs, four cites in the Northeast were singled out: Harbin; Changchun; Shenyang; and Dalian (a coastal city in the developed economy region of Liaoning Province) (see Figure 7-1).

According to the summarized registration information on RACFs in 2020 in these four cities, there are 374 in Changchun; 169 in Shenyang); 261in Harbin; and 476 in Dalian. In this study, using a designated sampling approach, 34 RACFs (see Table 1) were chosen and surveys were conducted after approval being granted to access the care facilities.

The occupants living in the selected RACFs are provided with board, three meals, activity spaces, basic medical provisions, and laundry service. Depending on the scale and construction features of properties (whether retrofitted or not), the selected RACFs were classified into categories. Table 7-1 presents information about the selected RACFs. Following GB 50867–2013: Designs Code for Buildings of Elderly Facilities (of China) ("Code for architectural design of pension facilities," 2014), the categorized

RACFs include elderly apartment, nursing home, and aged care facilities, were further subdivided as follows:

Small: 150 or fewer beds

Medium: from 151 to 300 beds

Large: from 301 to 500 beds

Super-large: more than 500 beds RACFs of different sizes were selected for inclusion in the research surveys.

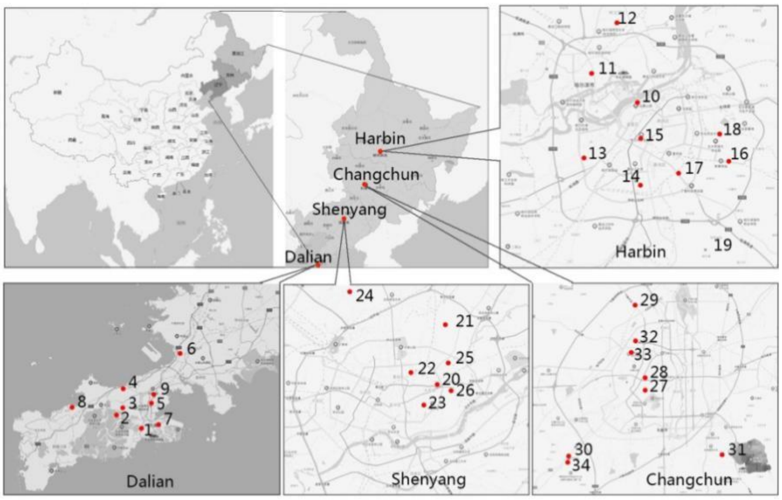
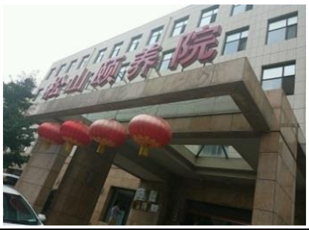


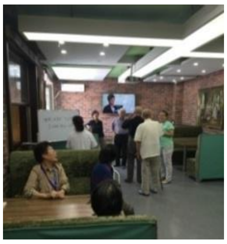
Figure 7-1. Geographical distribution of elderly facility locations

Table 7-1. Details of RACFs (all currency in Chinese Yuan)

Dalian, Shahekou District: Nansha Home for the Elderly 	City: Dalian Building area: 4500 Number of beds: 130 Construction date: 2008 Rebuild: no Ownership: public Price range: 1000–2000	Dalian, Ganjingzi District: Red Flag Welfare Center 	City: Dalian Building area: 8800 Number of beds: 260 Construction date: 2004 Rebuild: yes Ownership: public Price range: 1999–3199

Dalian, Ganjingzi District: Warm Garden Residential Aged Care Facility 	City: Dalian Building area: 9200 Number of beds: 300 Construction date: 2006 rebuild: no Ownership: private Price range: 660–1336	Dalian, Yihaizhu Apartment for the Elderly 	City: Dalian Construction area: 9000 Number of beds: 360 Construction date: 2012 rebuild: no Ownership: private Price range: 2600–5800
Dalian, Jiaojinshan Retirement Center 	City: Dalian Building area: 10000 Number of beds: 300 Construction date: 2016 rebuild: no Ownership: private Price range: 2500–3200	Dalian, Jinzhou District, Social Welfare Home 	City: Dalian Construction area: 29,000 Number of beds: 750 Construction date: 1999 rebuild: no Ownership: public Price range: 700–900
Dalian Songshan Residential Aged Care Facility 	City: Dalian Building area: 9269 Bed: 100 Construction date: 2011 Renovate: No Ownership ： private Price range ： 6000–10000	Dalian, longevity House Apartment for the Elderly 	City: Dalian Building area: 4200 Bed: 168 Construction date: 2009 Rebuild: Yes Ownership ： private Price range：1600–3000
Dalian, Ganjingzi District Happy Home for the Elderly 	City: Dalian Building area: 2700 Bed: 60 Construction date: 2010 Rebuild: Yes Ownership：public Price range：700–2300	Harbin Institute of Technology Group Apartment for the Elderly 	City: Harbin Building area: 6050 Bed: 150 Construction date: 2003 Rebuild: Yes Ownership ： public Price range：500–1000

Harbin Runfu Apartment for the Elderly 	City: Harbin Building area: 110000 Bed: 2000 Construction date: 2014 Rebuild: No Ownership : private Price range : 1800–4500	Harbin Ankang Social Welfare Home 	City: Harbin Building area: 66000 Bed: 1500 Construction date: 2003 Rebuild: No Ownership : public Price range: 1800–3500
Harbin Kaifeng Edge Residential Aged Care Facilities 	City: Harbin Building area: 2800 Bed: 135 Construction date: 2015 Rebuild: No Ownership : private Price range : 1580–2680	Harbin The First Social Welfare Home 	City: Harbin Building area: 15200 Bed: 550 Construction date: 1998 Rebuild: No Ownership : public Price range: 500–1000
Harbin Institute of Technology Activity Center 	City: Harbin Building area: 18000 Bed: 450 Construction date: 2008 Rebuild: No Ownership: public Price range : 1200–2500	Harbin Chun Hua DE Shan Apartment for the Elderly 	City: Harbin Building area: 8000 Bed: 500 Construction date: 2017 Rebuild: No Ownership : private Price range: 800–4000
Harbin, Xiangfang District: Fu Lao Nian Apartment 	City: Harbin Building area: 3000 Bed: 150 Construction date: 2018 Rebuild: No Ownership : private Price range : 2000–6000	Harbin Xinsongmayue Mountain aged care Apartment 	City: Harbin Building area: 18000 Bed: 292 Construction date: 2016 Rebuild: No Ownership : private Price range: 4000–7000
Harbin Kunlun Garden Apartment for the Elderly 	City: Harbin Building area: 8000 Bed: 200 Construction date: 2015 Rebuild: No Ownership : private Price range : 1300–1500	Shenyang Dadong Elderly Service Center 	City: Shenyang Building area: 10000 Bed: 300 Construction date: 2002 Rebuild: No Ownership : public Price range: 500–1000

Shenyang Ai Da Apartment for the Elderly 	City: Shenyang Building area: 11000 Bed: 250 Construction date: 2012 Rebuild: No Ownership：public Price range ： 1800–3000	Shenyang Huanggu District Social Welfare Home 	City: Shenyang Building area: 9000 Bed: 140 Construction date: 2004 Rebuild: Yes Ownership ： public Price range： 360–760
Shenyang Shenhe District: Rehabilitation Center for the elderly 	City: Shenyang Building area: 4600 Bed: 120 Construction date: 2001 Rebuild: Yes Ownership：public Price range：540–800	Shenyang Colorful Sunshine City Retirement Center 	City: Shenyang Building area: 130000 Bed: 3500 Construction date: 2014 Rebuild: No Ownership ： private Price range： 2500–5800
Shenyang Bo Yuan Old Care Center 	City: Shenyang Building area: 5000 Bed: 180 Construction date: 2009 Rebuild: Yes Ownership ： private Price range ： 1500–2600	Shenyang Dawn Residential Aged Care Facilities 	City: Shenyang Building area: 6000 Bed: 265 Construction date: 2004 Rebuild: Yes Ownership ： private Price range： 700–1500
Changchun Qinqinyuan Apartment for the Elderly 	City: Changchun Building area: 7677 Bed: 200 Construction date: 2016 Rebuild: Yes Ownership ： private Price range ： 6000–11000	Changchun Jian Yin Qi Xiang Yuan Retirement Center 	City: Changchun Building area: 1600 Bed: 60 Construction date: 2014 Rebuild: Yes Ownership ： private Price range： 3000–6000
Changchun Xi Hui Residential Aged Care Facilities 	City: Changchun Building area: 6000 Bed: 250 Construction date: 2013 Rebuild: Yes Ownership ： private Price range：800–2000	Jilin Changchun Yee Lok Rehabilitation Centre 	City: Changchun Building area: 54500 Bed: 500 Construction date: 2015 Rebuild: No Ownership ： public Price range： 1980–4800

Changchun Jingyueyikang Residential Aged Care Facilities 	City: Changchun Building area: 28000 Bed: 800 Construction date: 2017 Rebuild: No Ownership: private Price range: 2500–6000	Changchun Sunshine Home Residential Aged Care Facilities 	City: Changchun Building area: 4900 Bed: 290 Construction date: 2019 Rebuild: Yes Ownership: private Price range: 2500–9500
Changchun Green Park Happy Care Home for the Elderly 	City: Changchun Building area: 1500 Bed: 110 Construction date: 1997 Rebuild: No Ownership: public Price range: 800–1500	Changchun Social Welfare Institute 	City: Changchun Building area: 15000 Bed: 300 Construction date:2003 Rebuild: No Ownership: public Price range: 1000–3000

7.3.2 Questionnaire Design

The questionnaires were designed to focus on the IEQ of the acoustics, thermal, lighting, IAQ, odors, and overall satisfaction. During the survey, the elderly were asked to stay in the room for at least 15 min, during which a one-on-one interview was conducted.

An exploratory mixed approach was applied in this study to develop categorized classification.

The first step was the qualitative stage of the research.

Residential satisfaction/dissatisfaction and factors correlated to the quality of life had been explored and instruments needed such as the BSAB801 Sound Level Meters for the acoustic measurement, the GPH-1001 brightness Maters for brightness measurement, and the RH sensor (Centre 314 Datalogger) for the RH measurement that were discussed in chapter 6 were equipped in the qualitative stage. The basic framework and dependent variables were developed by reference to relevant literature. The empirical research was carried out over the course of one year.

The second step was personal interviews.

By applying a semi-structured interviewing approach, 80 face-to-face interviews were conducted at 10 different RACFs located in the selected cities.

The interviews started with the question: “Why did you select this elderly care facility to live in, and are you considering moving to another elderly care facility". A further question asked; "What is the reason behind your consideration of moving out or staying" to identify if problematic issues existed in the care facility. The occupant was welcome to elaborate on their daily lives, covering their activity arrangements, behaviors, mood alterations, feelings, thoughts, and so on. Each of the interviews lasted 30-45 minutes and all conversations were recorded in digital format. In the process of interviews, with the researcher's prompting, the participants talked about their feelings and thoughts on RS, IEQ, QoL, and AC.

The third step was applying "framework analysis" to evaluate the data acquired from the interviews.

Because the RACFs are different from the general community, and the elderly's needs are different from other age groups, some changes were made to the questionnaire design for RACFs in relation to RS and QoL factors.

For IEQ rating, the main issues concerned the indoor acoustic environment, daylighting, temperature and humidity, air ventilation, and IAQ (Maedot et al., 2019). On the basis of previous research results (Ibem & Aduwo, 2013) and incorporating the findings of interviews, the rating of RS was classified into six aspects: property management; characteristics of the facility; ambient conditions; room features; types of auxiliary service facilities; and location of auxiliary service facilities. For QoL rating, four factors were considered and the overall QoL was appraised with modification in accordance with the WHO Quality of Life Brief Scale (WHO., 1996).

A 7-point Likert scale, (ranging from 1: Strongly unsatisfied to 7: Strongly satisfied) was applied to measure the responses of the participants in answering questionnaires questions related to measurable items on AC (11 items), RS (19 items), IEQ (6 items) and QoL (14 facets). Additionally, participants' personal information and response to AC in different RACFs had been collected (see Table 2).

The responses for measurable AC items were quantified using a 7-point scale and then grouped according to their quantified value.

Table 7-2. Questionnaire

item	AC			RS						IEQ (F10)	QoL				
	F1-Planning policy	F2-Design principles	F3-Interaction with neighbors	F4-Management of estates	F5-Dwelling unit features	F6-neighborhood environment	F7—housing unit characteristics	F8—type and location of resident	F9—Dwelling unit supports services		Q1-Overall QoL	Q2-Physical health	Q3-Psychological health	Q4-social relationships	Q5-Living environment
Gender, age, educational background, income Marital status, Live time	F11 Commuting cost	F21 Benches in public open spaces for elders	F31 Neighbors' cooperation in payment of monthly charges and cleaning	F41 Management and maintenance of facilities	F51 Sizes of living and dining spaces	F61 Recreation/ sporting facilities	F71 Building materials used in the construction of houses	F81 Location of residence in the estate	F91 Water supply and sanitary services	F101 Acoustic environment	How would you rate your quality of life?	How satisfied are you with your sleep?	To what extent do you enjoy your life?	How do you evaluate your personal relationships?	How satisfied are you with the conditions of your living place?
	F12 Distance to urban facilities	F22 Lighting of public areas	F32 Conflict between neighbors	F42 Cleanliness of the housing estate	F52 Sizes of bedrooms in the house	F62 Prices of goods and services in the housing estate	F72 Privacy in the residence	F82 Public infrastructure and urban services	F92 Electrical services	F102 Lighting environment	How would you rate your overall health?	Do you have enough energy for everyday life?	How often do you have negative emotions, such as despair, blue mood, anxiety, depression?	How satisfied are you with the support you get from your friends?	How safe do you feel in your daily life?
	F13 Quality of constructions and need for repair	F23 Security in stairs and corridors	F33 Profligate tenants	F43 Security of life and property in the housing estate	F53 Sizes of cooking and storage Spaces	F63 Communal activities in the housing estates	F73 Cost of housing			F103 humidity			How satisfied are you with yourself?		Have you enough money to meet your needs?

		F24 Accessibility facilities		F44 Rules and regulations within the housing estate	F54 Design of baths and toilet facilities		F74 External appearance of the residence			F104 temperature			Are you able to accept your bodily appearance?		How satisfied are you with your access to health services?
		F25 Road lights								F105 Ventilation					
										F106 air quality					

Table7-3. Survey siteclassifications according to city, location, season, size, and residents' satisfaction levels

	Classification	Number	Percentage (%)
City	Changchun	346	23.7
	Harbin	485	33.3
	Shenyang	420	28.9
	Dalian	206	14.1
Scale	Small	352	24.2
	Medium	280	19.2
	Large	625	42.9
	Super-large	200	13.7
Satisfaction level	1.Very dissatisfied	152	10.4
	2. Dissatisfied	150	10.3
	3.Slightly dissatisfied	174	11.9
	4. Neither satisfied nor dissatisfied	566	38.8
	5. Slightly satisfied	75	5.1
	6. Satisfied	176	12.1
	7. Very satisfied	164	11.3

7.3.3 Survey Participants

Upon completing the development of the questionnaires, 34 RACFs located in the selected cities were chosen stochastically for the research survey. A total of 1,457 participants aged 55 years and older, whose health status and psychological conditions were sound enough for enrollment into the research were randomly selected, and the survey was conducted in RACFs. Each interview took about 3-5 minutes. Among them 27.6% of validated questionnaires (402) were conducted in Winter, 26.8% (390) in Summer, and 45.6% (665) in the seasonal transition from Summer to Winter (Autumn) (see Table 7-4)

Out of consideration of the elderly's mobility and health issues, the survey was carried out by personal one-on-one interviews. Older residents The findings of previous research had suggested that demographic differences like age affect subjective assessment (Zhao & Wang, 2000). In order to minimize age-related negative effects or contingent errors, a balanced demographic structure of participants was developed. In addition, previous research had remarked that specific perceptions were subject different according to gender (Alkabashi & YÖRÜKOĞLU, 2019), thus in this research, consideration was given to achieving a gender balance. Taking into account considerations of income, marital status, education, age, and gender, the sampling size for each of these influencing factors was a minimum of 30 people. Lastly, it should be noted that female occupants outnumbered male occupants in all selected RACFs. In the final sample, the age of participants ranged from 55 to 95; and the Male/Female ratio was 1.07:1 (men: 704, women: 753) ensuring a balanced sex ratio of sampling. Table

7-4 presents classification information related to the social characteristics of participants.

Table 7-4. Classifications of the social characteristics of the participants

Social characteristics	Classification	Number	Percentage (%)
Gender	Male	704	48.3
	Female	753	51.7
Age (years)	55–60	271	18.6
	61–70	424	29.1
	71–80	359	24.6
	81–90	323	22.2
	91–95	80	5.6
Education level	No schooling	248	17
	Primary school	350	24
	Junior school	271	18.6
	Senior school	274	18.8
	College	284	19.5
	Graduate or higher	30	2.1
Income (RMB)	≤ 1000	197	13.5
	1001–2000	264	18.1
	2001–3000	278	19.1
	3001–4000	306	21
	4001–5000	241	16.5
	≥5001	171	11.7
Marital status	Unmarried	39	2.7
	Married	801	55
	Divorced	341	23.4
	Widowed	276	18.9
Duration of residency (months)	< one month	193	13.2
	1to six months	269	18.5
	6 months to one year	239	16.4
	1 to three years	222	15.2
	3 to five years	272	18.7
	Over five years	173	11.9

7.3.4 Physical Measurements

The most important IEQ physical factors to be checked were identified by reference to relevant national and organizational codes, guidelines, and regulations. Assessment primarily focused on acoustic, lighting, temperature, humidity, and overall IEQ. The study was implemented by applying quantitative analysis, which included fieldwork assessment performed in each designated region. Measurement was conducted during working hours (8:00 a.m. to 5:30 p.m.). Details of the measurement devices are listed in Table 7-5.

All measurements were conducted after completing the questionnaire survey. During measurement, the sound level meters were regulated to the low speed to better detect the environment. The distance between the measuring wall and other main reflecting surfaces is at least 1 meter, and the distance between the ground and the measuring position is 1.2 to 1.5 meters. One measurement was conducted every 10 seconds. The data for each location were recorded for 5 minutes. A calculation of mean value was conducted to obtain the corresponding $L_{Aeq,\ 5min}$. The light environment was measured at the height of the elderly line of sight and illumination and brightness were measured. For the spot measurement, which is measuring several specific spots within the RACFs, the variables of environment were recorded continuously for 20 minutes, and the average was calculated. For the thermal environment, both temperature and humidity were checked and the measurement based on the equations was presented in ISO 7726, which standardized the instruments of thermal environment measurement. (Standard & ISO, 1998).

Table 7-5. Measurement and instrument

Measurement	Instrument	Measurement Range/Accuracy
Acoustics	BSAB801 Sound Level Meters	19 dB(A) ~ 137 dB(A) (±0.1 dB(A))
Illumination	T-10A illuminance Meters	0.01 - 299,000 lux(±5%)
Brightness	GPH-1001 brightness Maters	20 cd/m^2~2000 kcd/m^2
Temperature	K-type thermocouple (Centre 314 Temperature/Humidity Datalogger, Centre Tech, Taipei, Taiwan)	−40–80 °C (±0.1°C);
Relative humidity (RH)	RH sensors (Center 314 Datalogger)	0–99% (±3%)

7.3.5 Data analysis

Statistical packages SPSS 22.0 and AMOS 22.0 were applied to analyze data acquired from questionnaire surveys. Firstly, to estimate the reliability and consistency of the questionnaires and validate the development of the questions, the measurement of Cronbach's Alpha Coefficient and Confirmatory Factor Analysis were done accordingly.

Secondly, for the rating of RACFs, difference analysis was conducted to investigate the differences in varied scales of architectural features (whether or not retrofitted) and at different times of the year; and the relevance of different variables was explored.

AMOS was used to carry out structural equation modeling in accordance with the assumed hypotheses and the conceptual model. The hidden variables can be reflected by the observable variables. The correlations among the hidden variables were examined. Through examining the degree of fit between actual data and the structural equation model, the theoretical hypotheses have been attested.

7.4 Results and Analysis

7.4.1 Reliability and Validity

This study investigated the overall quality of living conditions for the elderly residential care facilities in northeast China. It focused on three factors: AC; IEQ; and RS, and their relation to QoL in a questionnaire responded to by 1457 participants. An exploratory factor analysis of 50 items produced four variables as principal components of satisfaction (see Table 7-6).

Table 7-6. Reliability measurement

Variables	Cronbach's Alpha (α)	Number of items
AC	0.911	11
IEQ	0.939	6
RS	0.799	19
QoL	0.789	14

Cronbach's Alpha (α) is applied to assess reliability: if Cronbach's Alpha is higher than 0.9, the internal consistency of the variable is excellent; if 0.9 > α ≥ 0.7, the internal consistency of the variable is good and acceptable; if 0.7> α ≥ 0.5, internal consistency of the variable is questionable and poor; if α is less than 0.5 the variable is very problematic and unacceptable, and redesign should be considered (George & Mallery, 2009). According to Table 7-6, Cronbach's Alphas for AC and IEQ are excellent at 0.911 and 0.939; while both RS and QoL are greater than 0.7, which is good and acceptable for internal consistency.

Table 7-7. Construct validity analysis of AC

Factors		Items	Factor Loading				
			1	2	3		
F1 —Planning policy	F11	Commuting cost		0.773		0.902	
	F12	Distance to urban facilities		0.814		0.905	0.848
	F13	Quality of construction and need for repair		0.800		0.905	
F2—Design principles	F21	Benches in public open spaces for elders	0.736			0.903	
	F22	The lighting of public areas	0.762			0.899	
	F23	Security in stairs and corridors	0.813			0.898	0.887
	F24	Accessibility facilities	0.778			0.902	
	F25	Road lights	0.765			0.908	
F3—Interaction with neighbors	F31	Neighbors' cooperation in payment of monthly charges and cleaning			0.778	0.902	
	F32	Conflict between neighbors			0.872	0.905	0.868
	F33	Profligate tenants			0.82	0.905	

Eigenvalue	5.861	1.335	1.008
% of Variance	53.282%	12.137%	9.164%
Cum%	53.282%	65.418%	74.582%
KMO	0.889		
Bartlett measurement	10317.371		
Sig.	0.000		

Note: Profligate tenants refer to the tenants who do not follow the rules of the RACFs and act selfishly to meet their own desires.

Construct validity is the degree of correspondence between the actual value and the predicted value for the measurement results. Factor analysis is the most

(KMO) is a measure to determine how suited your data is for factor analysis (Glen, 2016), while Bartlett's measurement for Sphericity examines whether there is a redundancy among variables that can be summarized with certain factors. Table 7-7 shows that KMO is 0.889, which is higher than 0.5; the Bartlett spherical measurement statistic value is 10317.371, while the p-value is close to 0 and is less than the materiality level. It is eligible for factor analysis. Based on the principle that the cumulative variance contribution rate higher than 50%, and the eigenvalue is higher than 1, three primary factors can be extracted from (F1-F3) from 11 items in AC. The cumulative variance contribution rate of these three primary factors reaches 74.582%, which means that only a small amount of information has been removed, and the factor analysis results have significance. The loadings of the three factors are higher than 0.5, and there is no cross load of each item. Each item is clustered under a corresponding factor, thus indicating that these variables have good structural validity.

Table 7-8. Construct validity analysis of residence satisfaction (RS)

			Factor Loading						Cronbach's Alpha	
Factors	Items		1	2	3	4	5	6		
F4—Management of estates	Management and maintenance of facilities	F41	0.931						0.787	0.895
	Cleanliness of the housing estate	F42	0.852						0.788	
	Security of life and property in the housing estate	F43	0.877						0.790	
	Rules and regulations within the housing estate	F44	0.798						0.790	
F5—Dwelling unit features	Sizes of living and dining spaces	F51		0.845					0.788	0.868
	Sizes of	F52		0.828					0.791	

	bedrooms in the house									
	Sizes of cooking and storage spaces	F53		0.853					0.788	
	Design of baths and toilet facilities	F54		0.824					0.794	
F6—Neighbor hood environment	Recreation/sporting facilities	F61				0.902			0.792	
	Prices of goods and services in the housing estate	F62				0.835			0.790	0.806
	Communal activities in the housing estates	F63				0.777			0.794	
F7—Housing unit characteristics	Building materials used in the construction of houses	F71			0.819				0.789	
	Privacy in the residence	F72			0.749				0.788	0.817
	Cost of housing	F73			0.806				0.788	
	The external appearance of the residence	F74			0.793				0.788	
F8—Type and location of residence	Location of residence in the estate	F81						0.823	0.789	
	Public infrastructure and urban services	F82						0.867	0.795	0.666
F9—Dwelling unit supports services	Water supply and sanitary services	F91					0.852		0.792	
	Electrical services	F92					0.855		0.793	0.694
		Eigenvalue	4.16	3.047	2.063	1.98	1.318	1.224		
		% of Variance	21.896%	16.034%	10.86%	10.42%	6.936%	6.44%		
		Cum%	21.896%	37.931%	48.791%	59.21%	66.146%	72.586%		
		KMO	0.794							
		Bartlett measurement	11824.51							
		Sig.	0.000							

In Table 7-7, the value of KMO is 0.794, which is higher than 0.5, the Bartlett measurement is 11824.51, and the p-value is close to 0. The results show that the RS variable is suitable for factor analysis. Six main factors (F4-F9) were extracted from 19 items. The cumulative percentage of these six main factors reached 72.586%, the eigenvalue is more than 1, and the factor analysis results were reliable. The Cronbach's alpha for each factor is greater than 0.5, and the factor loading of each item is higher than 0.7, and there is no cross-loading between them, so these variables have good structural validity.

Table 7-9. Construct validity analysis of indoor environmental quality (IEQ)

Items		Factor Loading 1	Cronbach's Alpha	
F101	Acoustic environment	0.192	0.925	
F102	Lighting environment	0.183	0.932	
F103	humidity	0.189	0.928	
F104	temperature	0.199	0.921	0.939
F105	Ventilation	0.18	0.934	
F106	air quality	0.198	0.922	
Eigenvalue		4.606		
% of Variance		76.758%		
Cum%		76.758%		
KMO		0.897		
Bartlett measurement		7856.243		
Sig.		0.000		

In Table 7-9, the value of KMO is 0.897, which is higher than 0.5, the Bartlett measurement is 7856.243, and the p-value is close to 0. The results show that the IEQ variable is very suitable for factor analysis. There are six items in IEQ, the cumulative percentage of the IEQ factor reached 76.758%, and the factor analysis results are reliable. Cronbach's Alpha for temperature is 0.939, and the factor loading of each item is higher than 0.9, with no cross-loading between them, so these variables have excellent structural validity.

Table 7-10. Construct validity analysis of quality of life (QoL)

Factors		Items	Factor Loading 1	2	3	4	5	Cronbach's Alpha	
Q1-Overall QoL	Q11	How satisfied are you with your quality of life?			0.827			0.765	0.774
	Q12	How satisfied are you with your overall health?			0.865			0.778	
Q2-Physical health	Q21	How do you rate your quality of sleep?					0.912	0.786	0.677
	Q22	Do you have adequate energy					0.757	0.773	

		for daily activities?							
Q3-Psychological health	Q31	How much do you enjoy your life?		0.865				0.768	
	Q32	How often would you have negative emotions, such as despair, blue mood, anxiety, and depression?		0.750				0.766	0.827
	Q33	How satisfied are you with yourself?		0.785				0.784	
	Q34	Do you accept your bodily appearance?		0.802				0.782	
Q4-Social relationships	Q41	How satisfied are you with your interpersonal relationships?				0.834		0.784	0.663
	Q42	How satisfied are you with the support from your friends?				0.871		0.789	
Q5-Living environment	Q51	How satisfied are you with the conditions of your living place?	0.745					0.761	
	Q52	How safe do you feel in your daily life?	0.845					0.778	0.840
	Q53	Have you enough money to meet your needs?	0.808					0.778	
	Q54	How satisfied are you with your access to health services?	0.827					0.780	
	Eigenvalue		3.885	2.318	1.722	1.317	1.035		
	% of Variance		27.751%	16.558%	12.303%	9.408%	7.394%		
	Cum%		27.751%	44.309%	56.612%	66.02%	73.414%		
	KMO		0.782						
	Bartlett measurement		7484.62						
	Sig.		0.000						

In Table 7-10, the value of KMO is 0.782, the Bartlett measurement is 7484.62, and the p-value is close to 0. The results show that the QoL variable is suitable for factor analysis. Five main factors (Q1-Q5) were extracted from 14 items. The cumulative percentage of these five main factors reached 73.414%, and the factor analysis results were reliable. The Eigenvalue is more than 1. The Cronbach's alpha for each factor is greater than 0.5, and the factor loading of each item is higher than 0.7, with no cross-loading between them, so these variables have good structural validity.

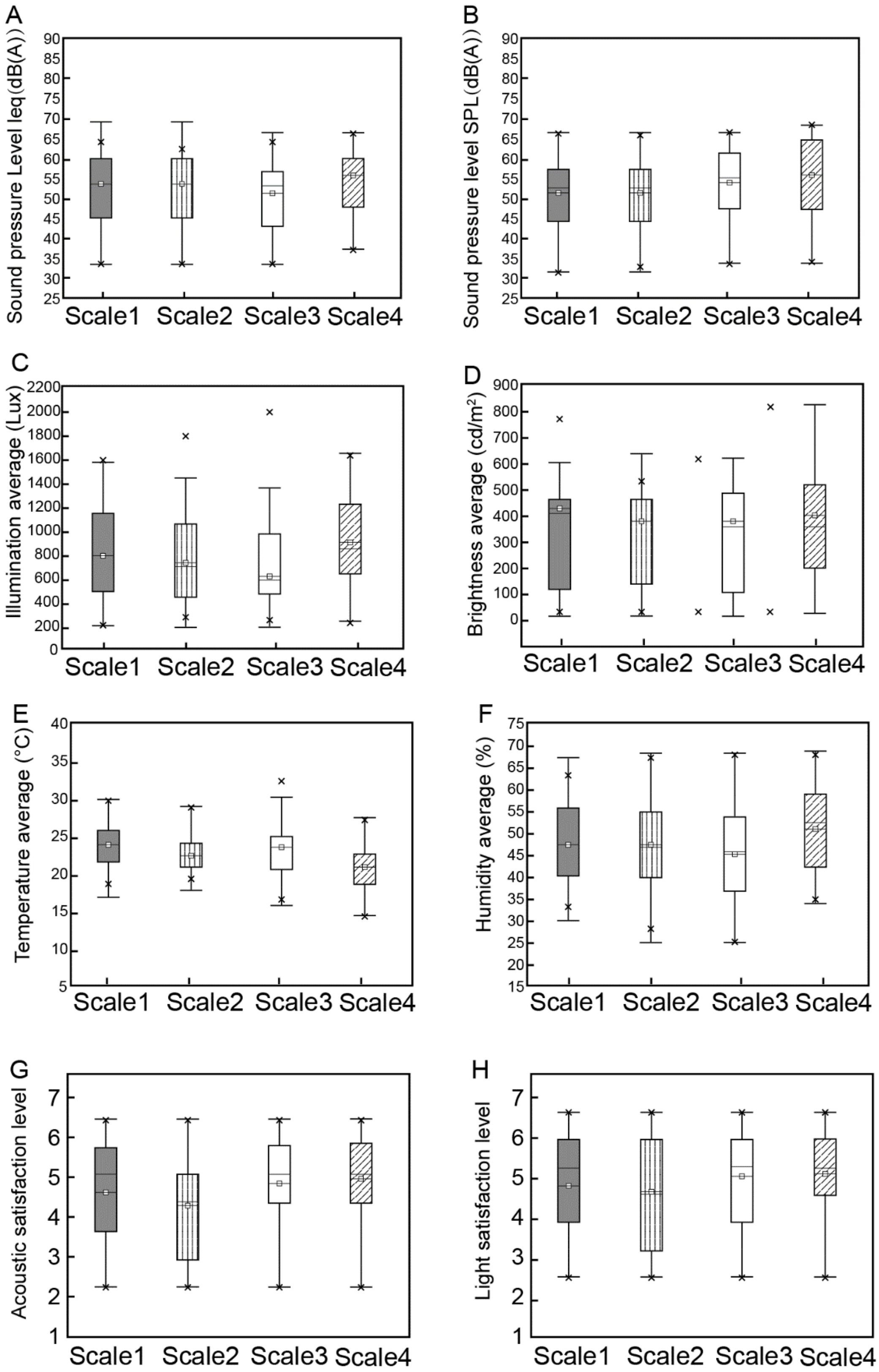
7.4.2 The Differences between Residential Care Facilities

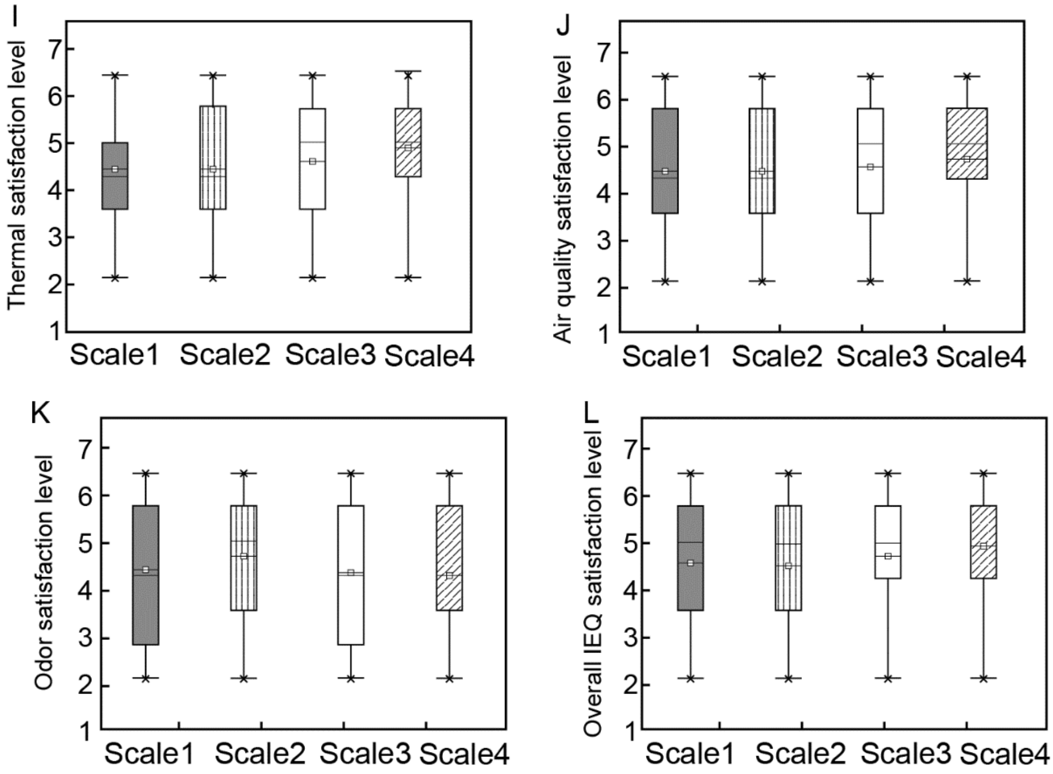
7.4.2.1 The Differences in the Size of Facilities

The p-values of the four variables show significant differences, P=0 ($P<0.001$) (Table 7-11), indicating that there are differences in the four variables of RACFs at various scales of facilities. Among the small and medium-size RACFs, RS has the lowest rating value and AC is the highest, because the small and medium- size RACFs have a small footprint and the staff is relatively simple to control air quality. In the large-size RACFs, the four indicators are relatively balanced, and the gap is small, and its overall performance is slightly lower than that of the small and medium-sized ones. Finally, mega- size RACFs have the highest rating value of IEQ. The reason may be that mega-size personnel, equipment, and funds are more likely to form a high-quality environment. However, the rating value of IEQ is still lower than that of medium- size RACFs.

For AC, the difference between small and medium scale is more significant than large scale; for RS, the difference between medium and large scale is more significant than small and mega-scale; for IEQ and QoL, the differences between medium scales the other three sizes are more significant than other variables. Although the large-scale RACFs have advanced facilities, the layouts are complex and difficult for the elderly to familiarize themselves with. Some seniors interviewed said that large rooms are far apart from each other and lack a sense of warmth. From these findings, the aged generally think that medium-sized RACFs feel best because there is enough personal space, the facilities are adequate, and the activity areas are acceptable.

From Figure 7-2, we can see that the satisfaction of each index of super large RACFs is higher than the others, and the difference between the highest value and the lowest value is the smallest among the four. On the contrary, the satisfaction of each index of small-size RACFs is not uniform, and the interval is relatively large. In terms of specific indicators, super large-size RACFs are basically the best, but their average humidity is higher than others. The average illumination of large-scale RACFs is the lowest, but its sound pressure level is also the lowest.


A
Sound pressure Level leq(dB(A))
B
Sound pressure level SPL(dB(A))
C
Illumination average (Lux)
D
Brightness average (cd/m²)
E
Temperature average (°C)
F
Humidity average (%)
G
Acoustic satisfaction level
H
Light satisfaction level
Scale1 Scale2 Scale3 Scale4



Note Scale 1: small ≤ 150 beds; Scale2：medium 151 to 300 beds; Scale 3： large 301 to 500 beds; Scale 4：super large > 500 beds.

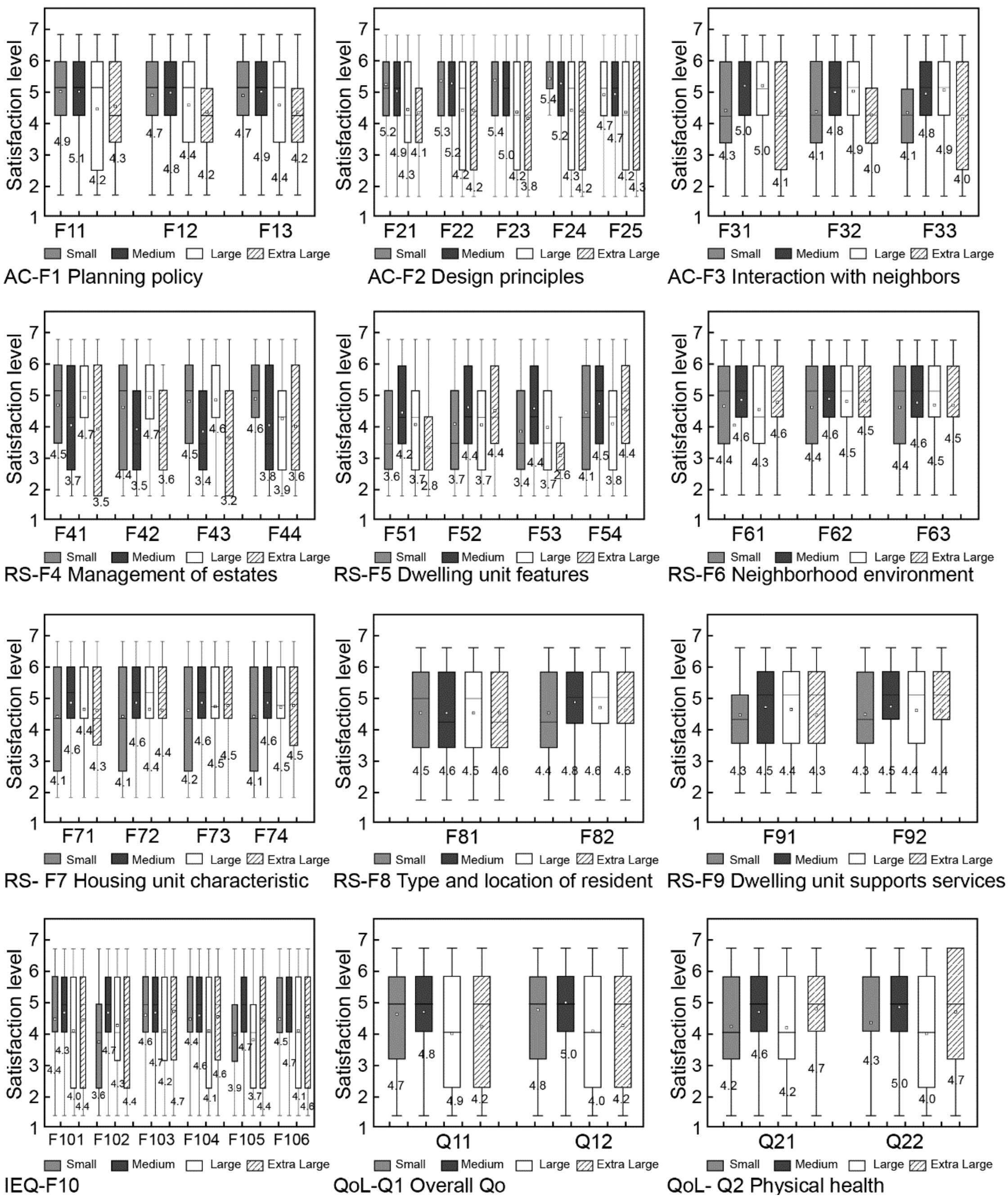
Figure 7-2. Comparison of the six environmental factors of different sized RACFs

Analysis of variance is used here. Among them, the P value is the significant relationship between the satisfaction of various indicators and the scale of different RACFs. The P value is also the difference between the four sets of data. There are significant differences between the four sets of data. From Table 7-11, we can see that three of the four indicators of medium-sized RACFs are the highest, and the RS satisfaction of medium-sized RACFs also ranks second. It can be seen that these four indicators of medium-sized RACFs can best meet the needs of the elderly. From a longitudinal comparison, the AC of small RACFs is the highest, and the RS is the lowest, indicating that the living feeling of small RACFs can satisfy the elderly. The same is true for Mega-type RACFs, but its IEQ is the highest, indicating that the indoor environment of Mega-type RACFs is relatively perfect. As for large-scale RACFs, the satisfaction gap of the four indicators is not large, and it is in a relatively low range.

Table 7-11. Difference analysis of each variable in different sized RACFs

	Small	Medium	Large	Mega	F	P	η_p^2
AC	4.790	4.954	4.231	4.107	35.254	0.000	0.065
IEQ	4.340	4.796	4.016	4.544	22.744	0.000	0.025

RS	4.196	4.310	4.330	4.045	7.651	0.000	0.038
QoL	4.219	4.509	4.230	4.322	7.102	0.000	0.017



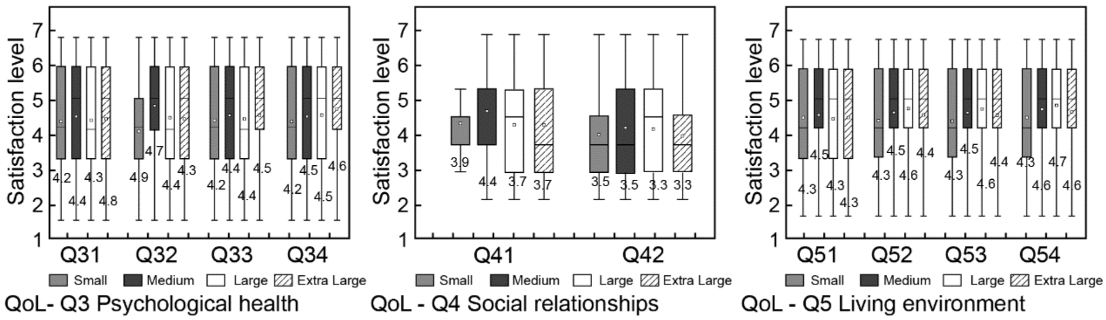


Figure 7-3 Ratings of 15 factors for different sizes of facilities

Figure 7-3 shows a rating survey of 15 factors for the different sizes of facilities. For the AC factor, negative rating by the elderly is mainly found in large-size and mega-size RACFs, while the positive rating is mostly found in small and medium RACFs. Price is one of the problems, but another major problem is that the building design and equipment do not fully meet the needs of the elderly, such as noise, temperature, humidity, ventilation, lighting, stairs safety, and accessibility facilities. The aged prefer to stay in their rooms, and because the scale is so large, communication between neighbors is difficult. The survey found that the details of some large-size residential aged care facilities are not perfect, for example, there is fewer staff, locations can be far from urban centers, which make it hard for children to visit, and leisure and entertainment places such as shops and parks.

In terms of RS, medium-sized RACFs performed better overall. Small-size individual hardware facilities are not perfect, while large-size and super large-size are lacking in caregivers. Therefore, the elderly in the middle-size RACFs have relatively high residential satisfaction. As for QoL, the indicators of medium, large, and ultra-large-scale RACFs are relatively good, especially for ultra-large-scale ones. The reason may be that the larger the scale of RACFs, the more complete the facilities and the easier it is to ensure the quality of life of the elderly.

In terms of housing management, small-size RACFs have the highest satisfaction, because the smaller number of residents is conducive to better management and care of the elderly by nursing staff. However, the less satisfactory aspects of small-size RACFs are that equipment is relatively too basic, private space is small and limited, privacy is poor, and the decoration is low grade. The satisfaction rating of small-size facilities is only 4.1 on the housing unit characteristics factor, which is lower than other scales. The physical facilities are improving in small RACFs, and satisfaction of management of small-sized and large-size RACFs is high, and, but is lower in medium and mega RACFs.

Here, the 6 factors selected here are not exactly the same as those in Figure 7-2. There is no thermal environment, and temperature, humidity, and ventilation are evaluated separately. Because in the six chapters, humidity, temperature and ventilation all have significant correlations to the rating (the values are ranged from 0.386 to 0.813), and the ratings between them are different, so when constructing the structural equation, these are evaluated as independent factors. Odor is also used as an independent factor to construct the structural equation, but in the calculation of the model, the rating of odor has no correlation with other factors, so there is no odor in the last factor of the structural equation.

This shows that RACFs in northeast China appear to be lacking professional elder care staff. However, overall satisfaction with medium-sized RACFs is significantly higher than other scales. This shows that for the elderly, the venue and scale should be neither too large nor too small, which is similar to the residential satisfaction results of Sikorska’s (1999) research.

7.4.2.2 Analysis of the Differences Between Purpose-built (unconverted) Buildings and Converted Buildings

The demands for RACFs have become increasingly urgent owing to the growing number of the elderly in the population. A large number of non-care facilities have been reconstructed and converted into care facilities, including former schools, hotels, and hospitals. It has yet to be determined whether the indoor environmental conditions of RACFs converted from other uses can satisfy the needs of the elderly and more research is required to determine if these converted facilities can successfully meet the standard requirements. It was necessary to contrast the indoor environmental conditions of the converted facilities with those of specially-designed elderly care facilities to assess the key points of the current investigation.

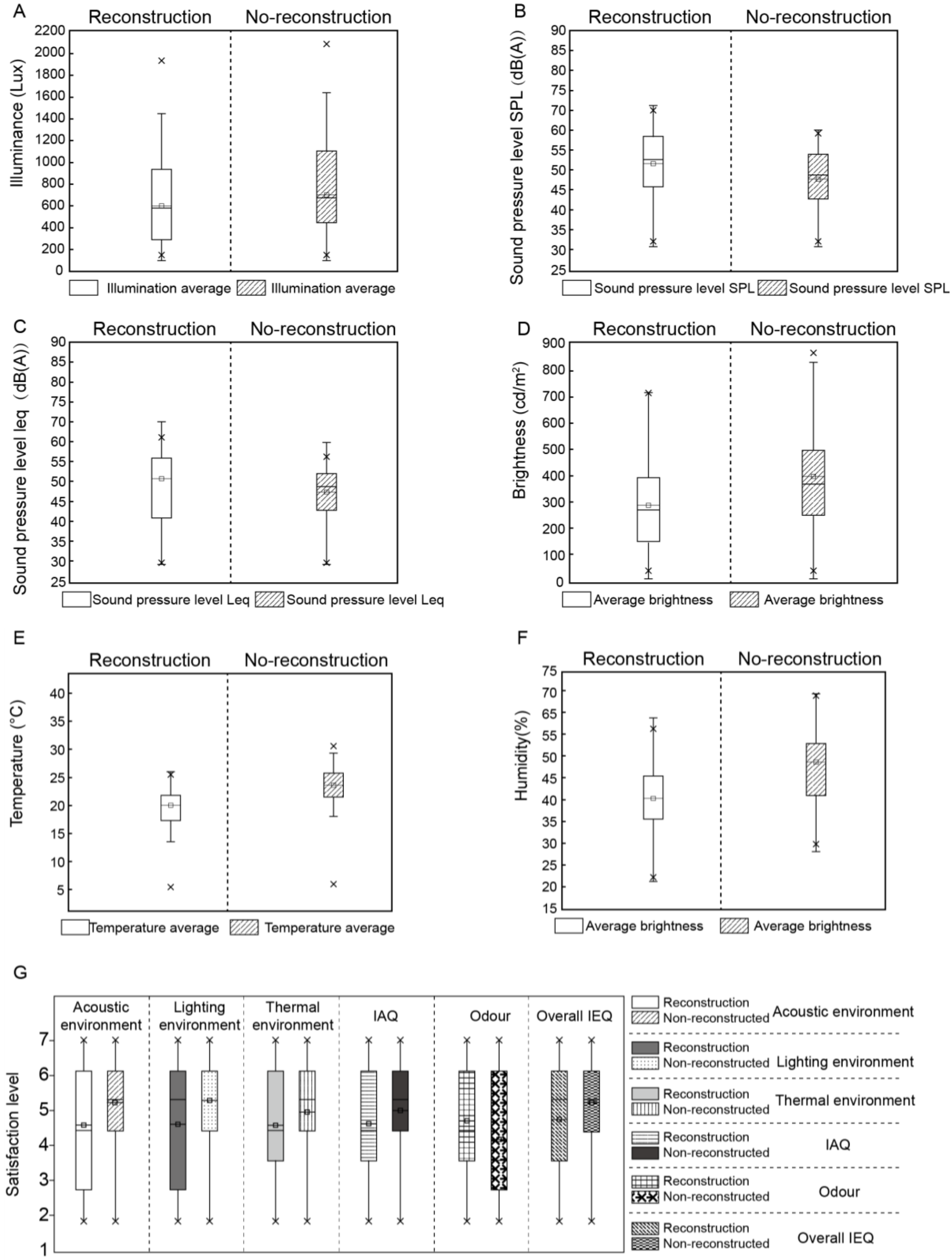


Figure 7-4 Comparison residents' satisfaction levels with physical environment factors between the purpose-built and converted RACFs (reconstruction refers to converted buildings, no-reconstruction refers to non-converted or purpose-built)

As illustrated in the figure 7-4, the illumination average of non-converted buildings is higher than that of converted ones. The SPL of the converted building is higher than that of non-converted ones. The average brightness of non-converted buildings is better than that of converted ones. The temperature average of non-converted buildings is higher than that of converted ones, and the humidity average of non-converted buildings is higher than that of converted ones.

In addition, in terms of various environmental factors, as shown in Figure 7-4 (G), reconstruction building and the non-reconstructed have the same highest satisfaction， which is 6. However, for acoustic environment, lighting environment, thermal environment, and IAQ, the satisfaction range of reconstruction building is larger than that of the non-reconstructed. The satisfaction interval of odor and overall IEQ is smaller than that of the non-reconstructed.

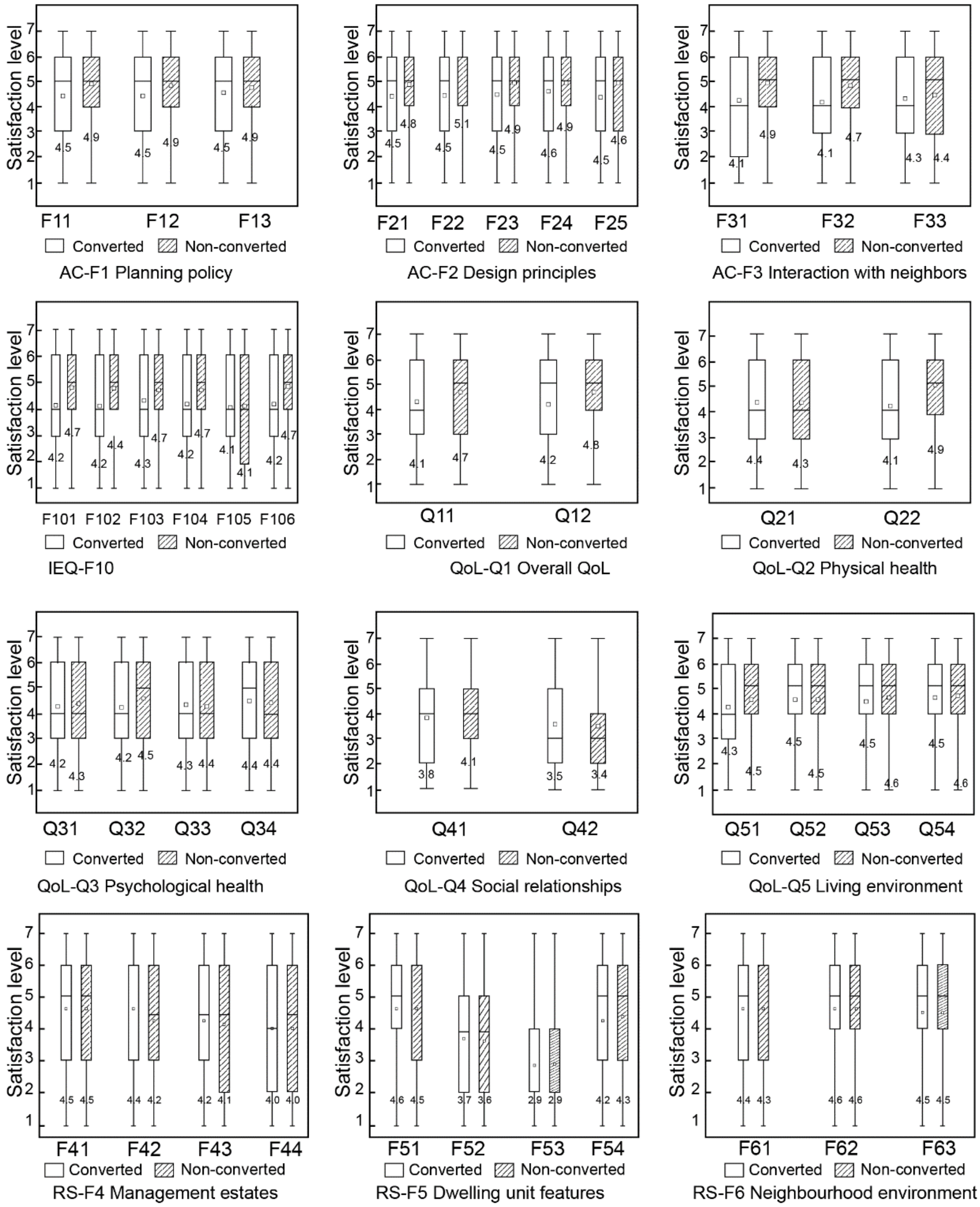
As a result of market demands and policy support, the RACF has become a leader of architectural transformation in China. The Chinese government encourages enterprises or vacant buildings to be converted into RACFs. For example, hotels that are about to close, closed schools and community service places are converted into RACFs (Yu et al., 2009). Two-thirds of the 34 RACFs in this survey have been converted to RACFs from other uses. This section compares and analyzes the differences in satisfaction between converted and non-converted RACFs.

Table 7-12. Differences between converted and non-converted RACFs

	converted	non-converted	F	p
AC	4.359	4.786	33.961	0.000
RS	4.276	4.188	3.523	0.061
IEQ	4.217	4.585	20.891	0.000
QoL	4.234	4.440	15.619	0.000

Table 7- 12 shows that except that the p-value of RS is greater than 0.05 meaning there is no material difference, other variables have significant differences between converted and non-converted buildings, also the significance of the difference of non-converted is greater than that of converting. The P value is also the difference between the four sets of data. There are significant differences between the four sets of data. The analysis of variance is used here. The converted AC has the highest rating value, as is the non-converted, which are 4.359 and 4.786. The rating value of the non-converted AC is higher than the former. However, the difference in the rating values of the various indicators of the converted is relatively small, which may be due to the fact that this type of building has been renovated to make all aspects more balanced. Due to economic and land restrictions on a new building, converted RACFs can provide

more living and activity space for the elderly. However, RACFs converted from schools, hotels, or residential buildings are limited by the original design of the building due to they were not originally built for RACFs, and the cost can be high (Xu & Liu, 2012). The community developed RACFs also face the problem of appropriating public resources for local community residents as it may generate conflicts with other residents in the local community. Therefore, the differences between converted and non-converted RACFs regarding the rating of satisfaction of the elderly are mainly reflected in AC and IEQ. RS rating is slightly higher, probably because of the new renovations and facilities.



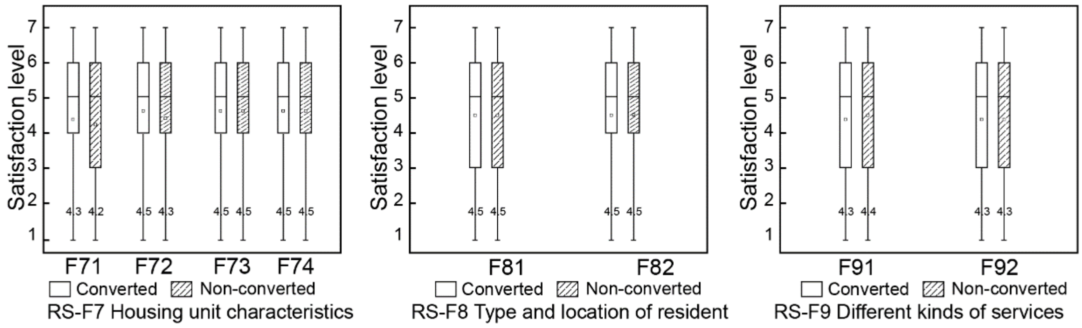


Figure 7-5. Ratings of 9 factors for the different types of construction

The rating of converted RACFs is lower than that of non-converted (purpose-built) ones shown as AC F1-F3 in Figure 7-5. Because the original design of the converted facility was not planned as RACFs, the facilities lack suitably planned layouts and do not meet the required technical standards. For example, the converted resort is relatively remote, and the surrounding facilities are incomplete; the converted hotel is in a troubled area, and the noise pollution is serious.

The overall RS of converted and unconverted RACFs is not much different, only in terms of individual indicators, the difference between the highest value (4-6) and the lowest value (2-4) of the unconverted RACFs is greater than the former. It can be seen that the conversion of the RACFs doesn't influence RS much.

Here, the 6 factors selected here are not exactly the same as those in Figure 7-2. There is no thermal environment, and temperature, humidity, and ventilation are evaluated separately. Because in the six chapters, humidity, temperature and ventilation all have significant correlations to the rating (the values are ranged from 0.386 to 0.813), and the ratings between them are different, so when constructing the structural equation, these are evaluated as independent factors. Odor is also used as an independent factor to construct the structural equation, but in the calculation of the model, we found that the rating of odor has no correlation with other factors, so there is no odor in the last factor of the structural equation.

The interviewed elderly people do not think well of converted RACFs in terms of AC and IEQ factors. Structural problems of the building itself - whether walls can be opened, whether a medical elevator can be installed, and whether the stairs, corridors, and door frames can be widened - all limit the creation of satisfactory conditions converted RACFs. The investigation found that some elderly people who used handrails, walkers, and wheelchairs had difficulties with the narrow door frames, corridors, and staircases. In short, the defects and deficiencies of accessibility in converted RACFs have led to lower satisfaction of the elderly. However, the advantages of converted RACFs are that they can quickly solve the problem of insufficient aged accommodation, with less investment and short construction periods. But in the long term, the government and enterprises still need to plan for the land, design, and construction of RACFs to meet the needs of the elderly.

7.4.2.3 The Differences between Seasons

The current study found that the indoor temperatures during Autumn are significantly higher than during the other seasons according to the results of the T-measurement ($p < 0.05$). However, the differences in indoor temperatures between mid-seasons and heating seasons were not found to be significant ($p > 0.05$).

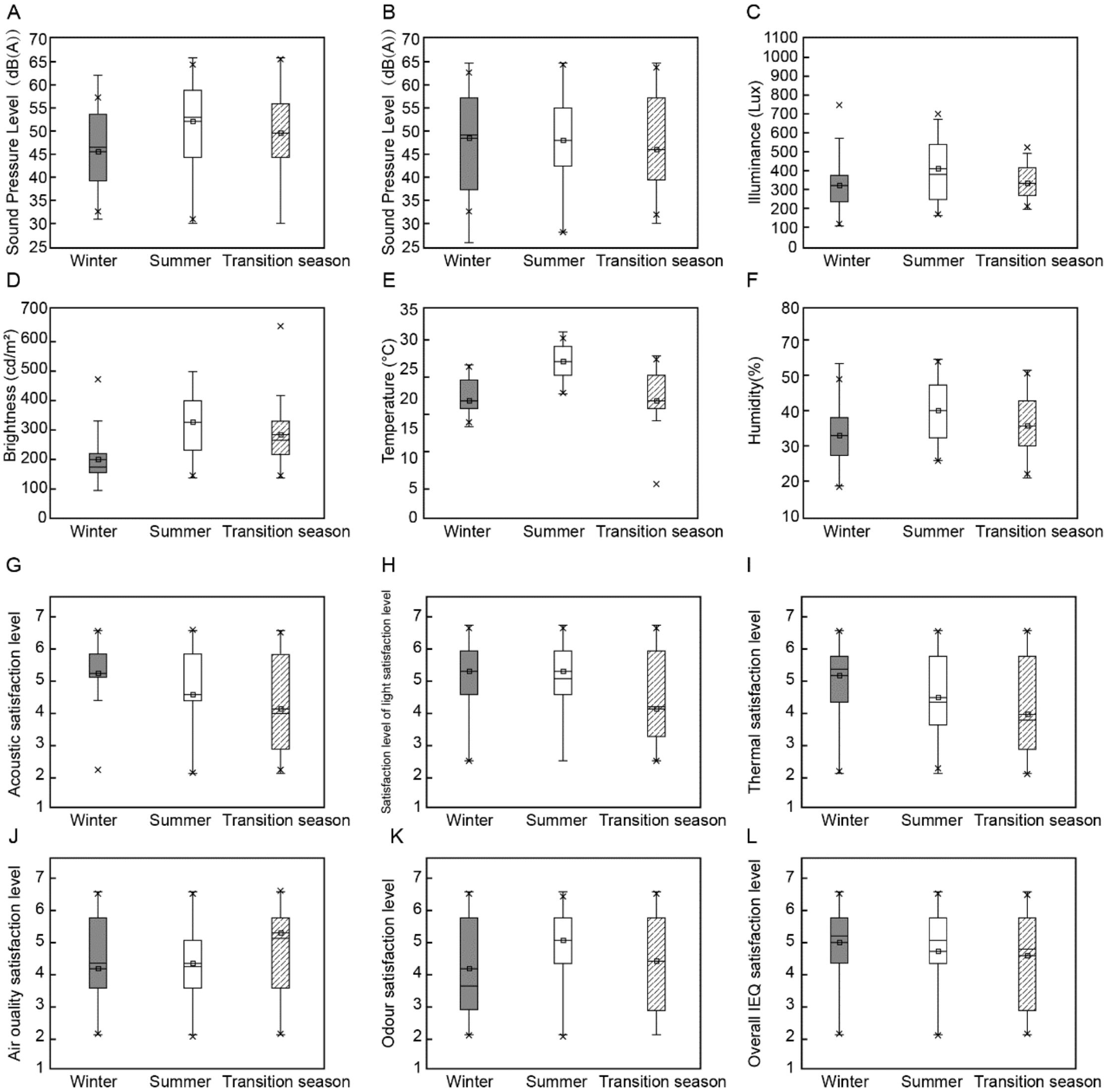


Figure 7-6 Comparison of residents' satisfaction levels for physical environment factors in different seasons

As shown in figure 7-6, the highest temperature, brightness level, and humidity degree occur in summer, while the lowest satisfaction level of acoustic, lighting, and thermal environment are all in a transition season, and low lowest satisfaction degree of odor is in winter, but the air quality in summer is the worst and the sound pressure level is the highest. Besides, the air quality satisfaction in summer is the lowest, which is 5. The reason may be that ventilation is required in summer, and air pollutants from outside the house will enter the room, causing indoor air quality to decline. In winter, the temperature, humidity, brightness, and illuminance all reached the lowest value. The reason is that the climate in Northeast China is cold and the sunshine time is short. At the same time, in winter, the satisfaction interval of the elderly with the acoustic (5.2-5.8) and thermal environment (4.3-5.8) is the smallest. Winter in northeast China is long, cold, and dry and the elderly usually reduce the frequency and times of going outside. Therefore, it is particularly important that building design and equipment should give priority to heating. This section discusses elderly people's satisfaction with their accommodation in different seasons.

Analysis of variance is used here, as shown in table 7-13. Among them, the P value is the significant relationship between the satisfaction of various indicators and different seasons. The p-values of the four factors are all less than 0.001, so there are significant differences between factors and between seasons. The respondents gave higher ratings (5-6) of the facilities in Winter showing that the surveyed RACFs generally provide adequate heating, and the elderly do not think that cold Winters causes problems for them. In fact, the indoor temperature is more conducive to their activities.

Table 7-13. Differences between seasons

	Winter	Summer	Transition	F	P	η_p^2
AC	5.028	4.608	4.087	75.743	0.000	0.094
RS	4.350	4.332	4.142	10.758	0.000	0.015
IEQ	4.621	4.312	4.156	13.816	0.000	0.019
QoL	4.469	4.251	4.216	10.440	0.000	0.014

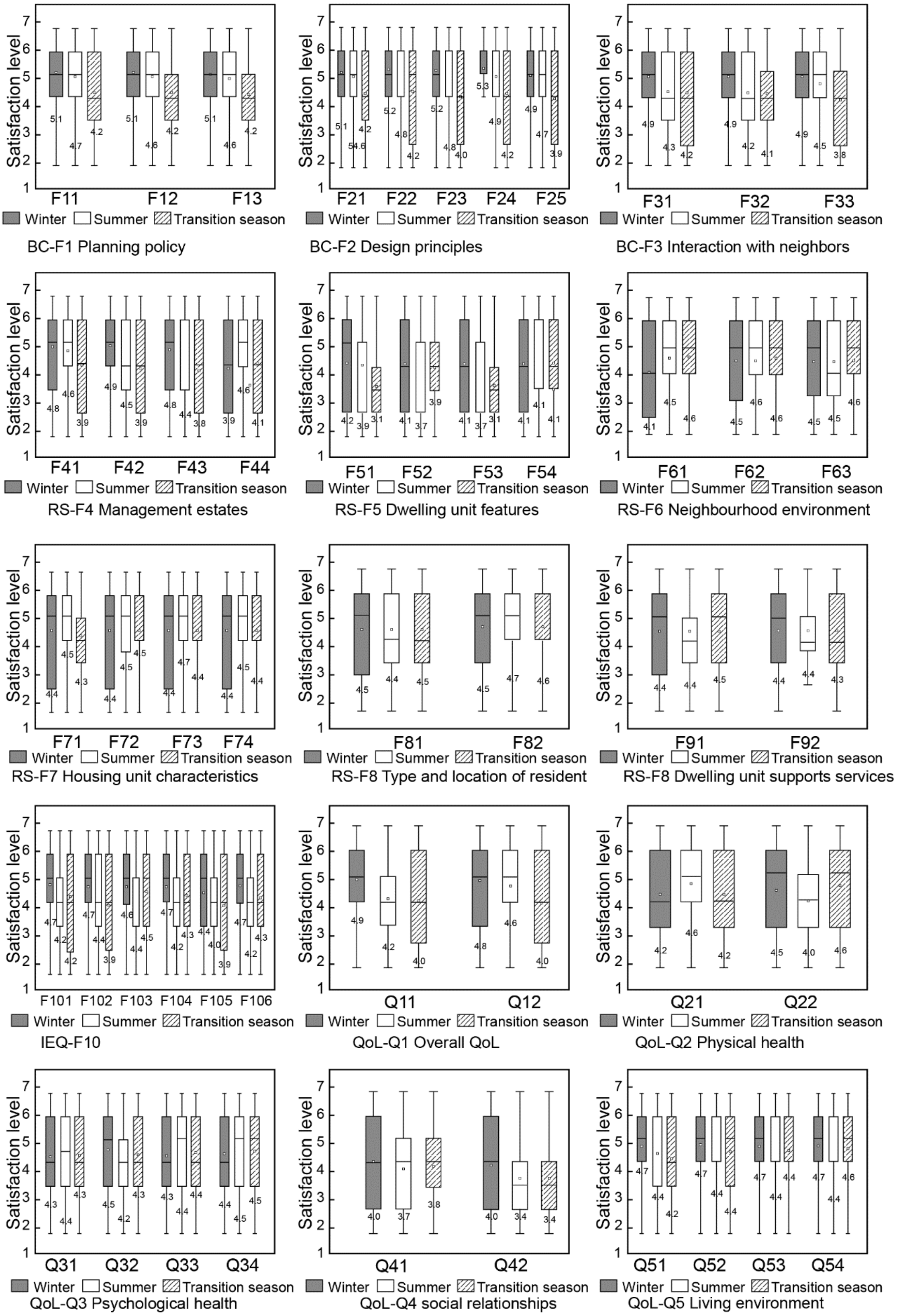


Figure 7-7. Ratings of 15 factors for the different types of construction

It can be seen from Figure 7-7 that respondents generally gave low ratings of spring and autumn air temperatures when the cold and warm weather changes rapidly. The rating value of planning policy is, except F11, higher in summer and winter (4.5-6), and lower in transition season (3.5-5). As for management estates, the highest value, which is 6, is basically the same in the three seasons, and the transition season has a larger interval than summer and winter. Yang et al.'s (2016) research on Korean seniors shows that these elderly people prefer the spring – a cool to warm season. Despite the similar climate between South Korea and Northeast China, this is a different finding from this study, possibly because spring and autumn were merged as a 'transition season' in the survey. Seasons with variable warm and cold weather (spring and autumn) can discomfort and even illness for the elderly. In northeastern China, spring and autumn have strong winds People have different perceptions of temperature in the changeable transition seasons: some like to open the windows for ventilation, and some need to close the windows to keep warm. This can lead to conflicts between neighbors in the RACFs and at these times of the year, satisfaction with Interaction with Neighbor (AC—F3) is only 4 points.

Here, the 6 factors selected here are not exactly the same as those in Figure 7-2. There is no thermal environment, and temperature, humidity, and ventilation are evaluated separately. Because in the six chapters, humidity, temperature and ventilation all have significant correlations to the rating (the values are ranged from 0.386 to 0.813), and the ratings between them are different, so when constructing the structural equation, these are evaluated as independent factors. Odor is also used as an independent factor to construct the structural equation, but in the calculation of the model, we found that the rating of odor has nothing to do with other factors, so there is no odor in the last factor of the structural equation.

Strong winds can also cause the surrounding environment to deteriorate, with rubbish being scattered everywhere will causes problems with cleaning and for elderly activities. The Chinese generally think of autumn as the season of withering, symbolizing departure and death, so people generally do not like autumn.

In terms of RS, satisfaction ratings between winter and summer are not much different; both averages are higher than for transition seasons. Indoor temperatures in the northeast region tend to be high in winter, and the indoor activity area of the residential care facilities can satisfy the needs of the elderly during the daytime, and they can also get sunlight without going out. But in the northeast region, air conditioners and humidifiers are usually not installed, resulting in high indoor temperatures and humidity in summer. Therefore, in the IEQ-F10 factor analysis, summer rating, most of which is 5, is low.

The elderly's sleep is affected by the season. In the QoL-Q2 (Figure 3), sleep rating in the summer is poor, which is consistent with the results of the Tsuzuki and Sakoi (2009) and Tsuzuki et al., (2015) surveys that specifically studied the sleep patterns of the elderly affected by the season.

Overall, for the respondents to this study, winter is most popular among the elderly, and transition seasons are the lowest.

7.4.3 Correlation Analysis between Variables

Analysis of variance is used here. The value of P is not listed in the table. According to Table 7-14, AC was positively correlated with RS, IEQ, and QOL, and the correlation coefficients were all greater than 0.5 (P < 0.01) except RS, which suggests that the correlations were relatively strong. AC and RS are also positively correlated, but the value is only 0.064, indicating that the correlation between the two is low. The correlation coefficient between IQE and RS was significantly negative and the value is close to -0.1 (P < 0.01), whereas the correlation coefficient between QOL and RS was significantly positive (P < 0.01) and the relevance is relatively middle. Further, there was a positive correlation between IEQ and QOL. The value is greater than 0.5 (P is less than 0.001), which shows that their correlation is strong.

Table 7-14. Analysis of correlations

	AC	RS	IEQ	QoL
AC	1			
RS	0.064**	1		
IEQ	0.659**	–0.104**	1	
QoL	0.521**	0.210**	0.521**	1

***,**,*represent P<0.001,P<0.01,P<0.05.

Confirmatory Factor Analysis (CFA) of the four variables was performed by AMOS 24.0 software. If the results of the factor analysis are close to the theoretical analysis of the variables, the convergence validity can be tested by the model's fit index and the normalized factor loading coefficient. There are three criteria for assessing convergence validity (1. All standardized regression weights must be higher than 0.5; 2. Composition reliability (CR) must be higher than 0.6; 3. The Average Variation Extraction (AVE) is higher than 0.5.

Table 7-15. Model index of fit

2	Fit index	3	X2/df	4	RMSEA	5	GFI	6	IFI	7	CFI	8	TLI	9	AGFI
10	Good Fit	11	<5	12	<0.08	13	>0.9	14	>0.9	15	>0.9	16	>0.9	17	>0.9
18	AC	19	4.795	20	0.078	21	0.956	22	0.971	23	0.970	24	0.956	25	0.918
26	RS	27	3.813	28	0.044	29	0.961	30	0.967	31	0.967	32	0.959	33	0.946
34	IEQ	35	4.481	36	0.071	37	0.895	38	0.945	39	0.944	40	0.907	41	0.856
42	QoL	43	4.774	44	0.082	45	0.926	46	0.912	47	0.912	48	0.880	49	0.884

In Table 7-16, the indices of AC and RS fully conform to the standard values, so they pass the CFA measurement, and the measurement model is effective and has a good fit. The GFI and AGFI of IEQ are 0.895 and 0.856 which is close to 0.9, and RMSEA, TIL, and AGFI of QoL are 0.082, 0.880, and 0.884 which are also close to standard values. Although they are not perfectly ideal models, the fit is acceptable. Also in Table 7- 15, the standardized factor loading of each item on their corresponding the variables was greater than 0.5, all CR and AVE values are greater than 0.6. This shows that the convergence validity of the four scales meets the standard. Therefore, the scales have a good combination of reliability and validity.

Table 7-16. Measurement model fit results for convergence

50	Factors	51	Items	52	Standardized factor loading	53	CR	54	AVE
		56	F11	57	0.836				
55	AC-F1	60	F12	61	0.798	58	0.652	59	0.849
		62	F13	63	0.787				
		65	F21	66	0.807				
64	AC-F2	69	F22	70	0.870				
		71	F23	72	0.899	67	0.621	68	0.889
73		74	F24	75	0.712				
		76	F25	77	0.616				
		79	F31	80	0.852				
78	AC-F3	83	F32	84	0.881	81	0.697	82	0.873
		85	F33	86	0.768				
87	RS-F4	88	F41	89	0.953	90	0.692	91	0.899
92		93	F42	94	0.791	95		96	
97		98	F43	99	0.834	100		101	
102		103	F44	104	0.733	105		106	
107	RS-F5	108	F51	109	0.779	110	0.621	111	0.868
112		113	F52	114	0.792	115		116	
117		118	F53	119	0.796	120		121	
122		123	F54	124	0.786	125		126	
127	RS-F6	128	F61	129	0.918	130	0.607	131	0.819
132		133	F62	134	0.759	135		136	
137		138	F63	139	0.634	140		141	
142	RS-F7	143	F71	144	0.771	145	0.605	146	0.818
147		148	F72	149	0.663	150		151	
152		153	F73	154	0.733	155		156	
157		158	F74	159	0.742	160		161	
162	RS-F8	163	F81	164	0.822	165	0.607	166	0.621
167		168	F82	169	0.621	170		171	
172	RS-F9	173	F91	174	0.751	175	0.602	176	0.695
177		178	F101	179	0.843	180		181	

182	183 F102	184 0.770	185	186
187 IEQ	188 F103	189 0.818	190 0.716	191 0.938
192	193 F104	194 0.932	195	196
197	198 F105	199 0.770	200	201
202	203 F106	204 0.928	205	206
207 QoL-Q1	208 Q11	209 0.955	210 0.675	211 0.801
212	213 Q12	214 0.662	215	216
217 QoL-Q2	218 Q21	219 0.528	220 0.609	221 0.741
222	223 Q22	224 0.969	225	226
227 QoL-Q3	228 Q31	229 0.903	230 0.607	231 0.830
232	233 Q32	234 0.740	235	236
237	238 Q33	239 0.640	240	241
242	243 Q34	244 0.668	245	246
247 QoL-Q4	248 Q41	249 0.930	250 0.601	251 0.716
252	253 Q42	254 0.534	255	256
257 QoL-Q5	258 Q51	259 0.814	260 0.612	261 0.837
262	263 Q52	264 0.763	265	266
267	268 Q53	269 0.711	270	271
272	273 Q54	274 0.710	275	276

7.4.4 Model Path and Intermediary Analysis

This section uses Path Analysis to find the relationship between the four variables to verify Hypothesis 7 (Section 1). The correction index M. I values between e7 and e10, e9, e10, and e11 are higher, as shown in Figure 7-8, and the model's fit index after correction is shown in Table 7- 16. All of the indices reached the standard value, including X2/df (=4.413≤5), RMSEA (0.07≤0.080), GFI (=0.916≥0.90), NFI (=0.902≥0.90), IFI (=0.913≥0.90), CFI (=0.913≥0.90), and TLI (=0.897≤0.9). The values for TLI are close to 0.90, and therefore, the intermediary model is a good fit.

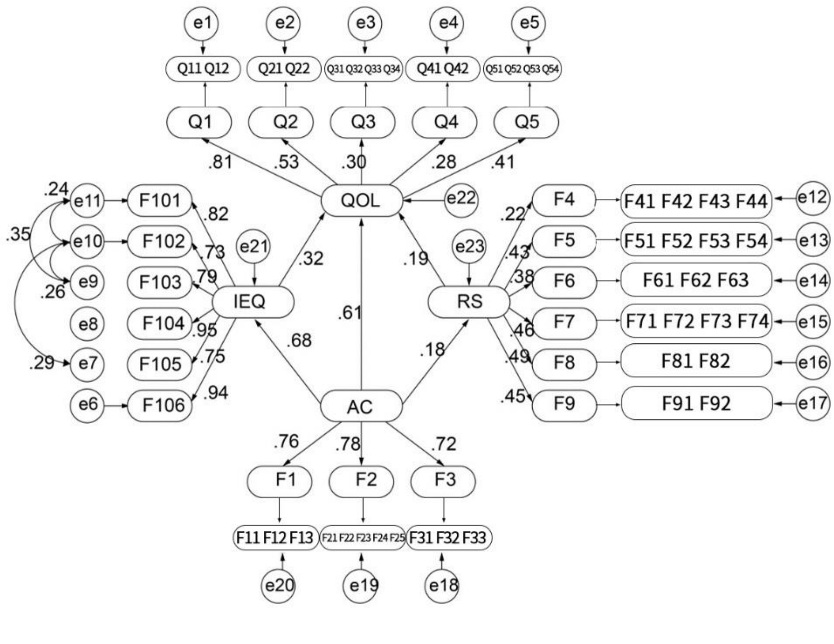


Figure 7-8 Intermediary model path

Table 7-17. Model index of fit for intermediary model

Fit index	X^2/df	RMSEA	GFI	NFI	IFI	CFI	TLI
Good Fit	<5	<0.08	>0.9	>0.9	>0.9	>0.9	>0.9
Model index	4.413	0.070	0.916	0.902	0.913	0.913	0.897

The elderly have special needs for activity space. Whether it is location or indoor layout, the needs of the elderly must be taken into consideration. The elderly generally hope that the activity room can accommodate enough people and will not affect the bedroom they live in, because the rating value of the acoustic environment during the activity is lower than that of the bedroom. In summary, it is necessary for me to conduct research on the acoustic environment of large-scale comprehensive event spaces.

Figure 7-8 shows the results of path analysis: the standardized path coefficient is 0.61 and AC has a considerably strong positive effect on QoL, which confirms Hypothesis 1. AC also has a considerably positive effect on RS and IEQ with the standardized path coefficient of 0.68 and 0.18, again confirming Hypothesis1. RS and IEQ also have a considerably positive effect on QoL with 0.19 and 0.32, and Hypothesis 2 is confirmed.

Table 7-18. Analysis of the effect of AC on QoL

	Effect	S. E.	LLCI	ULCI
Total Effect	0.863	0.02	0.823	0.903
Direct effect	0.613	0.045	0.601	0.828
Indirect effect	0.250	0.032	0.525	0.701

In order to verify the mediation effect more accurately, the Bootstrap Method(a statistical technique utilized to estimate the quantity of a population through averaging the estimates from multiple small data samples (Brownlee, 2019) was used to repeat sampling 2000 times, the confidence interval level was set to 95%, and the sampling method uses Bias Corrected. The results are shown in Table 7- 18: the total effect of AC on QoL is 0.863, and the 95% confidence interval CI = [0.823,0.903] does not include zero, and the total effect is material. The direct effect of AC on QOL is 0.613, which is the 95% confidence interval CI = [0.601, 0.828] without zero, and the direct effect is significant. The indirect effect of AC on QOL is 0.250, and the 95% confidence interval CI = [0.525, 0.701] does not include zero, and the indirect effect is significant. This shows that AC has a partly indirect effect on QoL. Combining the collation between the four variables, it can be proved that IEQ and RS are partial intermediary variables, rather than complete intermediaries, so the H3 is true.

The results show that the effect of IEQ on QoL of elderly people is greater than RS. This may be because RS is a subjective perception rating, and the elderly people's ratings may be affected by their feelings at the time, whereas the conditions of IEQ are relatively objective. Among the influencing factors of IEQ, indoor air quality and temperature have the greatest influence on IEQ. These two indicators are directly related to the body feeling of the elderly and the rating of RACFs. Light has the least impact on IEQ. At the same time, the acoustic environment will affect each other with lighting and humidity, so will the lighting, humidity and ventilation. Among them, the acoustic environment and light will affect each other, the value is 24. There is also an influence between light and humidity, and the degree of influence is similar to the former. At the same time, the acoustic environment will also affect the humidity, and the relationship between them is stronger than the first two. Finally, there is also a connection between light and ventilation. Both indirect and direct AC has a positive influence on the QoL of elderly people. This shows that the location of the RACFs and the relationship between the residents in the RACF significantly affect the elderly's ratings. Therefore, when designing and building the RACFs, priority should be given to geographic location; ease of elderly travel; whether is the location is easy for children to visit; whether it affects the attitude of surrounding residents; and whether the interior design and layout meet the needs of the elderly people.

7.5 Summary

Based on the analysis of Chapters 5 and 6, we can know that the elderly attach great importance to AC, RS, IEQ, and QoL, and these factors can indeed greatly affect the satisfaction of the elderly with RACFs. Therefore, AC, RS, IEQ, and QoL are selected as variables for the structural equations in this chapter. This chapter has the effects of AC, IEQ, and RS on the QOL of RACFs, especially combining different building types (converted or new purpose-built building), scale and size of the facility, and seasonal effects. The elderly have extremely high requirements for the physical environment of RACFs. First of all, the elderly hope that their living environment can be quiet enough. Secondly, due to the cold in the Northeast, the elderly have strict requirements on temperature, so the heating time in winter needs to be strictly managed. Finally, various household appliances must meet the needs of the elderly. The defects and deficiencies of accessibility in converted RACFs have led to lower satisfaction ratings. However, the advantages of the converted RACFs are that it can quickly solve the problem of insufficient RACFs for the elderly, with less investment and short construction period. Moreover, managers in poorly heated or insulated RACFs should understand the potential health risks of low indoor air temperatures, despite the elderly's subjective perceptions that their accommodation is not particularly cold. In this study, seasonal changes were found to have significant impacts on the rating levels of different physical environments, particularly thermal environmental conditions. At the same time, various factors are interrelated. For example, it is mentioned in Chapter 6 that acoustic rating is not affected by the season or room, but depends on the orientation of the windows and the light environment. This shows that there is a connection and mutual influence between the acoustic environment and lighting. Similarly, lighting and humidity and ventilation, as well as between the acoustic environment and humidity and lighting, will affect each other.

The following conclusions can be proposed regarding the original hypotheses:

（1）AC (including planning policy, design principles, and interaction with neighbors) significantly influences elderly people's perceptions of RS, IEQ, and QoL.

(2) RS and IEQ have the greatest impact on aged people's QoL in city residential care facilities in northeast China.

(3) In terms of the intermediary impact, AC has a direct relationship with QoL. Through RS and IEQ, it has an intermediary impact on the QoL of the elderly in a RACF.

The results show that as intermediary variables, IEQ and RS indirectly affect the effect of AC on QoL. Therefore, when some RACFs do not have ideal AC due to funds or reconstruction, managers can improve the QoL of the elderly by improving IEQ and RS.

Based on previous research, we already know that acoustics have a great influence on the feelings of the elderly. The effect of acoustic environment on human behavior, life and work. Changes in voice will eventually lead to changes in people's state. The elderly are no exception. In the next chapter, the influence of users' behavior under various acoustic environment will be analyzed, and the influence of building environment on the response of different individuals will be explored, by investigating the influence of different forms of music on personal satisfaction, emotional and behavioral responses.

8. Acoustic Environment in Communal Activity Spaces in Residential Aged Care Facilities in Harbin

8.1 Introduction

Residential aged care facilities (RACFs) are places where the elderly conduct their daily activities, and the frequent gathering of the elderly may lead to a complicated acoustic environment (Baba et al., 2004). Acoustics is the relationship between the sound people hear and the location where they are. After examining the relationships between the elements of Architectural Composition (AC), Residential Satisfaction (RS), Indoor Environmental Quality (IEQ), and their effects on the elderly's QoL residing in RACFs in 4 cities of northeast China, this chapter aims to investigate the acoustic environment of an activity space in a RACFs in Harbin, China, and comparing with previous chapters, this chapter specifically assesses the elderly's perceptions of, and preferences for different kinds and levels of sound and music, by means of site observation, sound measurements, and a questionnaire.

The objective of this chapter is to investigate the impacts of acoustics in different built environments on different individuals in specific spaces the acoustic environment of the large-scale comprehensive activity spaces in an RACF and the impacts of different acoustic environments on the behaviors, psychological feelings, and ratings of the users are explored and analyzed. After playing different kinds of music in the activity space and inviting participants to observe their reactions to different music pieces, the questionnaires elicited responses to examine approach-avoidance behaviors and entertainment-led emotion theory. By setting the indoor sound pressure, the relationship between the feelings of the elderly in different musical environments, and the correlation between the occupant numbers (density) and the acoustic environment and are analyzed.

According to Du (2019), the elderly have a higher tolerance for sound, but they are also more sensitive to it. In the literature on the acoustic environment, few researches has been carried out on the impacts of sound on the elderly in indoor environments; most studies focus on landscape design, architectural layout, and music-related buildings.

It has been shown that human behavior and perception can be influenced by sounds and soundscapes in cities, and AC can reflect different ratings of sound and soundscape (Meng & Kang, 2016). In terms of user behavior, AC is interrelated to the reason, frequency and the length of visiting the mall, and by the season of the year. In addition, people who participate in the research have higher AC levels than users who are idle or waiting to participate.

The sources of sound are also important factors in sound comfort (Du, 2020) . People prefer natural sounds, among which the sounds of bird and flowing water have been proved to be sounds especially preferred by human beings in previous studies. Soothing sounds (such as music, bird chirps, running water sounds) could help reduce stress. Natural sounds such as bird chirps had a restorative effect on young people's perceptions, and age was related to sound preferences (Semidor & Venot, 2008). In this experiment, the elderly prefer the sound of birds and water. Tamura (1998) found that the majority of the people surveyed preferred natural sounds like running water, rain, and birdsong. In comparison, almost half disliked mechanical sounds. When mechanical sounds are predominant, relaxation is reduced, resulting in reduced AC (Yang & Kang, 2005).

China's RACFs typically contain a communal activity hall the elderly' leisure activities(Wu, 2012) . With the increasing numbers of the elderly engaging in hobbies and the purchase of new activity equipment in RACFs, sound types have also increased, resulting in complex acoustic environments in. This can create discomfort from a noisy environment or an environment in which there is poor communication. Joosse (2011) found that staff voices are also a significant factor that affects the acoustic environment of RACFs. The SPLs generated by staff conversations are even higher than those of residents. The noise generated by mechanical equipment such as central air conditioning and large fans also reduces the indoor acoustic environment. Currently, research on mechanical noise mainly concentrates on large public places, while it is relatively little on RACFs. Activity spaces in RACFs have played background music for many years, and some studies have pointed out that both background and foreground music can enhance the attractiveness of the environment for individuals and heighten people's sense of happiness (Yi & Kang, 2019b). Therefore, as places with complicated acoustic environments, RACFs must systematically study their sound sources and effects to improve the acoustic environment of their residential indoor spaces.

An investigation into the influence of space design and music on individual perception, emotion, satisfaction, and behavior in large activity spaces of RACFs was carried out. With the rapid development of the field of space design, people have started to pay an increased amount of attention to the coordination of acoustics into their environment, because this not only affects their quality of life (QoL) but also restricts their physical behaviours. Research has shown that people's perception of sound in a given space differs. This includes not only their physical perceptions, but also the more spiritual aesthetic perceptions (Aucouturier et al., 2007). Therefore, studying the characteristics of soundscapes in specific environments and comprehensively analyzing the emotional impact of soundscapes on human behaviour is extremely critical for accurately assessing open spaces in urban landscapes and supporting human health.

Research on the impact of acoustics on human behavior in cities mainly focuses on the role of these sounds and soundscapes in relation to urban landscape design (Yang & Kang, 2005). Kang (2006) proposed that the quality of sound in the urban landscape depended on how long people have lived in area. Another research has shown that animal sounds in the city can positively affect people's behaviors of people (Davies et al., 2013); Meng and Kang (2013) found that people's assessment sound comfort was mainly affected by the frequency and time of sound (Meng & Kang, 2013). Various sound sources in the urban landscape may also cause various ratings of acoustic comfort. Therefore, studying sound changes in an open space environment is of great significance for understanding people's behaviors.

In this respect, it is necessary to design acoustic environments related to the activity strategies of the elderly in different settings which could significantly improve the QoL of the elderly.

To study the rating of the acoustic environment of the elderly in activity spaces and the impact of different sound sources on behaviors, the activity hall in a RACF in Harbin, China was invested where acoustic environment measurements, behavioral observations, and questionnaires were deployed.

The major research objectives of this chapter include an overall assessment of the acoustic environment in the activity hall based on the measurement of sound pressure levels (SPL) and reverberation time (RT); To investigate the impact of sound types and sound sources on ratings of the acoustic environment; to explore the influence of the elderly's activity types and behaviors on the ratings of the acoustic environment ratings in different areas of the activity space; and to analyze the personal and social factors that influence the elderly's ratings of the acoustic environment ratings.

Further objectives were to explore the effect of environmental sound in a specific space on individual responses. In particular, the effects of different music types on satisfaction, emotion, and behavioural responses were explored.

The research questions in this chapter can be broken down as follows:

(1) What are the impacts of sound on personal responses?

(2) What are the impacts of different music types on the rating of the acoustic environment of the activity rooms?

(3) What are the assessments of the elderly with different behaviors (different types of activities) under different music environments?

(4) What are the assessments of the elderly persons with different social backgrounds different music environments?

(5) What are the behaviors and assessments of different types of activities in different music environments?

(6) What is the relationship between different acoustic environments and crowd density (number of people per area) in large spaces?

To answer these questions, it is essential to test the effects of specific environmental factors on people to accurately control the visual and audio variables in a specific type of space. After playing different musical clips in the space, the behaviours of the older adults were recorded. The older adults were invited to participate in completing a questionnaire regarding approach-avoidance behaviour and to determine what type of entertainment they prefer, as well as to measure the influence of acoustic environmental factors on their perception and activity.

8.2 Methodology

This study on the effects of acoustic environments in RACFs employed a questionnaire and field measurements to collect relevant data. Pre-surveys and trap questions (trap questions that utilized in surveys can check and identify whether the respondents answer honestly) were used to increase the credibility of the responses. An assessment of the different areas in the facility's activity space was made and the measurement points of the best locations were deployed. Measurement methods used in this research including behavior observation, chang of the background music, measurement of SPL, and measurement of RT points. The data obtained were statistically sorted and analyzed.

A mixture of qualitative and quantitative methods was used for this research. First, the indoor sound pressure of a large-scale activity space was measured, and different musical pieces were played to change the acoustic environment of the space. The questionnaire interviews were conducted with the elderly in different environments to explore the effects of different music on individual activities. Second, the impacts of sound sources on the elderly from different sound activities and the assessment of sound comfort by users of sound-related activities and different sound backgrounds were determined, in order to study the relationship between the density of occupation of the space and the acoustic environment. The impacts of different music backgrounds on the behavior and psychological feelings of users in the activity room are discussed and analyzed.

8.2.1 Survey Site

According to the 2015 census, the population of the case study city, Harbin, over 65 years old totals 1.0420 million—11% of the city's total population. Given this increasing proportion of elderly people in the city's population, a large-scale residential aged care facility was selected as the survey site, and the reason for selecting large RACF is that the number of residents are adequate to be selected as participants, and the physical facilities are comprehensive that the elderly residents would not be affected by other factors when exploring the impact of acoustic environment on them. The floor plan of the communal activity hall is shown in Figure 8-1.

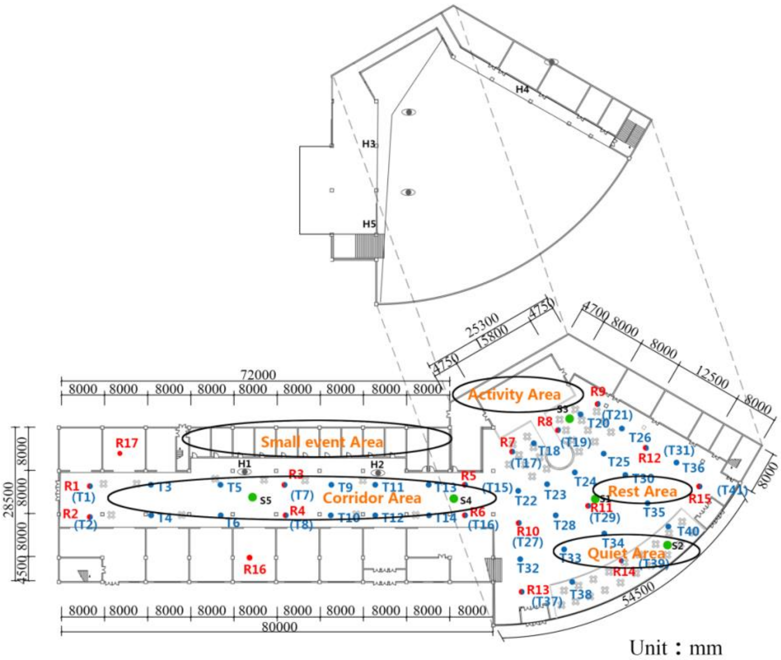


Figure 8-1. Floor plan of the communal activity space

(T is temperature, R is residential satisfaction, H is humidity.)

Figure 8-1 is the floor plan of the communal activity hall of the selected RACF showing the measure of area of each part of the activity hall. From the figure we can see that the length of the corridor area is about 80 m and the width is between 9 m and 10 m. There is an activity area next to the corridor, its length is about 56 m, the inner part has become a lot of small rooms. There is a larger active area on the right that is 15.8 meters in length. There is also a rest area and a quiet area. The two areas roughly form a fan shape, and the outermost length reaches 54.5 m. The activity hall has two sections: the fan-shaped sunshine hall (1700 m^2, 14 m high) and the rectangular living area (850 m^2). Both sides of the living area are set up as various small activity areas such as a calligraphy and painting room, chess room, and lecture room, totaling 1200 m^2. The fan-shaped sunshine hall is divided into three main parts: a quiet area, rest area, and activity area. There is no clear boundary between the rest and the activity areas, and the total area can be shared according to the needs of an activity type. The quiet area is adjacent to the 14m high glass curtain wall of the fan-shaped hall, which has good lighting and views of the outdoors. There is no clear partition between the corridor area and the fan-shaped hall, but owing to the difference in the building structure and building materials of the two areas, the feeling and function of the space are quite different.

8.2.2 SPL and RT measurements

Existing research (Meng & Kang, 2016) have indicated that behavioral patterns and various sound sources affect the AE and the perceptions of people in indoor and open spaces and that the acoustic environment can, on the other hand, affect people's acoustic perceptions. The most significant indexes that influence the acoustic environment are the RT and SPL (Tavossi, 2003), and the measurement points of them are demonstrated in Figure 8-1 and cover the sound source points (S1–S5), SPL monitoring points (R1–R17), and RT measurement points may influence sound feelings in indoor spaces, it was considered in this study. The number of people in the small activity rooms in the research was normally between 5 and 30. The difference in the RT was only 0.12 seconds through the calculation employing the Eyring formula,; therefore, theimpact of RT was not considered in the small activity rooms.

The SPL measurements were conducted when the activity space was in use between 8 a.m. and 6 p.m. During every measurement, the 801 sound level meters were set to fast mode and $L_{\mathrm{Aeq,\,5min}}$ was measured and recorded. To avoid variability in sound source each measurement point's, each SPL at each measurement point was measured 10 times and was measured hourly, and the results were represented by the average value of the 10 sets of data were taken as the result of this measurement point represent the average of the other points. The measurements in each space were taken from a minimum of five different points, which were at least three meters apart from each other, to avoid measurement errors, the measurement in each space was recorded from at least five points that were at least 3 m apart. In addition, to study the impact of different types of activities of the residents on evaluation of the acoustic environment, the sound lever meter was setup the same as before and took instant readings every 10 s after each questionnaire was completed.

The RT was measured at night while the activity room was closed and unoccupied, thus the environment was very quiet. An dodecahedron omnidirectional loudspeaker (BSWA OS002) was was applied to play 500 Hz white noise at the measurement points. After stabilization, the sound source was suddenly turned off and the time it took for the sound to decay by 30 dB(A) (T30) was recorded as the RT (after extrapolation to 60 dB(A)) . Since the activity hall was a large space, we chose to measure T30, instead of T60. The equipment selection and measurement process followed the ISO3382 standard.

8.2.3 Observation of the Elderly’s Behaviour

Image recording is one of the important research methods when observing and studying the behaviour of people; for example, in a previous research of Meng et al. (2020) who recorded children’s behaviors with an HD video camera in a playground of Harbin, China. For the research for this thesis study, the interviewers made group videos using different locations to measure behaviour with the knowledge and permission of the management and the residents. To prevent the normal activities of the elderly in the activity space being influenced by the research process and also avoid blind angle, before the elderly engage in activities, the staff will install the video equipment. The camera locations were placed around the activity space and the ring corridor on the second floor. The cameras installed must be able to cover every corner of the activity room. In addition, camera equipment is also installed at the corners of the corridors or at the entrances, as shown in Figure 8-1 (H1–H5). One recording took place every 30 seconds and lasted 5 minutes (Meng & Kang, 2015).

By observing the activities in the activity hall, the noises generated by the activities of the older adults could be divided into three categories. The first category covered the silent types of activity, which includes resting, reading books, and surfing the Internet. The second category was low-decibel activity and comprised of activities that produced some small sounds or included light conversation, such as meeting guests, chatting, walking, and playing chess. The third category covered activities that produced high-decibel sounds, such as loud music and dancing. When the third type of activity was conducted, it was usually accompanied by the sound of foregrounded music. The elderly's activities in the space were not limited to one type of activity. Recording and observation continued throughout the survey, with the recording time for each activity type was set at 15 minutes (Liu et al., 2018).

Data from the questionnaire included the attitudes of the participants which were categorised on a seven-point Likert scale (Table 8-1) (Sanchez et al., 2017). The reliability coefficient of the questionnaire was estimated at 0.81 (Cronbach's Alpha). (Sanchez et al., 2017).

Table 8-1. Questionnaire and scales

Category	Questions	Scale
Background information	Gender; age; education level; pension; length of residence, usage duration, usage frequency	
Subjective rating	Rating of the overall acoustic environment	1 strongly noisy to7 strongly quiet
	Satisfaction of acoustic environment	1 strongly unsatisfaction to7 strongly satisfaction
	AC of the overall acoustic environment	1 strongly uncomfortable to strongly comfortable
	Subjective impression of reverberation	1 strongly long to 7 strongly short
	AC of a variety sound sources	1 strongly uncomfortable to 7 strongly comfortable
	Loudness of a variety sound sources	1 strongly low to 7 strongly high
	Intelligibility of a variety sound sources	1 strongly clear to 7 strongly unclear
	Noise level of a variety of sound sources	1 strongly noisy to 7 strongly quiet
	Preference degree of various sound sources	1 strongly disliked to 7 strongly liked

Considering that participants need approximately 20–30 minutes to respond to the acoustic environment in a given space (Qi et al., 2013), the elderly who had been in the activity space for less than 30 minutes were not interviewed which makes the selection of participant more strict than previous chapters. The interviews were one-to-one and completed within five minutes, and at least 10 interviews were implemented at each survey point. The elderly in this survey were considered qualified participants based on the frailty scales proposed by Rockwood et al. (Rockwood, 2005) and had the appropriate physiological and psychological capacity to enroll in the study. A total of 320 questionnaires were distributed, with 307 valid ones in this study.

The participants were invited to record the sound sources they perceived at each time point. The sounds in the activity space were separated into five categories: activity sounds, speech sounds, machine sounds, background music, and foreground music. All other sources such as sounds of eating or the sound of dragging chairs accounted for less than 1% of all the sounds in that area and were excluded from the analysis (Liu et al., 2018). Different types of music were played, music played in the activity hall and the music played by the elderly themselves or when there was a group activity such as dancing or singing (Yi & Kang, 2019b). In order to determine the impact of music and sound on the elderly auditory' perception of stimuli and related activities, two types of situations were analyzed: the situation of the elderly in the case of no music; and the activity of the elderly in the case of music. The indoor activities and behavior patterns in different situations were recorded. To study the effect of acoustic environment and especially music on different activities and behaviours during free activity time in large-scale spaces, music pieces were played, and the changes in the behaviors of space users are recorded.

8.2.4 Sound Settings

Two music settings were designed: settings 'without music' and settings 'with music'. For the 'with music' settings, the experiment was divided into two groups. In the first group, three different pieces of music were played: instrumental music, musical instruments with lyrics, and natural sound. In the second group, two pieces of music with different melodies were selected: fast-rhythm instrumental music and soothing slow-rhythm instrumental music.

Before the experiment, the researchers monitored and recorded each sound signal's A-weighted equivalent continuous sound level (LAeq), retrieved on site. All the music pieces are set within 100–110 beats per minute (bpm), apart from the fast-rhythm instrumental music, which was used as a contrast. For this experiment, musical pieces that older adults are familiar with were selected. The 'musical instruments with lyrics' piece was a song, popular among older adults named Qia Si Ni De Wen Rou (Just Like Your Tenderness) by the famous female Chinese singer Cai Qin, with Chinese lyrics and a rhythm of 109 bpm. The selected ‘instrumental music’ piece was a famous tune, Yu Zhou Chang Wan (Fisher Boat at Nightfall), played on a guzheng (a classical Chinese instrument) with a rhythm of 107 bpm. The natural sound was a combination of bird calls and flowing water, taken from the Silver Mountain sound installation at the Contemporary Music Museum, with a rhythm of 106 bpm.

In the control experiment using instrumental music, different musical rhythms, fast and slow, were compared to reduce the impact of lyrics and instrument differences on the advanced rating. In this control experiment, two music pieces played by the same instrument, a traditional Chinese musical instrument called the pipa, were selected: “Chun Jiang Hua Yue Ye” (A Spring Night on the Riverside where Flower Blooms) with a slow soothing rhythm of 103 bpm and Shi Mian Mai Fu (Total Ambush) with a fast rhythm of 142 bpm.

8.2.5 Questionnaire Survey

Questions about sound comfort were asked immediately after each measurement of SPL. To investigate the impact of activities on the assessment of hearing comfort ,some interviews were also carried out at the site (Meng & Kang, 2015) The questionnaire interviews were also carried out immediately after behavior measurement. Normally, the interviewer completed each questionnaire within 3-5 minutes (Litwin, 1995). 302 valid questionnaires are obtained at the survey site. The questionnaire comprises two parts. The first part is initial personal information about the participants; and the second part is the rating of the current acoustic environment. To analyze the psychological status of the participants, the widely used pleasure-arousal-dominance (PAD) emotion status model was adopted, which was developed by Mehrabian and Russell (Mehrabian & Russell, 1974) and is utilized to describe and measure the emotional status with the three numerical dimensions, pleasure (positive or negative feelings), arousal (degree of physiological activation), and dominance (feelings of control).

8.2.6 Measurement of Crowd Density

To investigate the impacts of the crowd on the acoustic environment and the auditory sense of the elderly in the large-scale activity space of the elderly care facility, the density of the crowd is measured using a photographic method (Meng et al., 2017). To prevent the investigate affecting the normal activities of the elderly in the activity space the method of un-influencing recording is used to record the density at different times and in different acoustic environments. In addition, photo locations were selected around the space and in the ring corridor on the second floor. The second-floor corridor location meant that recording could take place without affecting the activities of the elderly. To prevent the normal activities of the elderly in the activity hall being influenced by the experimental process and also avoid blind spots, the camera locations were placed around the activity hall and the ring corridor on the second floor, and the camera will be fully set up before the elderly start to move. In addition, camera equipment is also installed in places such as corridor corners or entrances, as shown in Figure 8-1 (H1–H5). A photo was taken every 30 seconds for 5 consecutive minutes (Meng & Kang, 2015). The entire activity area is taken to be the measurement site. The positions of the users were marked with a dot on the planar graph, and different types of activities were distinguished, which is classified by the measurement area to obtain the average number of people per square meter. The reference object were set in the divided area. For example, the pillars in the hall and some marked reference points will be posted on the ground. The measurement unit is person/square meter (Yu & Kang, 2017). As shown in Figure 8-2, the positions of users appearing in each photo are marked with dots, and a 3 m × 4 m grid is used to measure the standard value of all individuals in the photo-recorded area for each five minutes of recording.

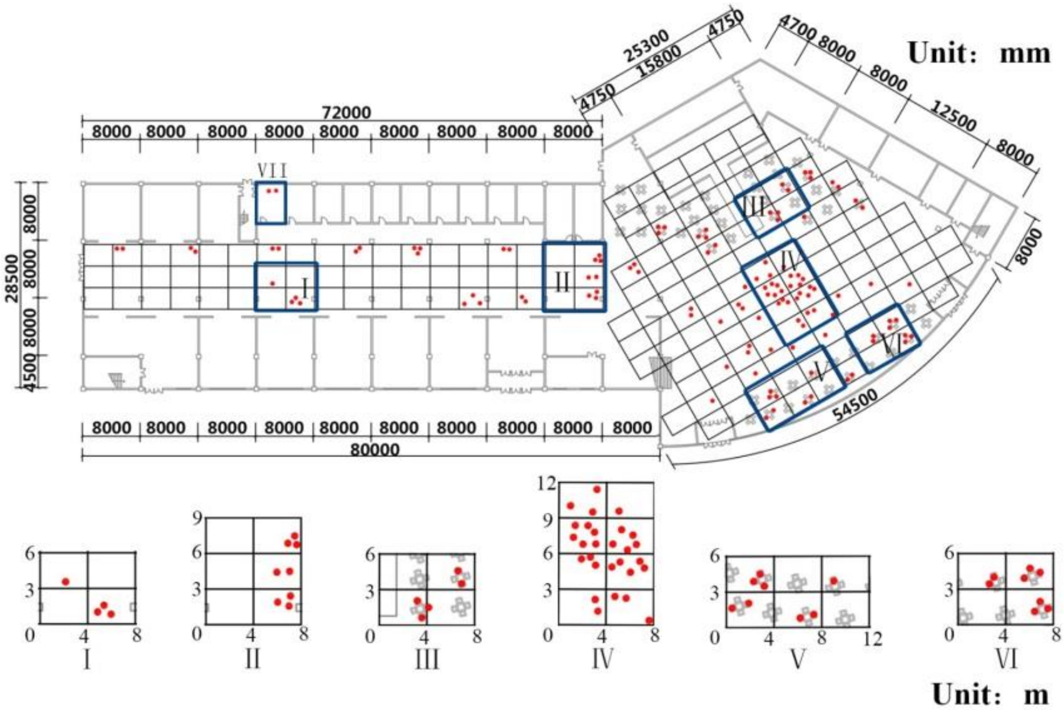


Figure. 8-2 Photographic method of measuring the density of people in the space

8.2.7 Statistical Analysis

SPSS 20.0 was applied to create a database with subjective and objective outcomes (Zhang et al., 2018). Pearson's Correlation Coefficient was applied to examine the dominant sound sources factors and that influenced the elderly's perceptions of the acoustic comfort, and the mean differences were utilized to explore the impacts of whether or not the sound sources dominant background influence the elderly participants. Regression analysis and Pearson's Correlation were then applied to determine the factors influencing the acoustic comfort of the dominant sound sources from the sound source characteristics. The factors influencing the elderly's acoustic comfort ratings are discussed in relation to demographic and social factors.

8.3 Results and Analysis

8.3.1 The Acoustic Environment in the Activity Space

The physical environment of the activity space was first measured using the SPL and RT in an attempt to discover both the behavioral habits of the elderly and the acoustic environment of the space.

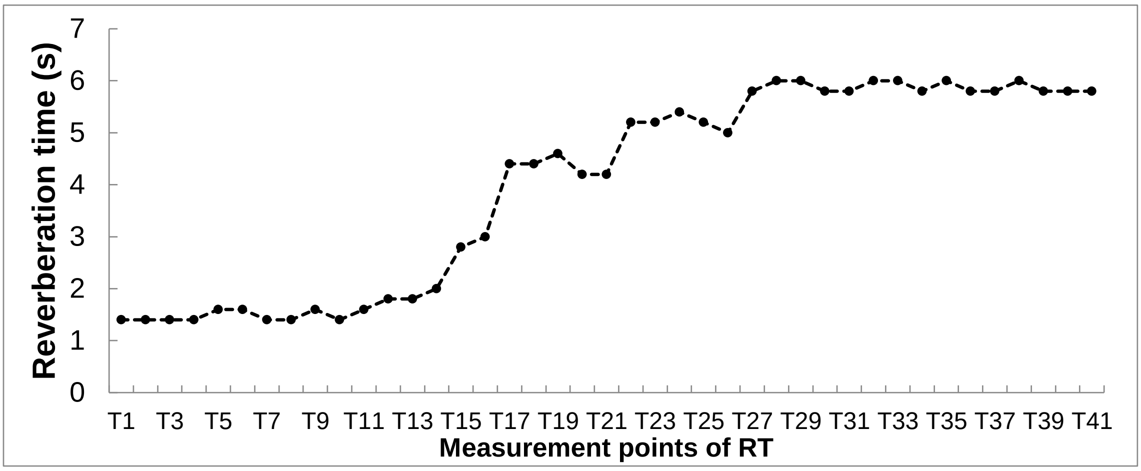
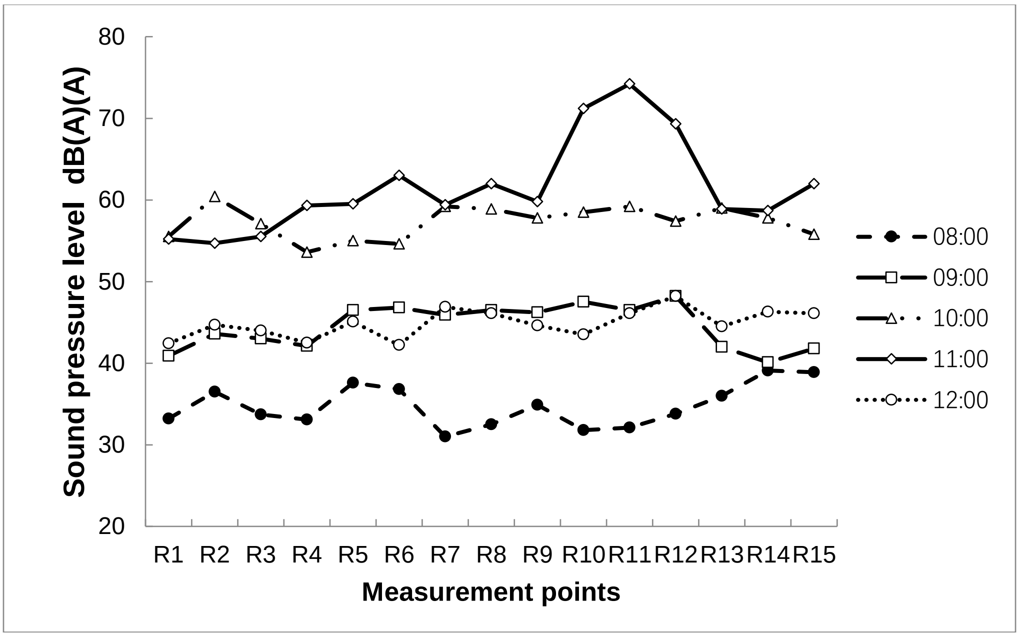
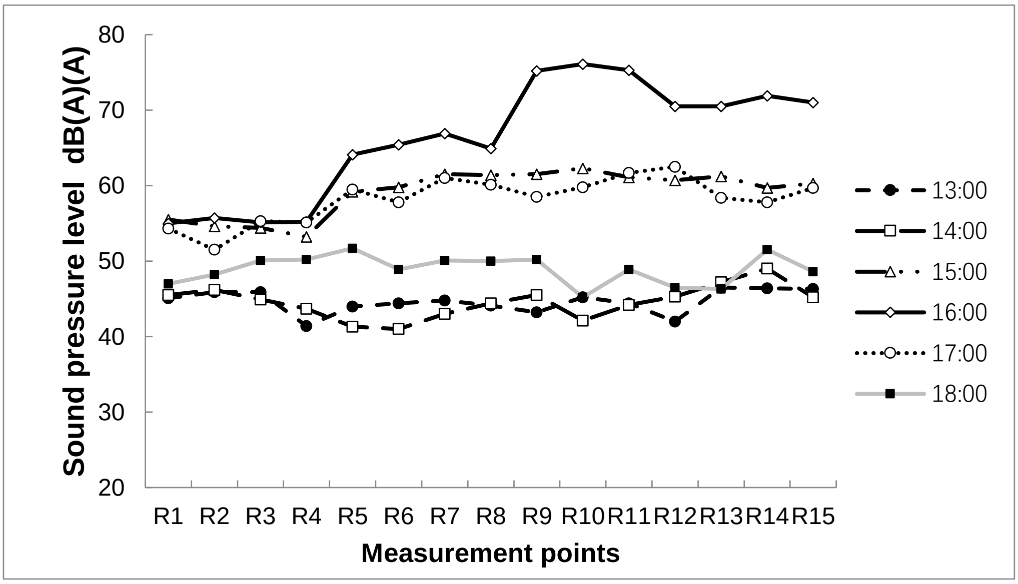


Figure 8-3. Measurement points of RT in the activity space

As shown in Figure 8-3, there are obvious differences in the RT in different areas. The fan-shaped sunshine hall's monitored RT is more than four seconds longer than the rectangular living area (corridor). The RT of the corridor is less than two seconds. That is because the indoor materials of activity hall have smooth surface, which not conducive to the absorption of sound.



(a) 8:00~12:00



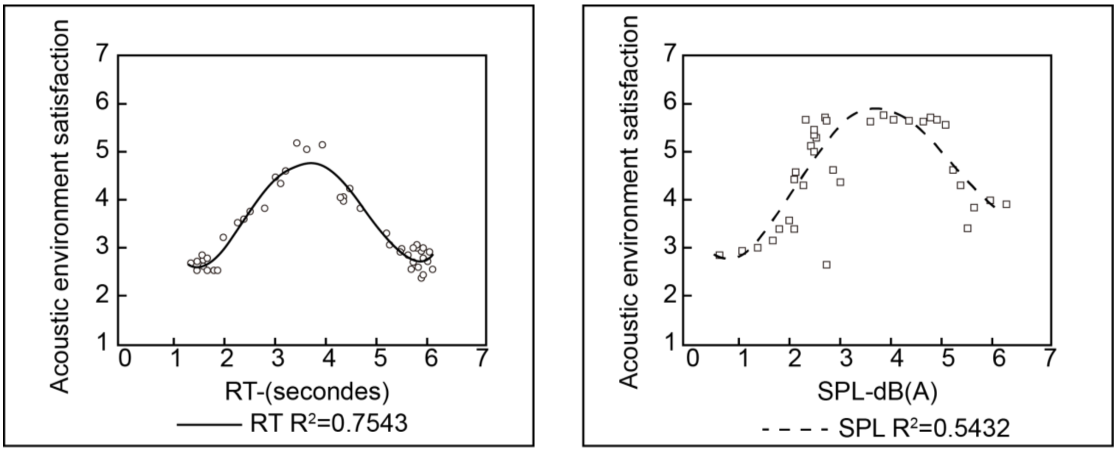
(b)13:00~18:00

Figure 8-4. Changes and distribution of SPL

Figure 8-4 shows the changes and distribution of sound pressure level of the activity space. The changes in the SPLs are shown between 8 a.m. and 6 p.m. (Figure 8-4). The SPL measurement results for the fan-shaped sunshine hall show significant variations. The SPL in the morning is the lowest of the day; the SPL at each detection location is below 40 dB(A). The two peak SPLs are between 11 am and 12 am (before lunch) and 4 pm and 5 pm (before dinner) at 74 dB(A) and 76 dB(A), respectively. As the elderly had the habit of taking a nap, the SPL tends to be flat and maintains a low level in the afternoon between 40 dB(A) and 50 dB(A). In general, the results of the SPL measurement show that the changes in the SPLs in the activity hall correlates with the activities of the elderly.

8.3.2 Relationship between the Acoustic Rating and the Measurement Results

In this section, the changing trends in acoustic environment rating using the measured RT and SPL as well as the evaluated values are shown in Figure 4 as a non-linear relationship.



(A) RT (B) SPL

Figure 8-5. Relationship between the acoustic rating and RT and SPL

Figure 8-5(A) shows that the acoustic environment rating raises with the increase of RT in music activities. This chapter is a curve relationship, and the curve fits better in linear analysis. At the same time, in some rooms with larger areas and harder building materials, the reverberation time of the sound will be prolonged.

When the RT is four seconds, the sound rating is the highest, at four points, because the elderly are mostly involved in music activities.. According to research by (Wu(a) et al., 2020) , when the RT exceeds 4.5 seconds, it can be perceived by a participant. In this study, when the RT exceeded 4 seconds, the background noise increased, and the elderly felt frustrated due to the interference with communication between them, this ultimately led to a reduction in the rating of the sound. The rating values in Figure 8-5 (B) shows the same trend. As the SPL increases, the rating of the sound presented earlier increases and then later decreases. When the LAeq exceeds 65 dB(A), the rating of the sound decreases.

8.3.3 Rating of the Acoustic Environment Based on Sound Types and Sources

8.3.3.1 Characteristics of Dominant Sound Types

Previous studies have shown that various sound sources of background noise can have different effects on people (Chen & Kang, 2017). Research for this thesis divided the activity sounds of the elderly in the selected RACF into three categories: silent, low-dB(A), and high-dB(A) activity types. The rating indicators of the sound characteristics included acoustic comfort, loudness, noise level, intelligibility, and preference level.

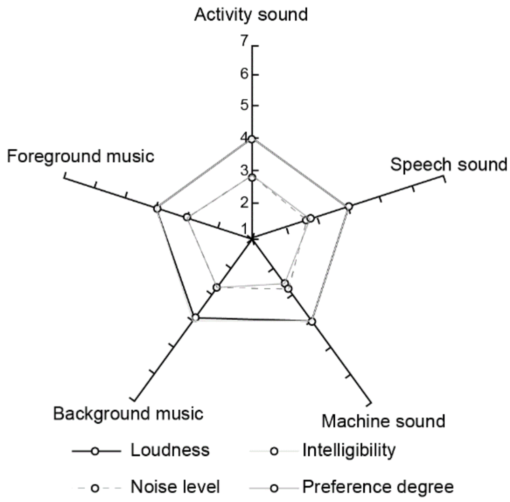
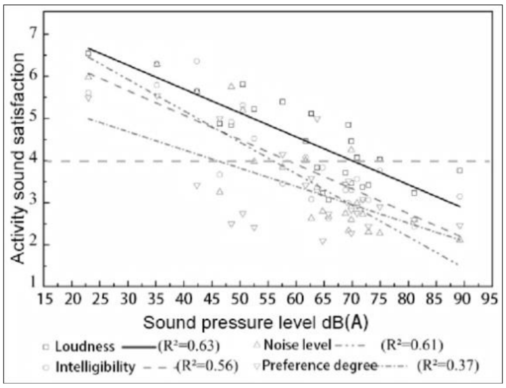
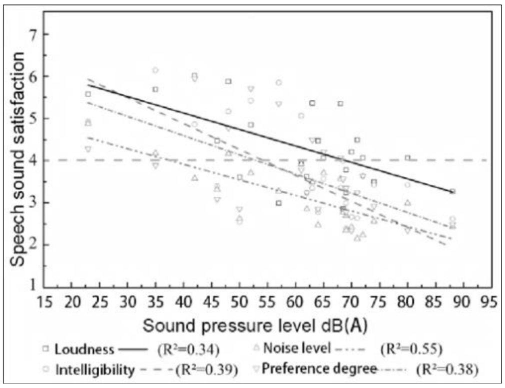


Figure 8-6. Characteristics of each sound type

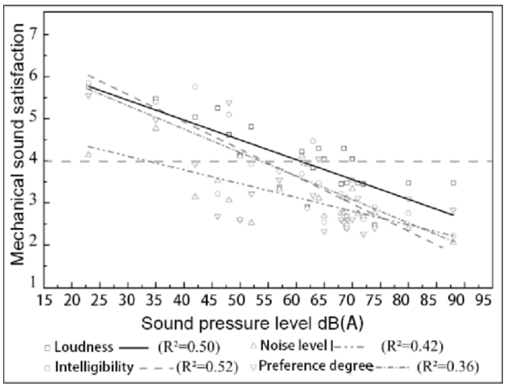
Figure 8-6 shows the characteristics of each sound type by averaging the scores of the four rating indicators: loudness, intelligibility, noise level, and the degrees of preference for these five different sound types: activity sounds, speech sounds, machine sounds, background music, and foreground music. As they were affected by subjective factors such as personal preference and bias, the respondents gave a median rating for the loudness and intelligibility of all sound types—around four points—meaning that they felt that their surroundings were acceptable or a little loud. At the same time, the rating of the noise level and preference for each sound type is low. The four indicators have a significant correlation with acoustic comfort ($p<0.001$), while the highest correlations are the preference level and intelligibility at 0.473 and 0.51, respectively. Overall, the acoustic comfort of the elderly is influenced by their subjective preferences and audibility.

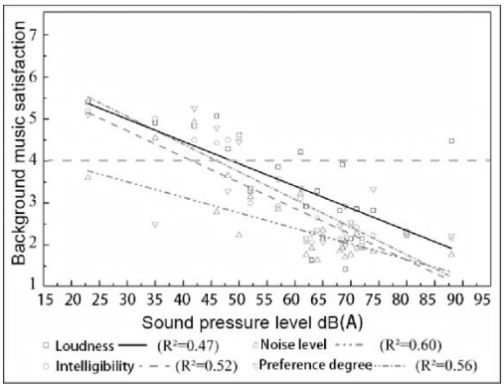
Due to these characteristics, the main sound types may have different effects on the SPL and acoustic comfort. Therefore, this section also analyses the relationship between the comfort level of different sound types and the SPL, as shown in Figure 8-7. This Figure also involves linear regression and correlation coefficients to obtain the trends in how comfort is affected by the SPL and the correlation between the sound types and the SPL.



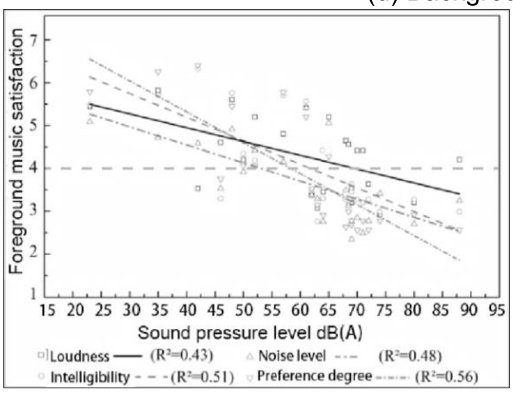


(a) Activity sound (b) Speech sound





(c) Mechanical sound (d) Background music

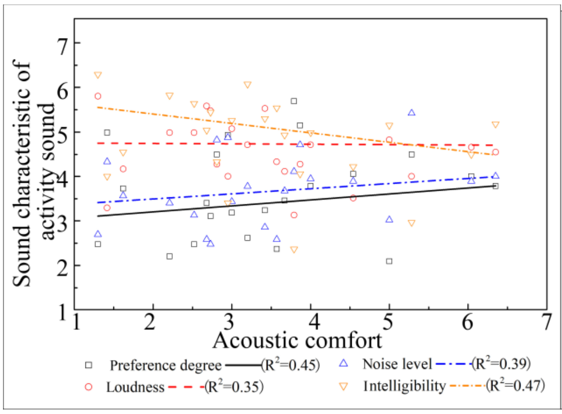


(e) Foreground music

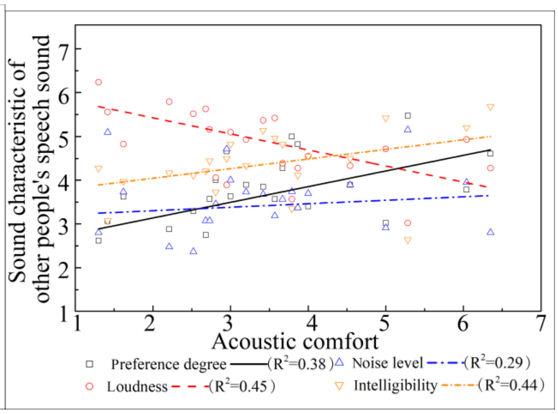
Figure 8-7. Relationship between SPL and characteristics of dominant sound types

Figure 8-7 shows that as the SPL increases, all rating indicators show a downwards trend. Activity sound, loudness, intelligibility, and noise levels are highly correlated with the SPL. As the measured SPL increased, the noise level of speech sounds decreased

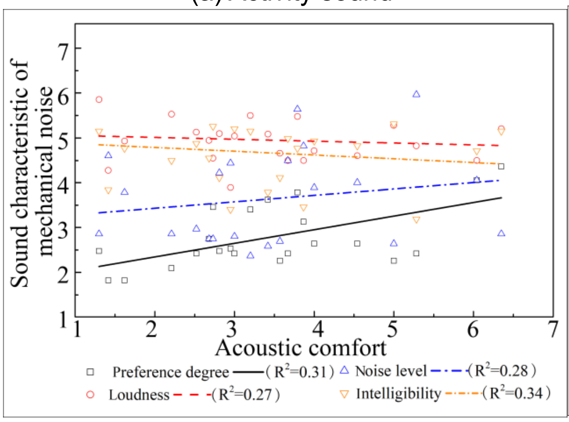
(R^2= 0.55). The indicators of speech sound, loudness, intelligibility and preference degree, were weakly correlated. Mechanical sound has similar results to those of activity sound, except for its preference degree, which shows a weak correlation, while the other indicators (noise level, loudness and intelligibility) show a correlation. The correlation between background music, foreground music, and SPL is similar. Except for the weak correlation of noise levels, the other three indicators (loudness, intelligibility and preference degree) are correlated. In terms of these results, the elderly's rating of a satisfactory acoustic environment will decline as the SPL increases. The decline in their rating of music is slower than that of other sound types, and the elderly's satisfaction and preference for music sounds are higher than that for the other sound types.



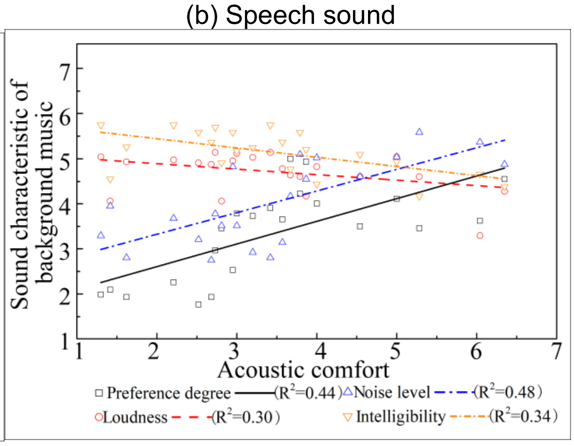
(a) Activity sound



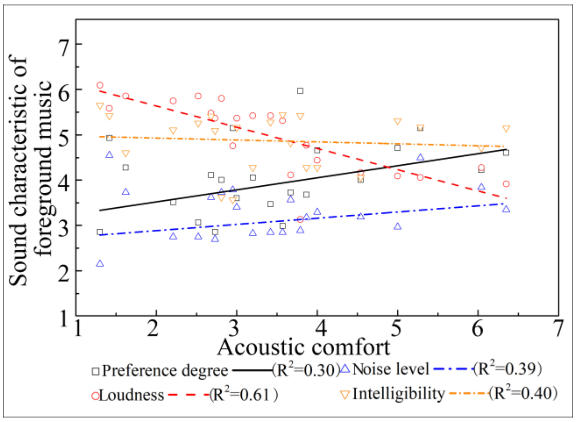
(b) Speech sound



(c) Mechanical sound



(d) Background music



(e) Foreground music

Figure 8-8. Relationship between acoustic comfort and characteristics of dominant sound types

In (a) and (c), the preference degree is a horizontal line. When an event is held, the voice will inevitably become louder, so the seniors team can accept it at this time. In (b), (d) and (e), the preference degree will decrease with the increase of acoustic comfort. For these three types of sounds, elderly people basically tend to have a smaller loudness.

In general, the rating of most of the sound types is either weakly related or unrelated to acoustic comfort (R^2<0.5) (Figure 8-8). However, when the rating of loudness decreases, the sound comfort will increase, and the most obvious source is the foreground music (R^2=0.61). This shows that the elderly do not like foreground music when it is too loud.

8.3.3.2 Correlation between Acoustic Rating and Sound Source in Different Areas

The elderly was asked about their subjective feelings when they heard sounds from different sources in different areas to investigate whether there is a correlation between acoustic environment ratings and sound types in different areas. The activity space of the residential aged care facility is divided into several areas (Figure 8-1), but the activities do not have to be limited to specific areas. Therefore, there could be many different sound sources in the rest area that may come from other areas.

Column A in Table 8-2 illustrates the mean and standard deviation of the elderly' acoustic comfort ratings and column B is the significance and correlation analysis. The number before the slash is the correlation coefficient. Among them, the quiet area is higher than all the other areas in the rating of all sound types, and the average is close to 4 points. The reason may be that the elderly primarily conducts silent activities such as reading, resting, and viewing from the window in this area. Another reason may be that the quiet area is adjacent to the 14-metre-high glass wall in the lobby, and the elderly can view the outdoor landscape through the glass to relieve stress. This confirms Davies et al. (2013) viewpoint that vision and landscape can improve hearing comfort.

It is worth noting that speech sounds were most offensive to the elderly with a minimum rating of 1.86 points in all areas. Respondents in the corridor stated that they felt that speech sounds came from all directions, were noisy, and caused extreme discomfort. This may be due to the complicated structure of the corridor and its walls that cause the sound to be refracted multiple times, thus making the participants feel that the sound is amplified and coming from different directions. Due to the poor overall acoustic environment in the activity space, the residential aged facility managers and employees have to speak loudly to in order to be heard and understood. Elevated SPLs cause frustration for the elderly, and some of the elderly stated that they did not like the managers shouting, as it causes them headaches and heart discomfort.

Activity sounds are even more complicated than speech, as there are more sound sources, and the respondents were less able to identify sound sources. The overall rating of activity sounds is higher than that of other sound types and is the second highest rating of sounds while mechanical sounds have the highest rating (which has an average of over 3 points) at a moderate acoustic environment level, which is slightly uncomfortable. In terms of sound sources, talking and singing sounds are the lowest rated, which, in some areas, are below 3 points. The rest area, activity area, corridor, and small event space are affected by the sounds of talking; the louder noises arise from activities such as talking, singing, and dancing. Most of the respondents had the lowest rating of speaking sounds but could tolerate mechanical sounds and activity sounds. Previous studies have described how elderly generally the elderly is less sensitive to low-frequency sounds. Since the different type of sounds have been recorded by the elderly themselves in the questionnaire it is safe to assume they were able to perceive the low-frequency mechanical sounds, however since they evaluated it higher compared to activity sounds, it could indicate that they are less sensitive to it and that the low frequency did not influence them. Meanwhile, the low rating of activity and in particular speech sounds could indicate a negative impact on their activities and emotional state.

In the activity area, we can see that the elderly has the highest rating value for dance music. When holding events, dance music can enliven the atmosphere and make the elderly feel happy. Similarly, the rating value of singing by the elderly is relatively high, with the maximum value is 3.462. At the same time, the large area of the activity room and long reverberation time can also increase this effect. In quiet areas and rest areas, the elderly generally has low ratings of staff talking (2.923 and 2.951). The reason is also very simple. In these areas, the elderly generally does not want the staff to talk too much. In addition, in the small event space, the elderly has the lowest ratings of singing (1.728) and talking on the phone (1.902). On the one hand, the elderly does not want anyone to sing or make phone calls here. On the other hand, the hard construction material leads to long reverberation time is also one of the important reasons.

Table 8-2. Correlation between sound sources and acoustic comfort

Name of area	***Sound types***	***Sound sources***	***A: Average value/variance***	***B: Correlation coefficient/p value***
	Activity sound		3.060/1.348	0.596/0.000（***）
Rest area		Card playing	3.262/1.701	0.342/0.006（**）
		Seat and table moving	2.962/1.746	-0.023/0.815
		Dancing	3.01/1.943	-0.036/0.718
		Chess	2.933/1.224	0.335/0.001（**）
	Speech sound		3.167/1.511	0.539/0.000（***）
		General talking	3.644/1.645	0.206/0.000(***)
		Staff announcements	2.869/1.674	-0.209/0.033(*)
		Staff talking	2.923/1.863	0.031/0.757
		Onlookers talking	2.933/1.829	0.098/0.323
	Mechanical sound		2.703/1.328	0.245/0.113
		Air conditioning	3.058/1.683	0.017/0.863
	Background music		2.77/1.638	0.494/0.001（**）
		Background music	3.172/1.448	0.452/0.000（***）
		TV	2.262/1.779	-0.095/0.340
	Foreground music		3.542/1.401	0.541/0.000（***）
		Dance music	3.748/1.585	0.269/0.002(**)
		Singing	3.462/1.689	0.351/0.000(***)
Activity area	Activity sound		2.956/1.032	0.187/0.172
		Walking	2.926/1.885	0.17/0.063
		Dancing	3.841/1.637	0.426/0.000(***)

		Chess	2.917/1.860	0.066/0.047
	Speech sound		3.162/1.411	0.588/0.000（***）
		Talking	3.273/1.812	0.145/0.112
		Onlookers talking	3.066/1.252	0.19/0.000(***)
	Mechanical sound	Trolley sounds	3.033/1.288	0.342/0.09(*)
	Background music	Background music	2.63/0.924	0.222/0.104
	Foreground music		2.846/1.278	0.624/0.000（***）
		Dance music	3.725/1.544	0.319/0.000(***)
		Singing	1.982/0.683	0.119/0.193
Quiet area	Activity sound		3.365/1.765	0.459/0.000（***）
		Seat and table moving	3.570/1.296	0.395/0.000（***）
		Walking	2.860/1.823	0.227/0.003(**)
		Chess	3.041/1.923	0.276/0.000(***)
		Using computer	2.959/1.733	0.272/0.000(***)
		Dancing	2.959/1.829	0.154/0.054
	Speech sound		3.147/2.028	0.640/0.000（***）
		Staff talking	2.591/1.731	0.225/0.000（***）
		Talking on the phone	3.281/1.763	0.155/0.003(**)
		General talking	3.058/1.651	0.044/0.565
	Mechanical sound		3.352/1.704	0.350/0.000（***）
		Trollies	3.547/1.641	0.220/0.000（***）
		Air conditioning	3.041/1.646	0.175/0.022(*)
	Background music	Background music	3.362/2.028	0.440/0.000（***）
	Foreground music		3.062/2.073	0.615/0.000（***）
		Singing	3.170/1.766	0.258/0.001(**)
		Dance music	3.023/1.598	0.261/0.000（***）
Corridor	Activity sound		2.765/1.255	0.324/0.021（*）
		Walking	3.197/1.031	0.315/0.014(*)
		Seat and table moving	2.297/1.433	0.222/0.086
		Card playing	3.049/1.784	0.149/0.003（**）
	Speech sound		2.386/1.077	0.188/0.186
		Talking	2.195/1.764	0.008/0.952
		Staff talking	1.966/0.636	0.226/0.08
		Onlookers talking	2.731/1.836	0.151/0.009（*）
	Mechanical		2.451/1.246	0.420/0.002（**）

	sound			
		Air conditioning	2.470/1.287	0.058/0.655
		Trollies	2.547/1.241	0.220/0.004(**)
	Background music	Background music	2.41/1.344	0.426/0.002（**）
	Foreground music		2.296/0.999	0.409/0.003（**）
		Music from electronic devices	3.023/1.598	0.261/0.001(**)
		Singing	1.728/0.557	0.223/0.084
Small event space	Activity sound		2.236/0.826	0.133/0.566
		Walking	2.331/0.839	-0.037/0.713
		Playing billiards	2.165/0.880	-0.045/0.653
	Speech sound		1.973/0.915	0.411/0.030（*）
		Talking on the phone	1.902/0.510	-0.069/0.487
		Onlookers talking	2.123/1.066	-0.242/0.013(*)
	Mechanical sound	Air conditioning	2.50/1.036	0.663/0.000（***）
	Background music	Background music	2.46/1.401	0.691/0.000（***）
	Foreground music	Music from electronic devices	2.14/1.044	0.359/0.061

Column B in Table 8-2 shows that the acoustic comfort rating of the rest area is affected by activity sound, speech sound, background music, and foreground music. In this area, almost no mechanical sounds can be heard as a result of the conversation, music, and activity sounds. According to the rating of the various sound sources shown in column A in Table 8-2, the lowest rating is TV sounds and the highest is dancing sounds.

In the activity area, foreground music and speech sounds have the highest correlation with sound satisfaction (0.624 [P<0.01] and 0.588 [P<0.01] respectively) because these activities require communication with each other such as participants and onlookers talking. Music can help the elderly exercise and enjoy themselves. Because they are focused on their activities, they pay less attention to external activity sounds and background sounds; the correlation between these two sound types and satisfaction is low. The most preferred sound sources in the area are dancing and the accompanying music. The most unpopular sound source is singing, which may be because it can easily affect and interfere when the elderly is talking to each other.

It is interesting to see that the respondents in the quiet area rated all sound sources at a median level, and that most of the sound sources have a rating of more than 3 points. It seems that they are relatively accustomed to or accept these sound sources.

The sound sources in the corridor may be multi-directional, and due to the short time spent in the corridor, respondents were less able to identify sounds (Müsch, 2008). The survey results show that the correlation between activity and speech sound sources and the satisfaction with the acoustic environment of the corridor is low. Mechanical sound and musical sound with a longer duration, such as trolley sounds and music from electronic devices, have a greater impact on the corridor area.

In the small event space, mechanical sound and background music have the highest correlation with sound satisfaction, due to respondents' subjective experiences of participating in high decibel activities in this area. The lowest-rated sound source in this area is speech sounds. Since the rating of each sound type in the small activity room is at a low level, it can be assumed that the small activity room is a small space with loud sounds.

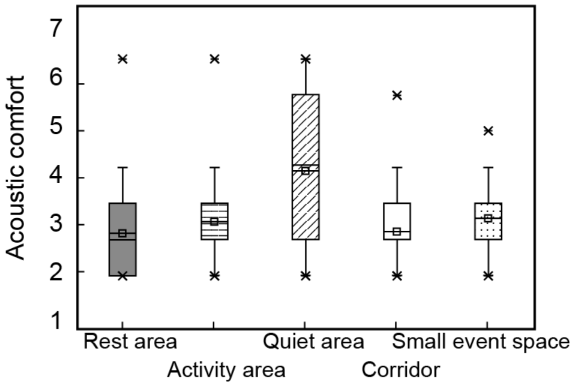
Overall, the elderly had a lower rating of the acoustic environment of the activity space, and they were uncomfortable with the acoustic environment. Age-related hearing decline might be affecting their perceptions of speech, especially when the background is noisy, and the combination of voices and background music influences their ability to hear clearly (Müsch, 2008). In general, the rating of music was on the lower side and might be caused by the size of the space. It can be assumed that in a large multifunctional space different sounds are mixed together, and when the elderly is unable to recognize and judge the sound content, they may become anxious and this may lead to a lower level of comfort leading to a lower rating of the various sound sources in the rectangular living area (including the corridor and small activity room) than for the fan-shaped sunshine hall (activity area, quiet area, and rest area). Air-conditioning sound and background music can be heard in all areas, but the volume is slightly higher in the fan-shaped area than in the living area. Therefore, for the same sound source, the relatively noisy area received a slightly higher tolerance and rating of sound than the relatively quiet area.

8.3.4 Rating of the Acoustic Environment Based on Behaviours

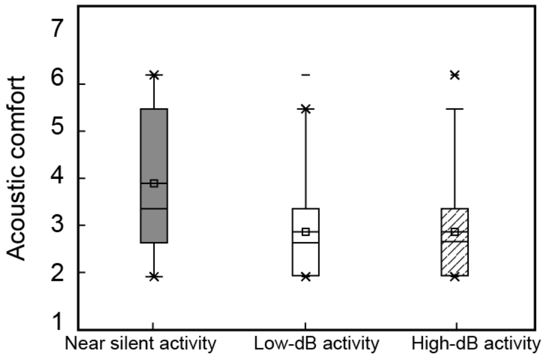
8.3.4.1 Sound Characteristics of the Activity Types

The analysis of variance is used here. As mentioned in the previous section, activity sound type and sound source are diverse and complex. In this section, activity sounds are classified in order to distinguish the impacts of different SPL on acoustic environment rating. The three types of activity sound classification are near silent activity; low-dB(A) activity and high-dB(A) activity (see Section 2.3).

Figure 8-9 illustrates respondents' subjective perception of the comfort of the overall acoustic environment in the activity space and comprises acoustic environment ratings of different areas and different types of activities. Figure 8 (a) shows that the overall acoustic environment rating of the fan-shaped sunshine hall is low. Except for the 4-point average in quiet areas that are considered as being 'neither comfortable nor uncomfortable', the acoustic environment ratings in the other areas are generally less than 3 points. Figure 8-9 (b) shows respondents' subjective ratings of the acoustic environment when performing different types of activities. The rating of the acoustic environment of near silent activities is significantly higher than that of low-dB(A) activity and high-dB(A) activities, but there is no difference in the rating of low-dB(A) activities and high-dB(A) activities. This finding is similar to the results of Wu et al. (2018), that when the SPL increases, the sound comfort decreases(Wu(a) et al., 2020)



(a)



(b)

Figure 8-9. Rating of the acoustic environment in the activity space

Table 8-3. Comparison of acoustic environment ratings of three activity sounds

	Near silent activity	Low-dB(A) activity	High-dB(A) activity	F	p	η_p^2
acoustic comfort	3.80	2.28	2.31	28.280	0.000	0.157
Loudness	3.65	4.50	3.92	8.932	0.000	0.056
Noise level	3.53	2.77	2.92	8.124	0.000	0.051
Intelligibility	3.78	4.76	4.45	11.540	0.000	0.071
Preference level	3.36	2.72	3.06	5.826	0.003	0.037

Table 8-3 shows the differences in the rating of acoustic comfort of different types of activities (F = 28.280, P<0.001). The mean value of acoustic comfort of (near) silent activities (3.8) is significantly greater than that of low-dB(A) activities (2.28) and high-dB(A) activities (2.31). In addition to acoustic comfort, the rating of low-dB(A) activities in the other characteristics is also significantly higher than the other two. This shows that the elderly expects quiet activities and quiet surroundings. However, it is strange that the rating of low-dB(A) activities is lower than the rating of high-dB(A) activities, as a high decibel sound ($P<0.001$). This may be because low-dB(A) activities are related too many speech sounds and previous surveys found that the elderly have poor ratings of speech and singing sounds. Among them, the rating of low-dB(A) activities' loudness and intelligibility exceed 4.5 points, showing that the elderly thought that low-dB(A) activities were noisy ($P<0.001$). High-dB(A) activities like dancing and playing music attracts the attention of the elderly and received a higher rating. While research by Meng and Kang (2016) indicated that music can increase people's concentration and improve comfort, this study found that the elderly prefers (near) silent activity sounds, while the sound rating of low-dB(A) activity sounds and high-dB(A) activity sounds depend on the degree of participation and personal preference.

8.3.4.2 Influence of the Participation Degree on Acoustic Comfort

There were different ratings of sound comfort between the participants and the onlookers during some of the activities. As Meng and Kang (2016) found, activity type has an impact on sound comfort. For instance, music-related activities increase the comfort of participants and onlookers, while activities related to human voices reduces the sound comfort of onlookers (Meng & Kang, 2016). In order to confirm this statement, four of the most participated-in activities in the RACFs were selected for acoustic environment analysis, as shown in Table 8-4.

Table 8-4. Acoustic comfort of participants and onlookers in different activities

Playing chess	Participants	Onlookers	t	p	η_p^2
acoustic comfort	2.973	2.222	1.532	0.131	0.042
Preference level	3.243	2.500	2.141	0.037	0.051
Loudness	2.784	2.278	1.217	0.229	0.019
Noise level	3.568	2.333	3.482	0.001	0.127
Intelligibility	3.000	2.111	2.334	0.023	0.059
Playing cards	Participants	Onlookers	t	p	η_p^2
acoustic comfort	3.583	2.167	2.550	0.021	0.289
Preference level	4.583	1.667	6.667	0.000	0.735
Loudness	3.417	2.000	3.400	0.006	0.259
Noise level	3.833	2.500	2.126	0.049	0.220
Intelligibility	4.500	2.500	2.579	0.020	0.294
Dancing	Participants	Onlookers	t	p	η_p^2
acoustic comfort	4.143	2.571	2.696	0.01	0.134
Preference level	3.457	2.714	1.434	0.161	0.033

Loudness	4.086	3.000	1.823	0.075	0.066
Noise level	4.057	2.714	2.49	0.016	0.117
Intelligibility	3.514	2.357	2.205	0.035	0.075
Singing	Participants	Onlookers	t	p	η_p^2
acoustic comfort	4.080	3.038	2.408	0.020	0.106
Preference level	3.520	3.077	0.812	0.421	0.013
Loudness	3.800	2.577	2.964	0.005	0.152
Noise level	3.480	2.654	1.556	0.126	0.047
Intelligibility	3.760	3.231	1.098	0.278	0.024

The P value represents the relationship between the various influencing factors in different activities and the rating values of participants and onlookers.

Table 8-4 shows that in addition to playing chess, of which the p value is 0.131 and higher than 0.05, the p value of all three other activities is lower than 0.05, which means the difference of acoustic comfort of participants and onlookers is significant. The onlookers have lower acoustic comfort levels than participants, and music-related activities (singing and dancing) are more comfortable than vocal activities (playing chess and cards). However, the noise level of playing chess is higher than the other indicators, which means that participants are susceptible to interference from surrounding sounds. This may be because playing chess requires both concentration and a quiet environment to avoid distractions. In terms of playing cards, the rating of loudness and intelligibility for the participants are higher than those of the onlookers ($p<0.05$). This shows that the onlookers are more relaxed and can communicate with each other, but the speech sounds of the onlookers will affect the participants and reduce the participants' sound comfort. It is interesting to see that the participants' preference level for playing cards has the highest rating out of all the activities (4.583 points). Subjective preferences may be one of the reasons for the higher comfort levels of the participants when playing cards. In terms of noise levels, there are differences in the rating of the dancing participants and the onlookers ($p<0.05$), and the participants are easily distracted by other sounds.

In short, the differences in the acoustic comfort of the elderly are expressed in their degree of participation; that is, whether they are a participant or an onlooker. The acoustic comfort of the participants in music-related activities is higher than those who participate in other activities, confirming Meng and Kang's (2016) study. However, the activities have little effect on the acoustic comfort of onlookers who prefer to talk to each other and are unbothered by loudness and SPL; it is the participants who are disturbed by the surrounding sounds.

8.3.5 The impact of Different Sound Environments on the Psychology of the Elderly Participants

The results indicated a significant difference in the mean value of the emotional threshold of the older adults in the ‘with music’ setting ($p < 0.01$). When there is music, the rating value of the elderly (3.5-5) is higher than when there is no music (2-3). In the ’with music’ setting, the average values of pleasure, arousal and domination in the emotional performance of the participants were increased by 1, and their intervals were expanded by 4 times, 2 times and 3 times respectively (Fig. 8-10 (a) and (b)). These results show that older adults think more positively with music and the dominance over their emotions continued to increase. This is consistent with the research results of Sweeney and Wyber (2002), who showed that music can affect customers' perception of product quality and service, as well as their excitement and pleasure ($p < 0.001$), and the value setting range of ‘with music’ in comparison to ‘no music’ is much larger.

In the comparison of different music types, a significant difference in the mean value of emotional threshold could be found when the music type changed ($p < 0.01$). Under the influence of slow-rhythmed instrumental music, the average satisfaction increased by 2, and its threshold range expanded by two times. The dominance measure was significantly different compared with fast-rhythmed instrumental music. Slow-rhythm instrumental music can help the older adults meet their psychological needs and occupy a more dominant position. According to a study, the preference for slow-rhythmed instrumental music is related to personal character and external environment (Scherer, 2004). These results show that when older adults are in a bad mood, they prefer slow-rhythm instrumental music (Altenmüller et al., 2002), and their satisfaction is significantly improved, and dominant position is significantly different from that of fast-rhythmed instrumental music. Overall, the psychological needs of the older adults were significantly positively correlated with whether the music rhythm was slow ($p < 0.001$), but there was no correlation of significance between music style preference and personality ($p > 0.05$). This is consistent with the research results of Lally, that is, slow-rhythmed music can improve people's satisfaction (Lally & Communities, 2009) as shown in Figure 8-10 (c) and (d).

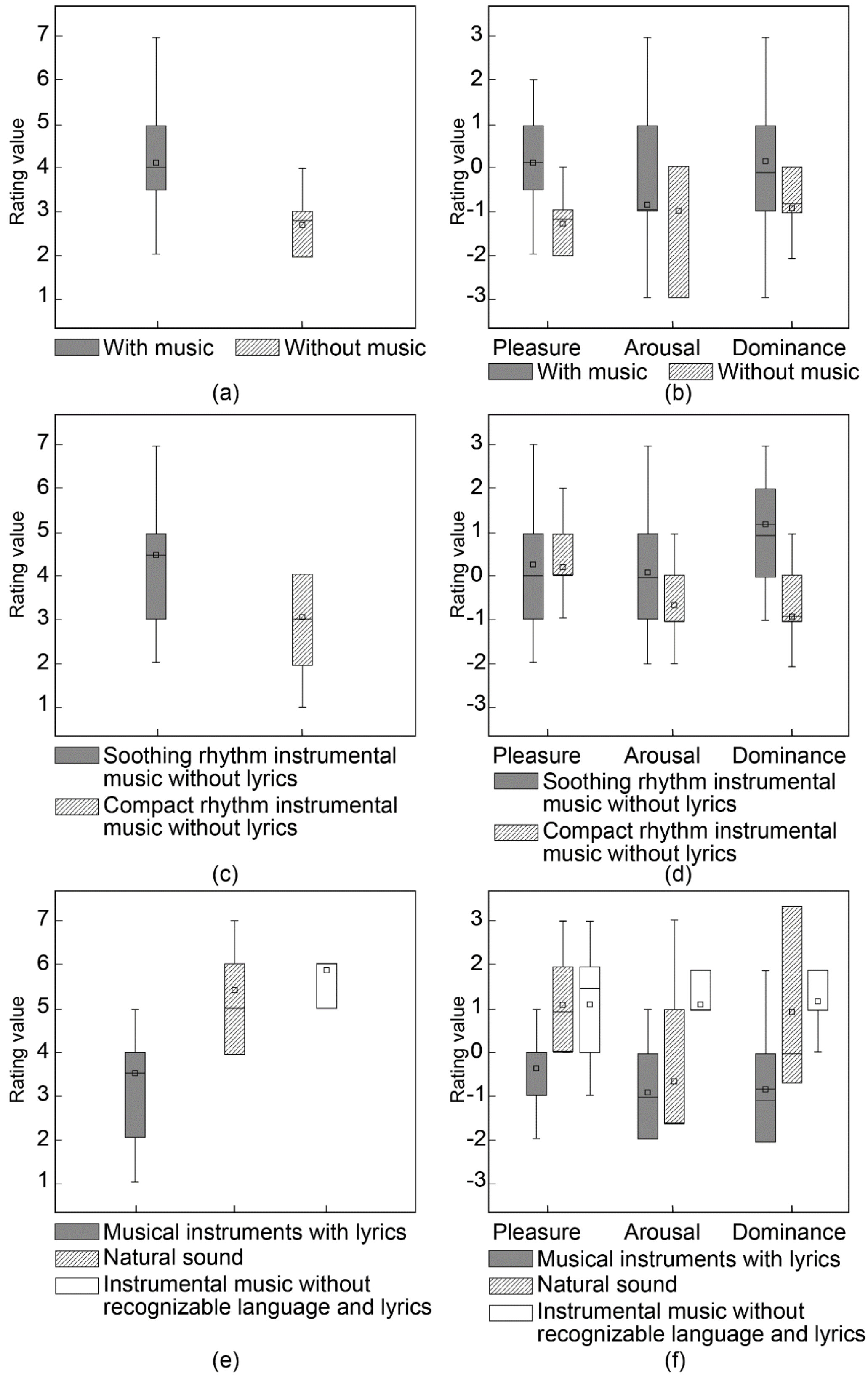


Figure. 8-10 The impact of different sound environments on the psychology of the same group of elderly participants

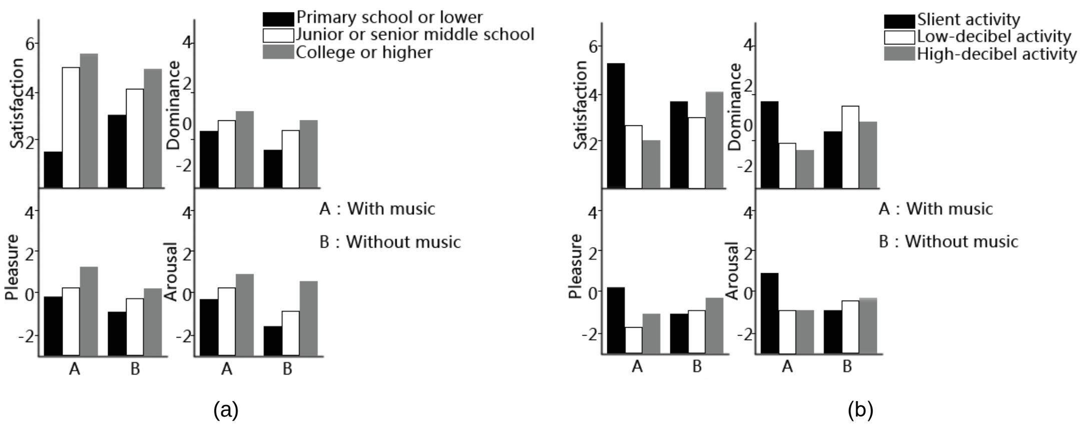
Compared with different types of music, the rating value with music is higher than the rating value without music, and cutting music can promote people's emotions. In music without lyrics, the elderly prefers smoothing rhythm, and it has a stronger effect on people's emotions. When listening to musical instruments with lyrics, the satisfaction statistics decreased from 5 to 1, and there were significant differences in approach-avoidance behaviour, pleasure, arousal, and dominance. The lowest rating values for music with lyrics was lower than other types of music. and compared with musical instruments with lyrics, the rating value of natural sound was higher, with a statistical value of 5.5. This is consistent with Sataloff's (1992) results, which indicated that natural sound and music can significantly improve people's satisfaction and arousal. It has also been reported that different types of music make older adults display different personality characteristics (Laukka, 2007); natural sound helps to reduce their stress, while musical instruments with lyrics can improve their logical thinking ability and instrumental music can improve their aesthetic ability (Dhar & Chang, 2009). The statistical data are shown in Figure 8-10 (e) and (f).

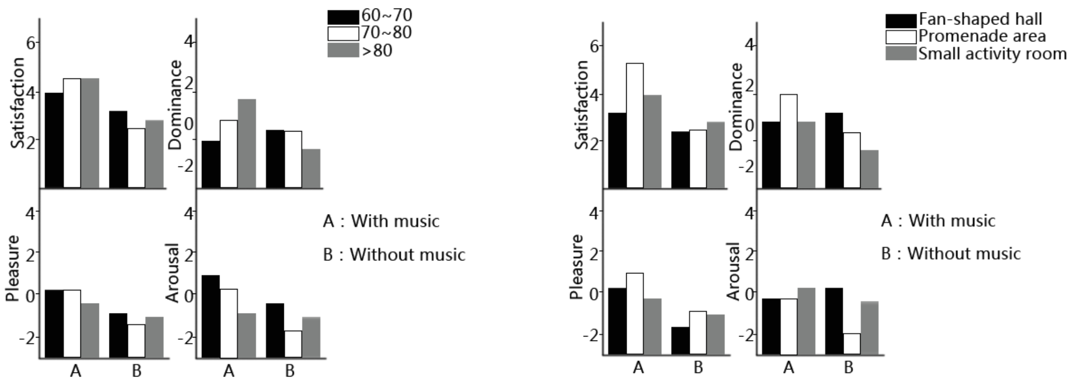
8.3.6 The Impact of Personal Factors on the Psychology of the Elderly

8.3.6.1 The Impact of Surroundings without Music/ with Music on the Psychology of the Elderly

The survey results indicated that the older adults' level of cultural literacy also has a profound impact on their sense of PAD. In 'with music' environments, those with higher cultural literacy are more likely to be affected by the music. As shown in Figure 8-11(a), older adults with primary school education or lower are less sensitive to music compared to the higher educated ones. The score of older adults with primary education increased by 2.09, with or without music. In the 'with music' environment, their values for arousal (0.41), pleasure (-0.50) and dominance (0.31) were at the lowest level. The older adults with a college degree or higher had the highest values, both with and without music, with values of 1.07 for arousal, 0.75 for pleasure, and 1.77 for dominance. The older adults with a medium education level were in the middle level of values for PAD. The results indicated a significant correlation between the education level of the older adults and whether they had musical appreciation ($p < 0.05$). At the arousal level, the perception of the older adults, with highest education backgrounds, on the existence of music is the same. As shown in Fig. 8-11(b), satisfaction is significantly different between different activity conditions, and older adults conducting the quietest activity have the highest satisfaction with the sound environment. Kantono et al. (2016) found that instrumental music could provide unique sensory enjoyment. Chebat et al. demonstrated that older adults with higher education pay more attention to the beauty of sound (Chebat et al., 2001). In an environment with music, the indicators of silent activity are the highest, and high-decibel activities are the lowest. In an environment without music, except for dominance, the indicators of high-decibel activities are generally the highest. This can show that when there is no music, the elderly still hope that there will be some sounds around to wake up or improve their mental state.

In terms of pleasure and arousal, the results show that people aged 60 to 80 are more susceptible to music and arousal was also positively correlated with age. With regard to melodious music, older adults are more likely to conduct activities in a good mood. The results show that music can improve the satisfaction and dominance level of older adults while conducting activities. In the pleasure and arousal sections, people aged 60-80 are more susceptible to music and Arousal was positively correlated with age. With melodious music, the elderly are more likely to do activities with a good mood. It is not difficult to find a significant difference between music and activity types ($P < 0.05$). The results show that music can improve the satisfaction and domination level of people with activities. It is found that due to the existence of stereo sound, the satisfaction and pleasure of the elderly in the central position are improved more significantly. The results show that acoustic differences in where people are seated lead to differences in perception of different kinds of music (Lokki et al., 2016).





(C) (d)

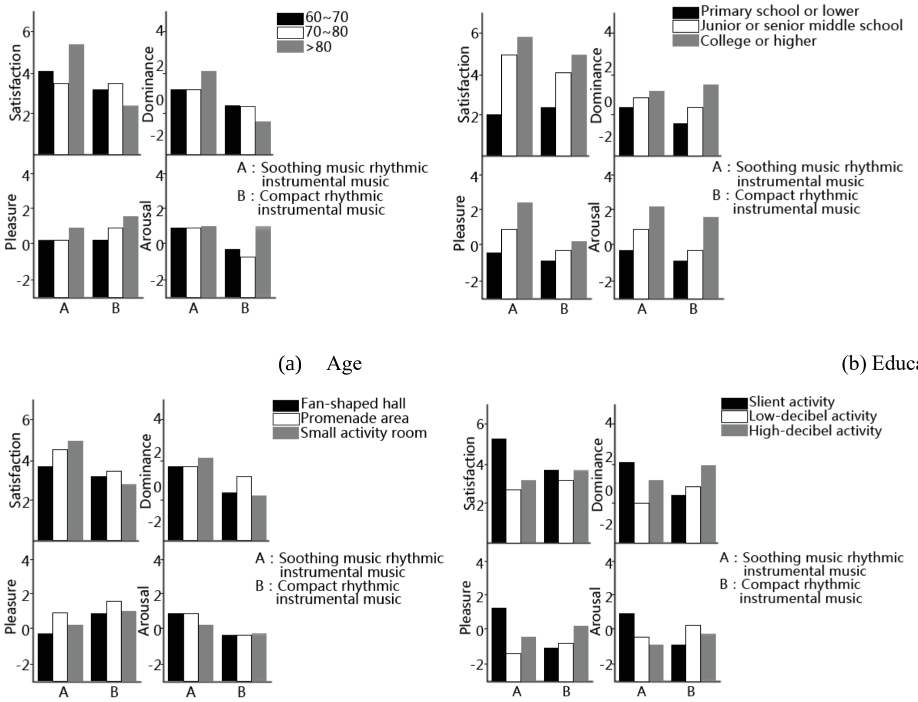
Figure 8-11 .The impact of surroundings without music/ with music on the psychology of different groups of elderly participants

8.3.6.2 The Impact of Different Music Types on the Psychology of Different Groups of Elderly Participants

In the comparison of different music types, slow-rhythmed and fast- rhythmed instrumental music were regarded as two typical music types and compared from the perspective of age, education level, activity area and activity type. As shown in Figure 8-12(a), compact music has a stronger awakening effect on elderly people over 80, but they do not like this kind of music, so they are less satisfied with compact music (Satisfaction is below four). At the same time, they are very satisfied with soothing music. The comparison of music rhythm and education level showed significant differences in the values of pleasure between the two music rhythms ($p < 0.05$), but no significant difference between these two in regard to dominance and arousal ($p > 0.05$), as shown in Figure 8-12b. Under the influence of soothing instrumental music, the satisfaction of elderly participants in each group was improved.

Although older adults over 80 preferred rhythmic instruments, soothing slow-rhythmed music still dominated overall. Older adults with a higher educational background preferred slow rhythm instrumental music. One possible reason is that older adults want to spend more time enjoying life in their later years (Levitt & studies, 2009) and slow-rhythmed music makes them feel more relaxed. A study found that slow-rhythmed instrumental music can improve the nursing effect of older adults (Wang et al., 2017). In addition, a study with similar results to ours stated that older adults with higher education prefer slow-rhythm instrumental music because different aesthetics can be heard in melody (Chung, 2007).

Comparing music rhythm in different activity areas revealed significant differences in pleasure and dominance ($p < 0.05$), but no significant difference in arousal, as shown in Figure 8-12(c). Figure 8-12(d) shows that the older adults are more satisfied performing silent activities. However, older adults who engage in low and high decibel activities prefer fast-rhythmed instrumental music (Satisfaction and pleasure both reached 4). A possible reason is that it can stimulate and improve cortical activity (Perham & Withey, 2012). However, slow-rhythmed instrumental music still dominates overall because it is dull most of the time (Staum & Brotons, 2000). As shown in Figure 8-12(d), the elderly have higher satisfaction (about 3.8) and dominance (about 4) values for compact music in high-decibel activities. At the same time, in an environment with compact music, pleasure is also the highest, but lower than soothing music. Different activities have different effects on different indicators (Haley et al., 2000), and slow-rhythmed instrumental music can greatly improve arousal. The reason is that it can cultivate the mind and emotion of the older adults (Kumar et al., 2020).



(a) Age (b) Education

(c) Activity area (d) Activity type

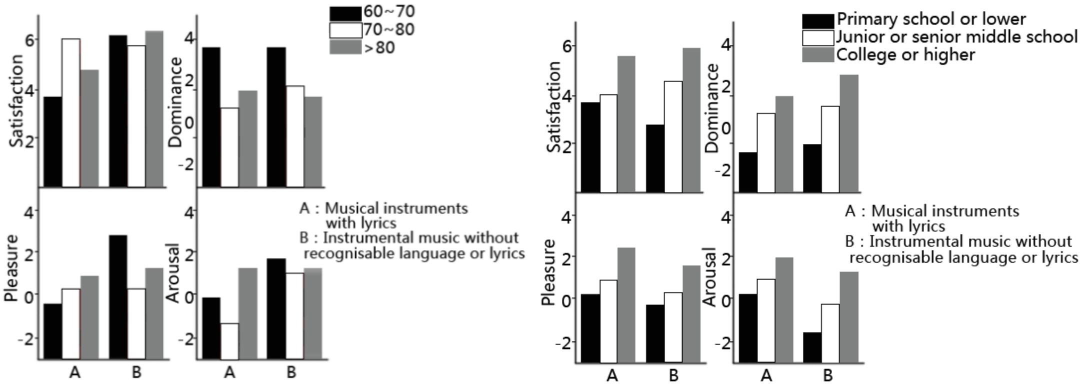
Figure8-12. The impact of different music types on the psychology of different group of elderly participants

8.3.6.3 The Impact of Different Type of Music on the Psychology of Different Groups of Elderly Participants

From the perspective of satisfaction, the satisfaction of music without lyrics (2.5-6) is higher than that of music with lyrics (3.5-4.5). But for people over 80, the arousal and dominance of music with lyrics (about 1.8 and 1) are stronger than music without lyrics (about 1.5 and 1). At the same time, regardless of whether the music has lyrics or not, the level of education has a significant impact on various indicators. Generally speaking, the higher the educational background, the greater the value of each index. For different activity types, the values of the four indicators show the opposite state under the condition of one word and five words. The value pairs of the four indicators of music with lyrics decrease as the number of decibels of the activity increases, and vice versa for music with lyrics.

Whether a song has lyrics directly determines the type of song. The elderly has different preferences, and of different ages have different feelings about music. In terms of dominance and pleasure, there was no great difference between age and whether there were lyrics (P > 0.05). In the measurement of arousal, the 60-80-year-olds seems to be more easily aroused, especially those aged 70 to 80 where a significant difference between the existence of lyrics ($p < 0.05$) could be found. According to the calculation, there is a great difference between the two (P < 0.05), as shown in Fig.8-13a, but they are easily influenced by lyrics regardless of their education level. There was no great difference between lyrics and education level (P > 0.05). Figure 8-13 (a-b) shows that older people prefer natural sounds and instrumental music to unintelligible languages or lyrics. The elderly aged between 60 and 70were most satisfied with instrumental music. The older adults with lower education level had the highest satisfaction and pleasure with instrumental music and those with secondary education had the best rating of natural sounds. These results are consistent with another study that states that educational background is related to the satisfaction and dominance of music content (Magowan, 2007).

The statistical results indicated significant differences in PAD ($p < 0.05$). However, it did not indicate significant differences between the existence of lyrics and activity types and areas, and the awakening of the PAD ($p > 0.05$), as shown in Figure 8-13 (c) and (d).



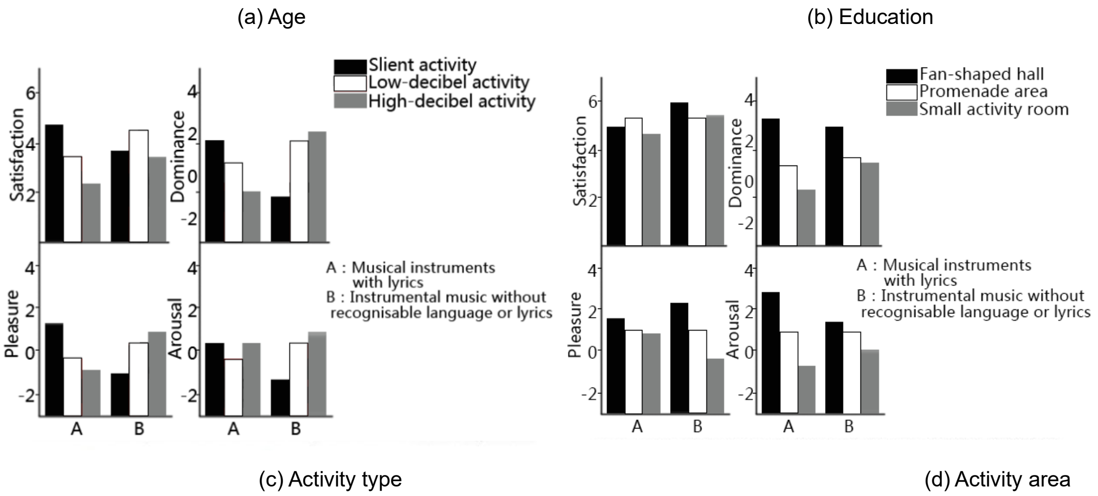


Figure.8-13 The impact of different music content on the psychology of different group of elderly participants

8.3.7 The Impact of the Sound Environment on the Activities of the Elderly

8.3.7.1 Activity Patterns in Different Sound Environments

The impact of different music environments on the three types of activities (high-decibel activity, low-decibel activity, and silent activity) in different activity areas (fan-shaped hall, promenade area, and small activity room) are shown in Figure 8-14. With the increase of natural sounds, most people were conducting low decibel activities in all three activity areas, and the difference was statistically significant ($P < 0.001$). Under musical instrument with lyrics, the ratio of people doing high-decibel activities in fan-shaped hall and small activity room, and people conducting low decibel activities in promenade area all increased significantly. Under the settings of music with language and lyrics and slow-rhythmed music, there was no one conducting high-decibel activities in the promenade area. The proportion of high decibel activities, low decibel activities and quiet activities of the elderly in the activity space, outdoor and small activity rooms is also shown in Figure 8-14.

In an environment with soothing music, silent activity takes the most part, while high-decibel activities take the least. This is also true in an environment with compact music. This shows that music can promote people's enthusiasm for silent activity. At the same time, when the surrounding sounds are noisy, the elderly do not want to have music around.

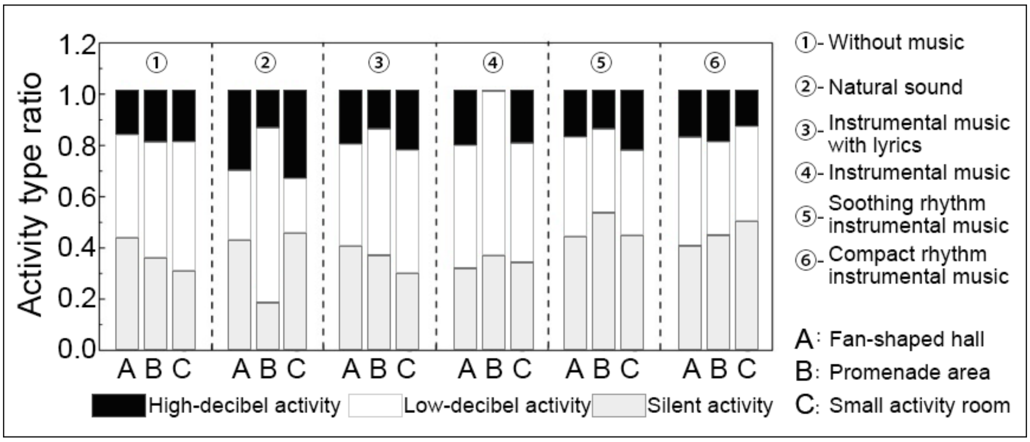
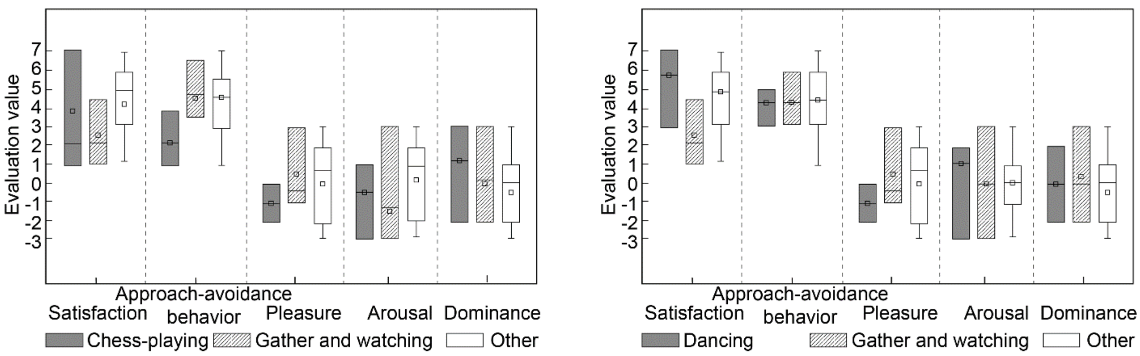


Figure.8-14 Proportion of various types of activities in the activity space with different acoustic environments

In the natural sound environment, the proportion of high-decibel music activities in the activity space increased by 15%, in the promenade area decreased by 5%, and increased in the activity room by 18%. In the experimental group with or without lyrics, the proportion was not obvious but there is a slight increase. These results suggest that music can increase the willingness of the older adults to participate in sport activities. Music can increase that type of activity, which is consistent with previous studies (Barney & Prusak, 2015). Compared with other music types, the proportion of slow-rhythmed instrumental music is larger, because it can increase the release of endorphins (Tarr et al., 2014). Under natural sound, activity decreases, which may be due to older adults doing more thinking and planning, which has been reported in previous studies (Sztubecka & Skiba, 2016). By increasing activities and music, the annoyance caused by noise can be reduced, and soft and slow-rhythmed music can ease the older adults' mood. A previous study has demonstrated that concerts with low arousal potential have a positive impact on human activities (Sheppard & Broughton, 2020).

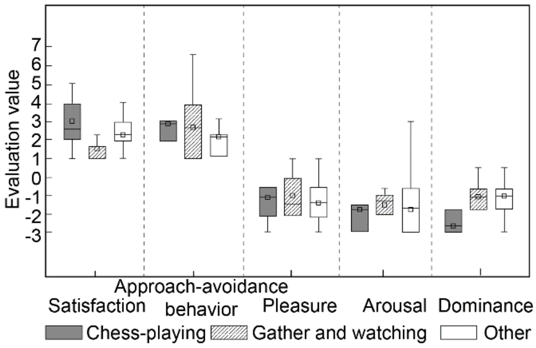
8.3.7.2 The Impact of Music on the Rating of Different Activity Groups

Figure 8-15 shows the reaction of three different types of people on a specific type of music, and the three types of people are: people who are conducting a specific activity (dancing, chess, and TaiChi), people who are onlookers, that is, gathering and watching, and people who conduct other activities (other), with these five indicators: satisfaction, behaviour, pleasure, arousal, and dominance. The older adults who were dancing and playing chess had high satisfaction under fast-rhythmed instrumental music (both are about 7). This is similar to a systematic review of active participation in music and dance which found that older adults prefer dancing to music since it can result in improved wellbeing, health, and QoL, in addition, slow-rhythmed music can think more clearly in a quieter and more soothing environment (Cassidy & MacDonald, 2007). However, the elderly may prefer to hear compact music when playing chess (the highest satisfaction is 7), because compact music can awaken the spirit of the elderly and keep them excited (the arousal is above 0). At the same time, chess is a low-decibel activity, and instrumental music is more likely to be satisfied by the elderly at this time. The average values of pleasure -1 and 0 for older adults conducting Tai Chi and dancer were the same. And as shown in Figure 8-15, chess, Tai Chi, and dance showed more individual activity than collective activity in terms of approach-avoidance behaviour and satisfaction ($p < 0.01$), which could indicate that the older adults prefer participating in these activities rather than watching or doing something else when music is being played. In the previous study, the acoustic comfort of the elderly for loudness was at a moderate level when playing chess, while the acoustic comfort for dancing was higher. Therefore, this conclusion can be confirmed here. Overall, the average values of the satisfaction of older adults conducting individual activity and other activities are significantly higher than that of the onlookers, which is consistent with the literature (Beidel et al., 1985) and again confirms that they prefer to participate. Furthermore, the results show that the older adults preferred natural sounds during simple activities such as playing cards and chess, which might be easier to carry out under natural sound that are perceived as vibrant or calm by most people.

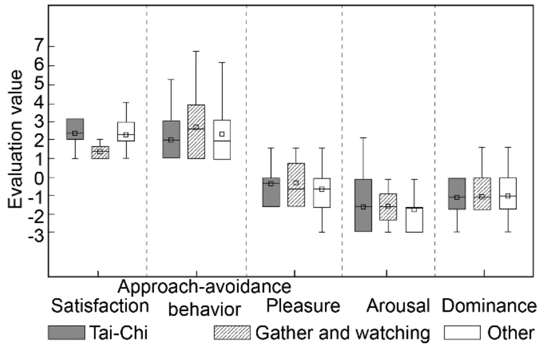


(a) Chess-playing activity under compact rhythmic instrumental music without lyrics

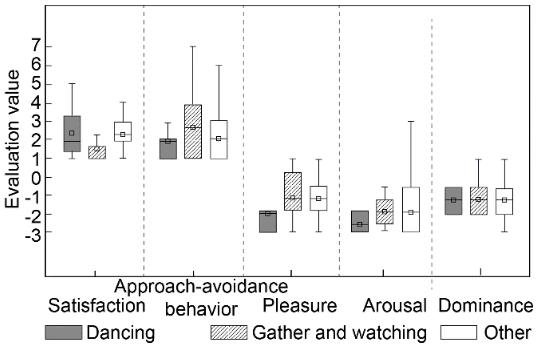
(b)Dancing activity under compact rhythmic instrumental music without lyrics



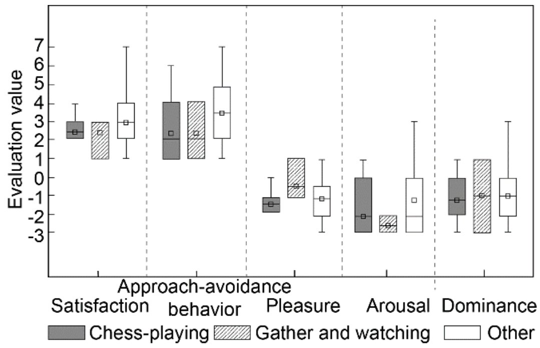
(c) Chess-playing activity under soothing instrumental music without lyrics



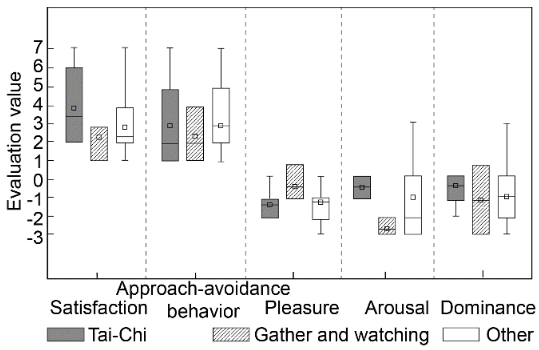
(d) Tai Chi under soothing instrumental music without lyrics



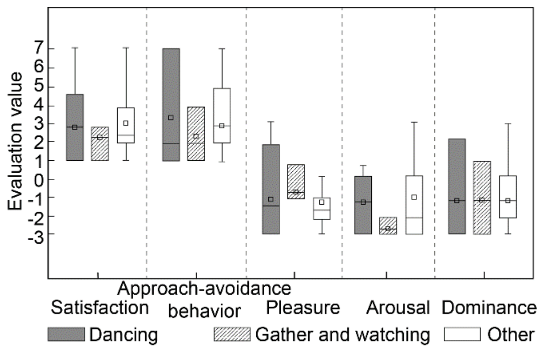
(e) Dancing activity under soothing instrumental music without lyrics



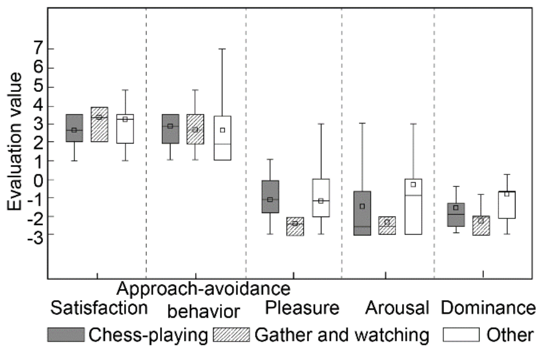
(f) Chess-playing activity under instrumental music



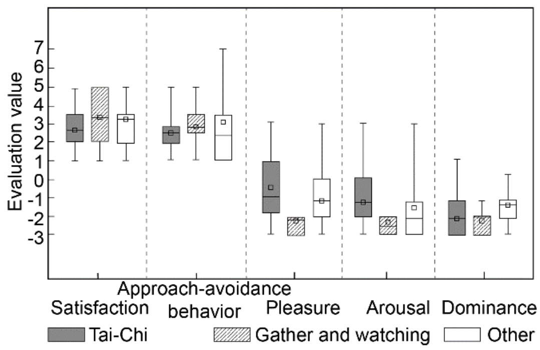
(g) Tai Chi exercise under instrumental music



(h) Dancing activity under instrumental music



(i) Chess-playing activity under natural sound



(j) Taichi exercise under natural sound

Figure 8-15 The impact of different sound environments on different activities of the elderly

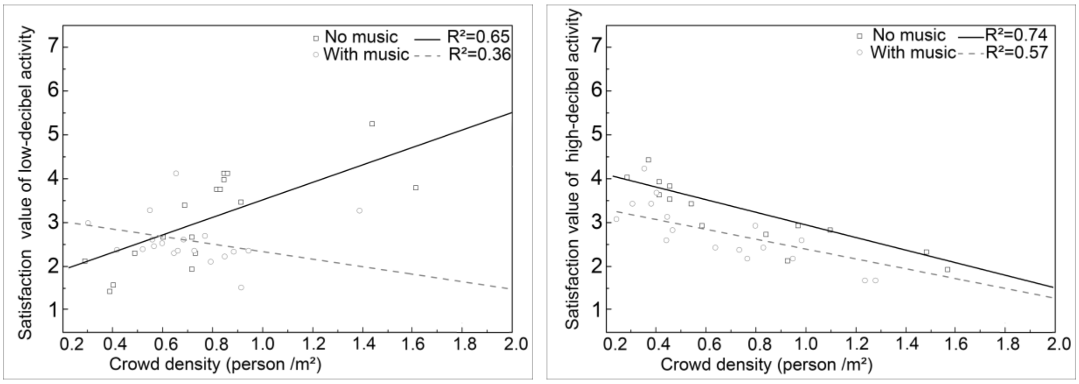
8.3.8 The Impacts of Sound Environment on Crowd Density

8.3.8.1 The Impacts of Music on Crowd Density

The relationships between crowd density and sound environment perception as well as satisfaction in different sound environments (with or without music) are shown in Figures 8-16 and 8-17, where the coefficients of determination (R^2) and the linear regressions and are also presented. With the increase of the crowd density during low--decibel activities, the impact of music is becoming smaller. The connection between crowd density and satisfaction perception of low-decibel activities in the 'with music' sound environment was low (R^2 = 0.36). However, when there was no music in the activity space, the R^2 value was 0.65. The relationship between crowd density and satisfaction perception of high decibel activities in 'no music' sound environments was relatively high (R^2 = 0.74), higher than in the 'with music' sound environment (R^2 = 0.68).

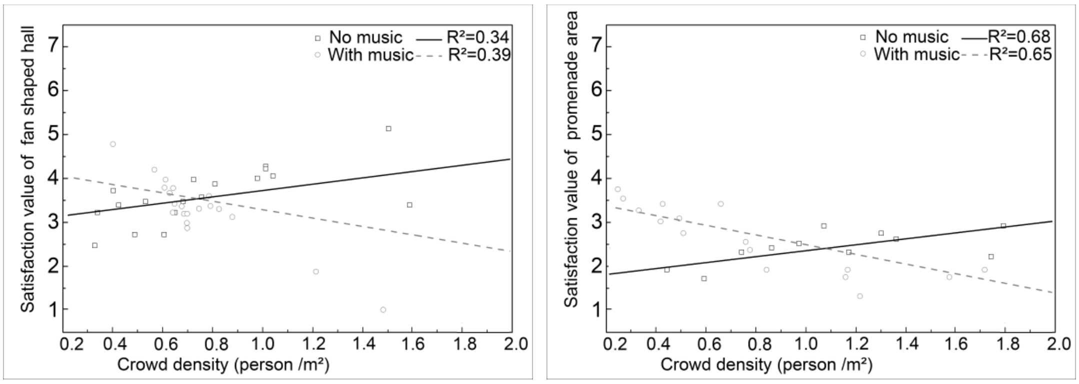
Based on the previous analysis, we can know that in an environment without music, the participation of the elderly in high-decibel activities is relatively low, and as the loudness increases, the satisfaction of the elderly will decrease. In contrast, the participation of low-scoring activities is higher, and satisfaction will increase with the increase in loudness.

However, with the increase of people per area, the overall trend decline, whether there is music or not (see Figure 8-16). If music is played, while conducting low-decibel or high-decibel activities, the correlation of satisfaction continues to increase with the decrease of crowd density. In the fan-shaped sunshine hall, satisfaction and boredom increased, while the correlation of pleasure decreased (see Figure 8-17). A similar decrease in pleasure was reported in previous studies (Layard, 2003). However, Lawton and Fujiwara (2016) found that at different decibel levels, satisfaction and arousal levels are different; if the external environment is quieter, the satisfaction will be higher; if the external environment is louder, it will be lower. Within a reasonable range, this may be due to individual differences in research samples.



(a) (b)

Figure8-16. The effects of music on different types of activities



(a) (b)

Figure 8-17. The effects of music in different areas of crowd density

8.3.8.2 Relationship between sound environment and crowd density

Figure 8-18 shows that in the case of ‘no music’, R^2 = 0.31 indicates that there is low correlation between crowd density and satisfaction. The natural sound, music with lyrics and instrumental music settings also showed low correlations, with the R^2 value being 0.40, 0.36 and 0.48, respectively. However, the R^2 of slow-rhythmed music and instrumental music was 0.70 and that of fast-rhythmed instrumental music 0.61. These results suggest that older adults prefer to listen to slow-rhythm instrumental music in a large space. In previous studies, most of the satisfaction of various music in the promenade area is relatively high, so this can be confirmed here. SPL also showed a trend of first increasing and then decreasing (as shown in Figures 8-18 and Figure 8-19). With the increasing crowd density, the correlation between instrumental music and lyrics also correlates with the crowd density. These results suggest that SPL is positively correlated with crowd density, which is consistent with previous reports (Mennitt & Fristrup, 2016). In addition, under fast-rhythmed instrumental music, the satisfaction of these two behaviours decreased faster. As we discussed before, compact music is arousal, but satisfaction is generally low. It can be seen that most elderly people like soothing music. A study has found that in places with a high crowd density, slow-rhythmed instrumental music can improve the mental state of the older adults and relieve their physical pain and mental pressure (Li et al., 2019).

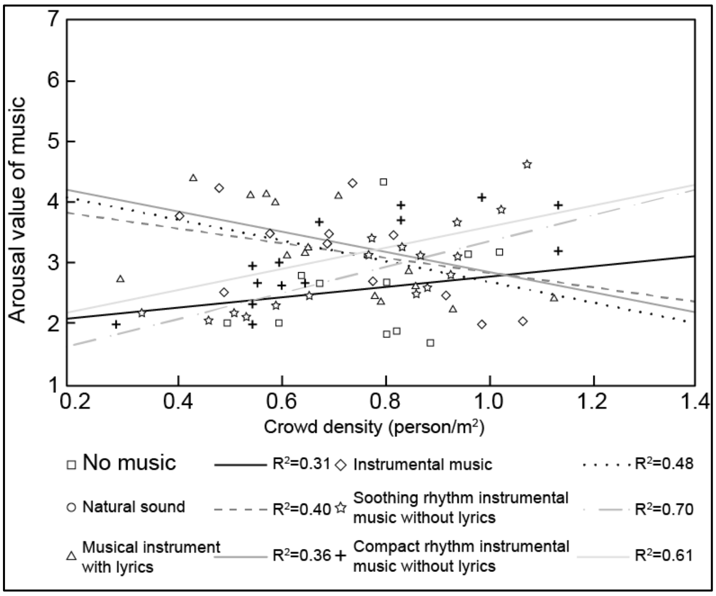


Figure 8-18 .Relationship between various music situations and sound rating in the large activity rooms

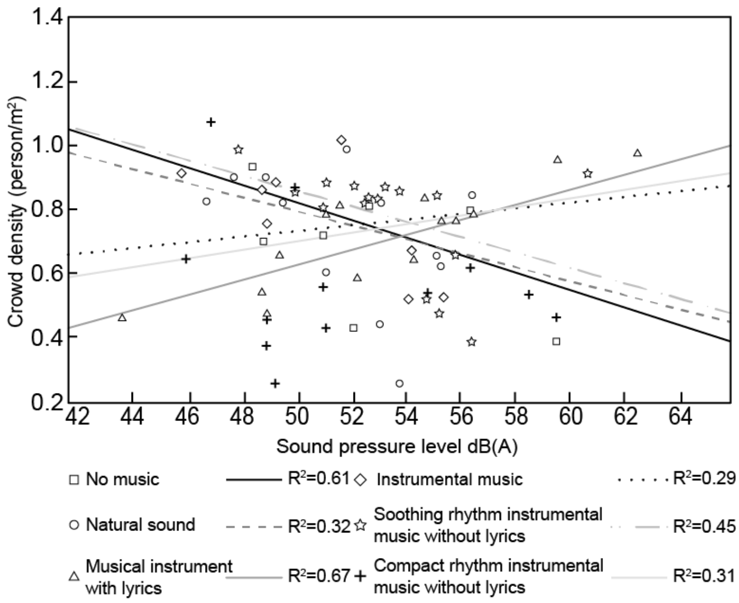


Figure. 8-19 Relationship between sound pressure level and crowd density in various music situations

8.4. Summary

This chapter has focused on the elderly's rating of their acoustic comfort and the impact of several types of music on personal satisfaction, emotional, and behavioural responses according to a site observation, sound measurements, and a questionnaire in an activity space of a residential aged care facility in Harbin, China.

In general, the elderly had a low rating of the acoustic environment in the activity space, that is, they did not find the acoustics comfortable. The measurement of level of sound pressure found that its two peaks in the event space occurred within one hour before lunch and one hour before dinner. When the RT exceeded 4 seconds and the level of sound pressure exceeded 65 dB(A), satisfaction of the acoustic environment decreased. The level of sound pressure of staff talking in the RACF is higher than that of residents, as the level of sound pressure increases, the rating indicators drop. Some of the elderly stated that they did not like the managers to shout when talking to the staff, as it causes them headaches and heart discomfort.

The research in this chapter is curve correlation. Combined with the analysis results in Chapter 6, we can also conclude that for different activities, the elderly have different requirements for the acoustic environment. For example, when playing chess, the elderly may need some compact music to stimulate their own spirit; when dancing, the elderly also need compact music, and the loudness should be moderately louder. All these can correspond to the research results in Chapter 6.

The correlation between background music, foreground music, and SPL is similar. Except for the weak correlation of noise levels, the other three indicators (loudness, intelligibility and degree of preference) are correlated.

Regardless of the types of sound, the elderly's rating of their satisfaction with the acoustic environment declined as the SPL increased. However, the decline in their rating of music was slower than other sound types, and their satisfaction with, and preference for music sounds were higher than the other sound types. The questionnaire found that speech sound had the greatest impact on the respondents and this score was the lowest. The results imply that they were unbothered by mechanical sounds in the hall since they were less sensitive to it and the low frequency did not influence them. In the small event space, mechanical sound and background music have the highest correlation with sound satisfaction. This is due to the subjective influence of the elderly participating in high decibel activities in this area. The lowest-rated sound source in this area is speech sounds.

The foreground music score was the highest, and it appears that music that the elderly enjoy to listen provision can help improve the elderly's rating of the acoustic environment.

The elderly preferred slight, gentle, and soothing sounds, while the sound rating of moderate and high volumes depended on both the degree of participation in an activity and personal preference. The degree of participation in an activity influences the acoustic comfort of the elderly, and the acoustic rating by participants in an activity was generally higher than that of the onlookers. The elderly prefer music-related activities (singing and dancing) than vocal activities (playing chess and cards). However, onlookers talking affected the rating of the participants in an activity, but this effect was offset by an increase in concentration. It is worth noting that speech sounds were the most offensive to the respondents, with a minimum rating of 1.86 points in all areas.

Sound comfort, preference, and noise level are affected by subjective perceptions, and loudness and clarity are affected by physical conditions. The indicators of speech, loudness, intelligibility and degree of preference, were weakly correlated. mechanical sound had similar results to those of activity sounds, except for the degree of preference, which showed a weak correlation, while the other indicators (noise level, loudness and intelligibility) show a correlation. The sound comfort of the elderly men was generally higher than that of the women. The sound comfort of the younger the elderly (60–70 years old) was higher than the older ages. Respondents with a junior high school education had the highest rating of sound. The longer the length of residence in the residential aged care facility, the lower the satisfaction, and the respondents who occupied the activity spaces for a long period of time had higher satisfaction with the acoustic environment than those who only occasionally used the space.

Although this Harbin residential aged care facility had good overall environment and facilities and a large-scale communal activity space, the acoustic environment is not ideal. Although the lobby has separate areas designated as a rest area and an activity area, the sound interfere each area: large spaces and diverse types of activities make it difficult to eliminate the negative effects of sound and the residents may feel nervous and irritable due to the complex acoustic environment in large spaces. Therefore, it is recommended that elderly facilities should not include large activity spaces.

In addition, some residents watched videos with sound on their mobile phones in the rest area, while others read newspapers in the activity area, which suggests that RACFs should have two or multiple section in the activity area and separate the residents who are conducting quiet activities from others who may generate noise, and this requires the staff in the RACFs to ensure that the elderly are conducting right activities in the corresponding area, for example, the elderly who are making any forms of noise would be persuaded to go to the activity area. .

The questionnaire found that respondents had a high rating of both background music and foreground music; thus future research could consider adding music that is suitable for the elderly to test their rating of large spatial acoustic environments. Or future studies could analyze the satisfaction of the elderly by comparing the acoustic environment of the open lobby area with that of closed rooms.

Questionnaire responses indicated that the elderly generally showed a willingness to participate the survey, but the questions were difficult for them to understand and thus their responses did not always reflect their satisfaction or lack of it. The questionnaire design should have been more concise and clearer, avoiding professional terms and confusing words. This chapter also explored the impacts of various types of music on personal satisfaction, and emotional and behavioral responses.

The differences between the variables with and without music were that when there is BGM, individual satisfaction levels raise significantly, the sense of pleasure increase. Respondents have relatively high ratings of BGM and FGM, they enjoy participating activities with music involved, but they do not like mechanical sounds and the chatting of others.

The results of comparing the effects of music and rhythms in different sound environments show that the elderly do not have strong preferences between environments with or without music. In terms of music rhythm, respondents preferred slow rhythm music without lyrics and in terms of music types, they preferred natural sounds.

There was a material positive correlation between the education level of the older adults and slow-rhythmed music ($p<0.001$) which showed that higher educated older adults were most satisfied by slow-rhythmed instrumental music. Although the emotions of the older adults were more easily affected by the music style, there was no significant correlation between music style preference and personality ($p > 0.05$).The influence of sound environments on psychological aspects of the older adults is mainly reflected in the way music enhances individual behaviours and demonstrated that the older adults generally evaluated the acoustic environment as higher, i.e., more satisfied, compared to the onlookers. Under the setting of natural sounds more low-decibel activities were conducted in all three activity areas, which was statistically significant ($P<0.001$) and with musical instrument with lyrics, the ratio of older adults conducting high-decibel activities increased significantly. These results show that the older adults are more willing to participate in activities with appropriate music environments. Observation of the activity spaces showed that music increases the crowd density, especially in an environment with natural sound since the older adults preferred a natural sound environment without interference by lyrics. With the increased time of play of natural sound, the proportion of activity types also increased. However, while conducting low- or high-decibel activities, satisfaction continues to decrease when crowd density increases. The nature of different indicators of various factors has been analyzed in as much detail as possible; however, due to limitations such as funding, the following aspects could be improved in the future: (1) The data processing and analysis are not comprehensive; the data are analyzed only from the perspective of the problem that current RACFs in China have, but the actual impacts are not discussed. (2) The samples may have some problems; since only the elderly are involved, the deviation of the personnel data may occur.

Through a number of studies, this chapter explores the effects of different sound environments, different types of sounds, and sounds in different activities on the elderly. These results can help us understand the different needs of the elderly in different situations. Generally, in high-decibel activities, the elderly like compact music. In low-decibel activities or silent activities, the elderly prefer soothing music, or even an environment without music. Based on this, we can design different indoor structures and prepare different music for different activities, and even amplify or delete the music when necessary. In the future, in-depth analysis could be conducted on people with various individual characteristics to analyze the mechanism of people's subjective consciousness under different acoustic conditions. Also, this study may help improve the elderly's QoL in RACFs by providing a reference for the construction and design of elderly facilities.

9. Conclusion and Future Work

9.1 Main Findings

This chapter summarizes the main findings from chapter 4 to chapter 8. Initially, this study aims to study and analyze the living environment in RACFs in China. Through interviews, questionnaires, and physical environment measurements, the needs of the elderly residents in RACFs in China are analyzed and categorized. In chapter 4, a comparison of China and the UK RACFs was conducted and showed that the RACFs in the UK are more rational organized with better caring facilities that China can draw lessons. A grounded theoretical hierarchical and coding of research analysis in the city of Harbin was conducted in Chapter 5, and the systematic factors affecting the needs and QoL of the elderly are obtained, which includes acoustic environment, lighting, illuminance, and brightness, quietness, heating, dietary, and barrier-free facilities, etc. And many of these needs are not well satisfied in China's RACFs. A physical survey and questionnaire survey were conducted in five RACFs of three cities in North China in chapter 6, which found that the physical environment of these RACFs was highly correlated with the indoor environment quality (IEQ) satisfaction. By using a mixed-research-method, which includes literature review, interviews, and questionnaires in chapter 7, an investigation of the impact of AC, indoor building environment, and RS on the elderly's QoL was carried out in 34 RACFs in urban areas in China, found that IEQ and RS as intermediary variables indirectly affected AC's influence on QoL. In chapter 8, by conducting SPL and RT measurement, behavior observation, questionnaire survey, crowd density measurement, and sound level measurement in an activity hall of a RACF in Harbin, it was found that the elderly prefer slow rhythm music without lyrics, and they prefer natural music. There is a material positive connection between the education level of the elderly and slow rhythm music. The elderly are more willing to participate in activities that are under the music environment, and music increases the crowd density.

In Chapter 6, the satisfaction of the elderly with factors such as loudness and sound pressure level is studied. The eighth chapter confirms the conclusion of the sixth chapter through different activities, different levels of participation, different music, and the research and results of the different academic qualifications of the elderly. At the same time, the impact of the built environment in Chapter 7 on various indicators is also a deepening of the research results in Chapter 6. Through these research results, we can more intuitively observe the impact of sound, light, heat and other factors on the life of the elderly, as well as the degree of satisfaction and acceptance of the elderly with these factors of RACFs. At the same time, based on these, we can improve the hardware facilities of RACFs more targeted to help the elderly to spend their twilight years in RACFs.

9.1.1 Comparison of RACFs between Chinese and UK

Among the current supply of RACFs in China, low-end and high-end RACFs have increased the supply of mid-range RACFs is still insufficient. In the UK, the government controls the RACF structure. The classification of the UK RACFs is relatively clear than that of China which China can draw lessons from, and builds specific RACFs for the elderly with different needs, such as self-help elderly, semi-incapacitated elderly, and incapacitated elderly. In recent years, many of the new-purpose-built RACFs in China are large-scale complexes with hundreds of beds and supporting facilities located in the suburbs of cities. These RACFs are usually large in scale with complete supporting service facilities, but the beds equipped in these RACFs are like hospital beds, the size of UK RACFs is usually small and varied and integrated into the community with a family atmosphere.

Some small RACFs in China tend to adopt simple spatial organizations more like the architectural model of a hospital or dormitory. Small RACFs in the UK pay more attention to create a family atmosphere, and space is more like a residence than an institution. Large RACFs in the UK are more spatially stratified, whereas small RACFs are more spatially flexible. China's RACFs tend to prioritize clear indicators such as sunlight, area, and economy, but do not give enough consideration to hidden indicators such as spatial quality. Both large and small RACFs take the form of public buildings and it is not easy to create small-scale living spaces.

In the UK, most RACFs are regulated by national bodies and would normally act on advice from local government. The sheltered elderly apartment is common in the UK and is worthy for China to draw lessons from. The living units in this kind of apartment are mainly single rooms, and the communal areas can include ordinary living rooms, dining rooms, laundry rooms, as well as providing offices for management. As sheltered apartments are affordable for most of the elderly, China can also consider this form of facilities as most of the elderly in China can only afford small and medium-scale RACFs.

China's RACFs are in short supply, and increasing the number of beds has become a long-term development indicator while at the same time, insufficient attention has been paid to the quality of RACFs. There are also some problems with resource allocation. The type system of RACFs in the UK is more clearly set out: the functions and services of different types of RACFs are clearly categorized; there is a large proportion of small elderly care institutions; family-style space creates a warm living atmosphere, and it is easier to integrate elderly accommodation into the surrounding community. These aspects have significant relevance for China. In the context of China's current wealthy aging, self-care elderly people increasingly need simple life support services. However, there are relatively few RACFs that provide such services. The sheltered elderly apartment model in the UK is suitable for elderly people with such needs. Drawing on the experience of sheltered elderly apartments in the UK, this research explored RACFs to satisfy the needs of elderly care in China. However, China and UK have different national conditions, and China cannot replicate the British experience. But the UK's positive experiences can still provide a partial model for the development of Chinese RACFS and influence the policies China is introducing to provide a foundation for the construction of RACFs.

9.1.2 The Elderly's demand on Living Environment

QoL is the individuals' rating and experience in living conditions comparing with their expectations, goals, concerns, and standards, and. Grounded theory was introduced in 1967 by Barney Glaser and Anselm Strauss, which emphasizes the progressive case selection and data collection. Thus, the grounded theory and hierarchical coding were adopted to explore the systematic factors that effect the QoL of the elderly. Through grounded theoretical research and analysis, the factors that have impacts on the QoL of the elderly were identified as the three main categories of "What needs? Why? and What Choices?". Among them, "What needs?" were composed of two relational categories: an individual's environmental needs and external environmental needs (religious needs, gardening needs, and traffic convenience needs). "Why do we need what we need?" included three types of relationships: the elderly's own factors, children's factors, and housing factors. "Why to choose?" analyzed the reasons for the choice of RACFs and why should we be more professional in the establishment of RACFs in China. These three questions play a substantial part in the QoL of the elderly and influence their choices. The key factors that influence the QoL of the elderly are found and categorized as follows:

- The elderly like quiet and private living spaces.
- In a cold climate like northeastern China, it is essential to keep the indoor environment warm for the elderly.
- Furniture and electrical appliances are one of the essential conditions in the living conditions of the elderly.
- The comfort of the elderly in RACFs is affected by service personnel.
- The sanitation is overall satisfied in the RACF.
- A diet that is both healthy and meets the elderly's taste. Private bathrooms and toilets are expected by the elderly.
- Indoor sports facilities are expected.
- Religious facilities are expected by the elderly. Convenient transport facilities are expected.

9.1.3 Indoor Environmental Quality of RACFs in Northern China

Therefore, the research method of IEQ in this chapter is the establishment of a whole set of research methods. Because all buildings need to consider the indoor environment during construction, the research methods in this chapter can be used not only to improve RACFs, but also to other building types.

The research for this thesis was conducted in five RACFs in North China, which are HGD, GX, SHQ, AD, and AK, and showed that in terms of the main environmental factors measured:

For the acoustic environment, the peak time for noise is 11 am in the summer bedroom in HGD, 7:30 am in the summer bedroom in GX, 8:30 am in the summer activity room in SHQ, 11 am in the summer bedroom in AD, and 7:30 am in the autumn activity room in AK, but they are not affected by seasonal factors;

The lighting conditions depend on the orientation of the windows - the more east-facing windows, the better the morning lighting conditions;

The temperature gap between day and night is large in summer, and the indoor temperature is stable in winter (17-21 °C);

The results of various RACFs show that the RH in Autumn is lower than that in Summer and Winter, at about 45%.

When the bedrooms and activity spaces are compared, the lighting assessment of the bedroom is usually higher than that of the activity room. The temperature measurement results show similar trends between the activity room and the bedroom. The indoor temperature in Summer is usually higher than that in Winter and Autumn, and the temperature in the morning and evening is lower. The relative humidity (RH) assessment of the activity space is slightly higher than that of the bedroom and is also affected by the size of the RACF. The key findings are as follows:

- Odor: The elderly are less sensitive to smell, and the correlation between smell assessment and overall IEQ assessment is poor.
- Acoustic: The acoustic rating has a linear relationship with the SPL. The threshold of SPL is 70 dB(A) in summer and 65 dB(A) in winter and autumn.
- Lighting: Brightness and illuminance have a non-linear relationship with lighting rating. The lighting rating is not affected by the season, and the generally acceptable brightness range is between 100–450 cd/m^2, and the illuminance threshold is between 450–1400 lux.

Thermal: For all RACFs, different seasons and rooms do not greatly change the RACF threshold, and the elderly are satisfied with the temperature of 25-26.5°C and the drier environment. The IEQ assessments of the four RACFs are highly correlated with the four physical parameters, with correlation coefficients of 0.66-0.85 ($p < 0.001$). The overall rating results show that in all five RACFs, the bedroom is more comfortable than the activity room. People under 65 and over 85 have the largest fluctuations in the assessments of their physical environment. There are clear differences between education level, pension level, and length of residence, marital status, and urban and non-urban location. But in summary, the elderly interviewed for this study seem satisfied with the overall IEQ environment of their RACF.

For the acoustic environment, due to the high noise in summer and easily affect the normal life of the elderly. Or, indoor air-conditioning equipment and ventilation equipment can be improved to reduce the need to open windows in summer, while external noise enters the room. As for humidity, there is a lot of rain in summer, which is relatively humid, and the elderly generally do not like humid environments, so you can install some dehumidification equipment indoors.

9.1.4 Living Environment Factors of the Residential Aged Care Facilities and It Effects on Quality of Life

A structural equation model was built to examine the associations between the elements of AC, RS, IEQ, and their impacts on QoL. The research conducted a large-scale questionnaire of 1457 participants to identify 50 items from the survey results for exploratory analysis and summarized the above four variables as the main components. The exploratory analysis included a different analysis of the four sizes of RACF, the difference between different construction models, and different analyses of different seasons. Various aspects of the researched RACFs were explored, especially the combination of different building types (converted or purpose-built building), scale, and seasonal effects. The defects and deficiencies of the accessibility in converted RACFs have led to low satisfaction; however, the converted buildings can quickly solve the shortage of RACFs with less cost and time to renovate. The study established a 50-factor mechanical equation model to study the association between AC, RS, IEQ, and QoL, as well as the impacts of a variety of factors on the QoL of the elderly. The findings can be summarized as follows:

1. AC (including planning policy, design principles, and interaction with neighbors) considerably influences the elderly’s perception of RS, IEQ, and QoL.
2. RS and IEQ have the greatest impact on the elderly’s QoL.
3. Regarding the intermediary impact, AC has a direct relationship with QoL. The RS and IEQ have an intermediary influence on QoL of the elderly in RACFs.
4. As intermediary variables, IEQ and RS indirectly affect the effect of AC and QoL. Therefore, when some RACFs do not possess ideal AC due to financial issues or renovation, and managers can improve the QoL of the elderly by improving IEQ and RS.

9.1.5 Acoustic Environment in Communal Activity Spaces in Residential Aged Care Facilities

The study in Chapter 8 was conducted in the activity area of a residential aged care facility in Harbin, China, through field observation, sound measurement, and questionnaire surveys to evaluate the sound comfort of the elderly. It was found that respondents had a low rating of the acoustic environment of the activity space. The SPL measurement found that the SPL in the morning is the lowest of the day, which is below 40 dB(A) at each detection location of the activity area. The two peak SPL is from 11 am to 12 am, and 16 pm to 17 pm at 74 dB(A) and 76 dB(A) respectively. The elderly normally take a nap in the afternoon, thus, the SPL tends to be flat and maintains a low level in the afternoon. Overall, the changes of SPL in the activity area highly correlate with the activities of the elderly. When RT exceeded 4 seconds and SPL exceeded 65 dB(A), satisfaction of the acoustic environment gradually declined., And in general, with an increase in SPL, respondents' satisfaction with different types of sounds declined. However, their rating of music declined more slowly than for other types of sound. And their preference for and satisfaction with music was also higher than that for other sound types. The questionnaire found that speech had the greatest impact on the elderly with the lowest score. Respondents were not very aware of mechanical sounds and sounds in the activity space did not bother them. For the same sound source, a relatively noisy area had a higher tolerance and sound rating than a relatively quiet area.

Respondents preferred slight or quiet sounds, and the rating of medium and high-volume sounds depended on the degree of participation in activities and personal preferences. Participants in music-related activities (singing and dancing) were more comfortable with other sound sources than respondents involved in quiet, speech-related activities (chess and cards). However, chatting by bystanders affected sound rating by the participants, and this effect required offsetting by increased concentration. There is no reliable evidence that reasons other than music-related activities lead to the decrease or improvement of its acoustic rating. The elderly man was generally more comfortable with speech-related sound than the elderly women. Younger respondents (60-70 years old) were more comfortable with the sound environment in general than older people. Older people with junior high school education gave the highest rating of voice and speech-related sounds. Respondents who spend large amounts of time in the activity space gave a higher rating of the acoustic environment than those who only occasionally used it.

Overall, the longer respondents had lived in residential aged care, the lower their satisfaction with the acoustic environment.

The study of the care facility in Harbin also show that the elderly prefer natural sound without lyrics, which help to ease their mind and release stress, and although the researched RACF has an overall good environment and a large-scale communal activity area, the acoustic environment is not ideal. Despite the lobby has separate areas that are designated as a rest area and activity area, the sound still interferes with the residents. In addition, some elderly residents watch videos with sound on their mobile phones in the rest area, while others read newspaper in the activity area, which suggests that RACFs should have two or multiple sections in the activity area and separate the residents who are conducting quiet activities from others who may generate noise, and this requires the staff in the RACFs to ensure that the elderly are conducting right activities in the corresponding area, for example, the elderly who are making any forms of noise would be persuaded to go to the activity area. The different sound environments have impacts on the psychological of the elderly participants, which the soothing rhythm instrumental music can help to meet the elderly's psychological needs.

9.2 Significance and Opportunities

In this section, the significance and contributions of this research and the opportunities for improving RACFs in northeastern China are illustrated in terms of three aspects of applying better knowledge of older people's needs and demands to design theory; design guidelines and techniques; and guidelines for relevant government policy.

9.2.1 Incorporating Improved Knowledge of Older People's Needs and Demands into the Theory

Insufficient attention is paid to the quality of RACFs in China. Through qualitative research drawing on grounded theory, the needs of the elderly regarding QoL were explored in this study, which has indicated that there are still many areas that should be improved in RACFs in China. The study has established that elderly people require a quiet and private living environment for their physical well-being, and they prefer living in single rooms. The elderly are worried about the cold, and particularly in northeastern China, it is important to keep the indoor environment warm. Many respondents complained that the heating system was not always working.

Different types of elderly people require different types of acoustic environments: some prefer smooth and soft music, while others prefer socializing, chatting, playing cards, or chess with others. Studies have indicated that acoustic environments can influence the mental and physical and health of the elderly and that poor mental health is more likely to be negatively influenced by noise than those with mental well-being. The elderly need a good acoustic environment to sleep, which helps to avoid high blood pressure, dementia, and damage to the nervous system.

Lighting is also important. Some respondents complained that it was hard to read in their bedrooms at night, and they really needed table lamps. They stated that sunlight was very important to them, but they also felt uncomfortable if it was too bright in the room, which could be a cause of eye disease.

Respondents wished that the staff of the RACFs could be more attentive to and considerate of them but at the same time freedom was considered important and they wished they were allowed to go out occasionally. Sanitation needs to be enhanced, especially to prevent the spread of bacteria. In terms of conditions on the different floors of the RACFs studied, the first floor is regarded as humid and higher floors are extremely difficult to access if there are no elevators. Barrier-free facilities are needed in specific areas, such as avoiding steep staircases. Some respondents complained about the flavor of the food and did not understand the significance of nutrition and protein: food needs to be healthy while making the flavor more acceptable to the elderly people.

The elderly is not as healthy as others, and sudden diseases may occur, so the elderly generally need a sound medical system. The elderly are not suitable for outdoor activities, so they need indoor entertainment in RACFs. In the selected RACF, activity rooms are also relatively complete, but since the elderly are already dangerous to use alone, it is necessary to assign specialized personnel to guide them. In addition, elements such as scenery and companionship are also the focus of attention of the elderly. Therefore, most of the RACFs are equipped with gardens, panoramic floor-to-ceiling windows, and even pets.

9.2.2 Design Guidelines and Techniques of Residential Aged Care Facilities

Insights relevant to design guidelines and techniques for constructing and improving RACFs can now be considered, based on the responses of the elderly regarding the QoL explored from the surveys. Privacy is highly valued by elderly people, yet, because of the huge population of China compared with that of Western countries, it is almost impossible to provide single rooms for every elderly resident in RACFs. Instead, when two or more elderly people have to share one room, there should be some kind of barrier such as curtains or screens between occupants, which they can open to talking to each other and close whenever they feel like having some private time.

The converted RACFs are found to have a lot of advantages, such as low investment, low renovation cost, and short timing of construction, thus it can quickly solve the problem of insufficient RACFs in China.

Many of the respondents were very worried about the cold: to create a warm indoor environment, there should be sufficient east-facing windows to ensure an acceptable indoor thermal environment during the day, and the heating system must be available 24-7 during winter, otherwise, in a cold environment, older residents might easily become ill. Indoor ventilation also has to ensure good IAQ, which not only requires the windows to be properly built but also a reliable central air-conditioning system with regular checks and maintenance. Considering many elderly people complained that the first floor can be quite humid, it is especially important to ensure good ventilation and day lighting on the first floor. In addition, some residents like reading in bed before sleep, and it is beneficial for them to have bedside lamps, but at the same time, the brightness ceiling lights should be moderate as the strong artificial light can lead to eye damage in the elderly.

RACFs of over three floors must be equipped with elevators and barrier-free facilities and medical rooms should be located on the first floor for emergency situations. Since outdoor exercise is not always possible, especially in Winter, indoor gyms should be built with specially designed equipment for elderly people. Gardens should be created outside, including flowers, vegetables, and even fruit, as many elderly people enjoy gardening. Gardening not only helps to facilitate the elderly’s physical functions but also helps to improve their mental health.

This study found that respondents of different ages and with different education levels tended to have different ratings of sound, speech, and music. Thus, would be good to have two or more activity spaces available for residents, with one activity room playing soft music suitable for reading in which people were forbidden to talk or make noises; and another activity room for residents to chat, play cards, and chess, etc. The activity rooms should play natural sound and soothing music without lyrics as these types of music are preferred by the elderly. The walls of the bedrooms should be adequately sound-proofed as the elderly can be easily awakened by noises, and the quality of their sleep is crucial for their daily moods and to avoid high blood pressure and dementia.

The research results in this paper can be used in the reconstruction of RACFs. Through the analysis of the needs of the elderly, the construction companies can improve the hardware facilities of the RACFs. At the same time, in different seasons, the building environment and indoor equipment can also be adjusted based on the feelings and needs of the elderly to effectively improve the quality of life of the elderly in RACFs.

9.2.3 Guidelines for Relevant Government Policy

Although China and UK have different domestic conditions, and China cannot replicate the British experience, some of the positive experiences of the United Kingdom may be helpful to the development of Chinese RACFs. China could produce a better classification of existing RACFs to respond to the different needs and demands of the elderly. For example, in the UK, the RACFs are classified over a range that covers the self-help elderly to semi-incapacitated persons, and to the frail and incapacitated elderly, and this enables people to select the RACF most appropriate for their needs if they can afford it. The number of low-end and high-end RACFs in China is increasing, but there are still insufficient numbers of middle-range facilities. This situation can be improved because people in China are becoming wealthy enough to invest their money in mid-range accommodation, but are not rich enough to be able to afford high-end facilities.

The design and layout of the current small and middle-scale RACFs are more like hospitals and dormitories: this could be changed and improved by establishing more RACFs in communities rather than in rural areas, where they would be more easily integrated into the community and create family-oriented environments for the elderly residents.

The large comprehensive activity room may meet the elderly's various activity needs, but the actual experience is not so ideal. The elderly still have a lot of dissatisfaction with the activity room and need for improvement. Therefore, based on the research results of this article, we can truly understand the dissatisfaction of the elderly and their expectations, and the government and relative department can issue or change some policies to urge RACFs to make improvements.

9.3 Limitations and Future Work

One shortcoming of this research is that the sampling described in Chapter 4 was mainly in China. And the samples were relatively small regarding the total population, and in some respects, the aged care system in China and the UK may not be comparable. China is a vast land with rich resources: the cultural differences between the north and the south are large, and these cultural differences are likely to affect the opinions and experiences of the elderly. The description and analysis of Chinese regional differences are still insufficient.

Chapter 5 reports on the statistics and analysis of the QoL of the elderly drawing on grounded theory. But the grounded theory itself has certain limitations. It requires researchers to carry out repeated in-depth investigations many times, but data collection and theoretical analysis will still have certain errors due to the elderly's subjective or even biased representation. In addition, a limited number of samples need to be considered. But while the standards for the acoustic environment, light environment, and thermal environment are suitable for most elderly people, the particularities of others should also be considered. Therefore, future work must take into account the needs of some special groups.

Chapter 6 reported that seasonal changes affect the IEQ assessment, and the transition period assessment is the highest. However, the general assessment of this factor is very low, which may be explained by the unclear description in the questionnaire, or it may just be abnormal data. For example, although humidity meets measured comfort standards, the elderly have low ratings of this factor. People over the age of 85 have high ratings for IAQ, but low ratings for smell, freshness, and cleanliness.

In addition, the relationship between the physical environment and environmental assessment may also have certain errors due to the inconsistency of indoor environmental conditions. The various factors considered at present are not all-inclusive, and there are still some factors that have not been considered. The sampling survey for each RACF does not represent all RACFs. In future research, these issues can be addressed to explore potential impacts or intermediary factors between various physical environmental assessments.

Chapter 7 showed that the influence of IEQ on QoL of the elderly is higher than that of RS. This may be because RS is a subjective perception assessment, and the feelings of the respondents at the time of the interview may have affected the assessment.

Future research would aim to carry out an in-depth study of the factors that specifically affect intermediary variables, as well as the effect of subjective and objective rating by the elderly on the intermediary variables in different environments and backgrounds.

There are some limitations to the research for Chapter 8. Data processing and analysis are not comprehensive enough, only analyzing the data from the perspective of the problem, but not discussing the actual impact of the outdoor physical environment on the elderly. There may have been some problems with the experimental samples, such as the limited number of samples, and the possible biased response that the elderly participants provided. As only the elderly are involved, deviations in personal data may have occurred, such as the uncertainty responses due to the recession of memory. Therefore, it is essential to study the responses of people of different ages in different regions under different acoustic treatments.

The elderly selected to take part in the surveys were usually willing to participate, but some of their responses seemed to indicate they had not understood the questions. In the future, the design of questionnaires should be simple and straightforward, and should avoid using professional terms and confusing words.

Hence, the initial purpose of this research is to investigate the needs of the elderly living in RACFs in China by analyzing their living environment and their satisfaction. Through the interview that conducted on the elderly residents in selected RACFs in Northeast China, it was found that many of the elderly’s needs are poorly met, and to achieve a better life for the elderly in China, there are a lot of areas to be improved, here to illustrate:

In addition, the research results in this article can not only be used for the management and construction of RACFs, but many of the results can also be used for construction projects, because other types of buildings are similar to RACFs in many aspects. In the construction of ordinary houses, sound insulation, lighting, communication between people, and the placement of indoor equipment also need to be considered. Therefore, this article not only helps us improve RACFs, but also has important reference significance for the entire construction industry. The research is also very helpful in the early-stage architectural design and planning, as well as the later use and management. When designing and planning, the relevant person in charge can select the location of the building based on the research results of this article, and adjust the internal structure according to factors such as sound, light and heat. At the same time, in the post-management after the completion of the building, relevant personnel can also use these results to monitor the owner's use, and transform and improve the building in a timely manner.

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APPENDIX A Questionnaire for Chapter 6

Questionnaire (Chapter 6) (Originally in Chinese)
No. : **Location:**
Time: **Activity states:** **Clothing:**
Part1
1 Your Gender:
□1**Male** □2**Female**
2 Your Age
□1 **<65** □2 **65-75** □3 **76-85** □4**>86**
3 Your degree of education
□1 **Primary school or lower** □2 **Junior or senior high school** □3 **Undergraduate or higher**
4 Your pension (monthly)
□1 **<2000 yuan** □2 **2000-5000 yuan** □3**>5000 yuan**
5 How long have you been living here?
□1 **< 1 year** □2 **1-3 years** □3 **3-5years** □4 **>5 years**
6 Which area did you live
□1**Villages** □2 **Town** □3 **Suburb areas** □4**Urban areas**
7 Your marital status
□1 **Single** □2 **Married** □3 **Widowed** □4 **Divorced**

Part2

1.Please evaluate the acoustic environment in this area

	Strongly dissatisfied	Dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Satisfied	Strongly satisfied
The satisfaction of acoustic environment of this space.	1	2	3	4	5	6	7
The loudness of the acoustic environment of this space.	1	2	3	4	5	6	7
Noise level	1	2	3	4	5	6	7
Intelligibility	1	2	3	4	5	6	7
Preference degree	1	2	3	4	5	6	7

2.Please evaluate the light environment in this area

	Strongly dissatisfied	Dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Satisfied	Strongly satisfied
The satisfaction of the light environment of this space.	1	2	3	4	5	6	7
Lighting equipment	1	2	3	4	5	6	7

Light distribution	1	2	3	4	5	6	7
Interior lighting	1	2	3	4	5	6	7

3.Please evaluate the thermal environment in this area

	Strongly dissatisfied	Dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Satisfied	Strongly satisfied
The satisfaction of the thermal environment of this space.	1	2	3	4	5	6	7
Temperature	1	2	3	4	5	6	7
Relative Humidity	1	2	3	4	5	6	7
Ventilation	1	2	3	4	5	6	7

4.Please evaluate the air quality in this quality

	Strongly dissatisfied	Dissatisfied	Somewhat dissatisfied	Neutral	Somewhat satisfied	Satisfied	Strongly satisfied
The satisfaction of the air quality of this space.	1	2	3	4	5	6	7
Odour	1	2	3	4	5	6	7
Freshness	1	2	3	4	5	6	7
Cleanliness	1	2	3	4	5	6	7

5. Please evaluate the indoor environment quality (IEQ) in this area.

□1Strongly dissatisfied □2Dissatisfied □3Somewhat dissatisfied □4Neutral

□5 Somewhat satisfied □6Satisfied □7 Strongly satisfied

Thank you for your participation!

APPENDIX B Questionnaire for Chapter 7

Questionnaire (Chapter 7) (Originally in Chinese)

Questionnaire
Record the following content:：
No. : **Location:** ____________ **Time:** **Activity states:** **Clothing:**
Scale： **Building types:** **Is it a converted building?**

Commuting cost	Distance to urban facility	Quality of constructions and need for repair		
Benches in public open space for elders	Lighting of public areas	Security in stairs and corridors	Accessibility facilities	Road lights
Neighbors' cooperation in payment of monthly charge and cleaning	Conflict between neighbors	Profligate tenants		

Part1
1 Your gender
□1Male □2Female
2 Your age
□1 55-60 □2 61-70 □3 71-80 □4 81-90 □5 >90
3 Your degree of education
□1 Under primary school □2 Primary school □3Junior high □4Senior high □5 Undergraduate □6 Postgraduate and higher
4 Your pension (monthly)
□1 <1000 yuan □2 1001-2000 yuan □3 2001-3000 yuan □4 3001-5000 yuan □5 4001-5000 yuan □6 >5000 yuan
5 How long have you been living here?
□1 <1 month □2 1-3 months □3 3-6 months □4 6 months-1 year □5 1-3 years □6 3-5 years □7 >5 years
6 How long have you been using this space?
□1 <1 hour □2 1-2 hours □3 2-3 hours □4 3-4 hours □54-5 hours □6 >5 hours
7 Which area did you live?
□1Village □2 Town □3 Suburb area □4 Urban area
8 Your marital status
□1Single □2 Married □3 Widowed □4 Divorced

Part2
1 Please evaluate the following indicators

	Strongly dissatisfied	Quite dissatisfied	Dissatisfied	Neutral	Satisfied	Quite satisfied	Strongly satisfied
Management and maintenance of facilities	1	2	3	4	5	6	7
Cleanliness of the housing estate	1	2	3	4	5	6	7
Security of life and property in the housing estate	1	2	3	4	5	6	7

Rules and regulations within the housing estate	1	2	3	4	5	6	7
Sizes of living and dining spaces	1	2	3	4	5	6	7
Sizes of bedrooms in the house							
Sizes of cooking and storage spaces							
Design of baths and toilet facilities							
Recreation/sporting facilities							
Prices of goods and services in the housing estate							
Communal activities in the housing estate							
Building materials used in the construction of houses							
Privacy in the residence							
Cost of housing							
External Appearance of the residence							
Location of residence in the house estate							
Public infrastructure and urban service							
Water supply and sanitary service							
Electrical service							

2 Please evaluate the physical environment in this space

	Strongly dissatisfied	Quite dissatisfied	Dissatisfied	Neutral	Satisfied	Quite satisfied	Strongly satisfied
The satisfaction of acoustic environment of this space.	1	2	3	4	5	6	7
The satisfaction of the light satisfaction of this space.	1	2	3	4	5	6	7
The satisfaction of the thermal environment of this space	1	2	3	4	5	6	7
The satisfaction of the humidity environment of this space	1	2	3	4	5	6	7
The satisfaction of the temperature environment of this space	1	2	3	4	5	6	7
The satisfaction of the ventilation environment of this space	1	2	3	4	5	6	7
The satisfaction of the air quality environment of this space	1	2	3	4	5	6	7
The satisfaction of the odour of this space	1	2	3	4	5	6	7
The satisfaction of the overall indoor environment quality (IEQ)							

3.Please rate the following indicators:

1——7 points Strongly dissatisfied to strongly satisfied

	1	2	3	4	5	6	7
How would you rate your quality of life？							
How would you rate your overall health？							
How satisfied are you with your sleep?							
Do you have enough energy for everyday life?							
How much do you enjoy life?							
How often do you have negative feelings, such as blue mood, despair, anxiety, depression?							
How satisfied are you with yourself?							
Are you able to accept your body appearance?							
How satisfied are you with your personal relationship?							
How satisfied are you with the support you get from your friends?							
How satisfied are you with the conditions of your living place?							
How safe do you feel in your daily life?							
Have you enough money to meet your needs?							
How satisfied are you with your access to health services?							

Thank you for your participation！

APPENDIX C Questionnaire for Chapter 8

Chapter 8 Questionnaire (Originally in Chinese)

Questionnaire

Record the following content:

No. : **Venue name:** **Location:** ____________

Time: **Activity states:** **Music type:**

Part1

1 Your gender

□1 Male □2 Female

2 Your age

□1 60-70 □2 71-80 □3 81-90

3 Your degree of education

□1 Under primary school □2 Primary school □3 Junior high □4 Senior high □5 Undergraduate and higher

4 Your pension (monthly)

□1 < 1000 yuan □2 1001-3000 yuan □3 3001-5000 yuan □4 > 5000 yuan

5 How long have you been living here?

□1 <1 month □2 1-3 months □3 3-6 months □4 6 months-1 year □5 1-3 years
□6 3-5 years □7 >5 years

6 How long have you been in this area this time?

□1 30-60 minutes □2 1-2 hours □3 2-3 hours □4 > 3 hours

7 How frequent would you come to this area

□1 at least once a week □2 once a week □3 2-4 times a week □4 4-6 times a week
□5 at least once a day

8 Your marital status

□1 Single □2 Married □3 Widowed □4 Divorced

Part2

1 Please rate the overall acoustic environment of this area:

1 2 3 4 5 6 7

Strongly loud □ □ □ □ □ □ □ Strongly quite

2 Please rate the comfort of the overall acoustic environment in this place:

1 2 3 4 5 6 7

Strongly uncomfortable □ □ □ □ □ □ □ Strongly comfortable

3 Subjective impression of reverberation

1 2 3 4 5 6 7

Strongly long □ □ □ □ □ □ □ Strongly short

4. Please rate the acoustic comfort

1 2 3 4 5 6 7

Strongly uncomfortable □ □ □ □ □ □ □ Strongly comfortable

5. Please rate the loudness of various sound resources（Loudness of various sound sources）

1 2 3 4 5 6 7

Strongly low □ □ □ □ □ □ □ Strongly high

6. Intelligibility of various sound sources

1 2 3 4 5 6 7

Strongly clear □ □ □ □ □ □ □ Strongly unclear

7. Noise level of various sound sources

1 2 3 4 5 6 7

Strongly noisy □ □ □ □ □ □ □ Strongly quiet

8. Preference degree of various sound sources

1 2 3 4 5 6 7

Strongly disliked □ □ □ □ □ □ □ Strongly liked

Part 3
Please rate the following content:

	Strongly dissatisfied			Neutral			Strongly satisfied
I am very satisfied with the environment of the space	-3	-2	-1	0	1	2	3
I might not come to this activity space any more.	-3	-2	-1	0	1	2	3
I might stay here longer than planned	-3	-2	-1	0	1	2	3
I would like to spend more time to join in activities in this space.	-3	-2	-1	0	1	2	3
I want to get out of this space as soon as possible.	-3	-2	-1	0	1	2	3
I will chat with other the elderly I meet here.	-3	-2	-1	0	1	2	3
I will try to hide from others and not talk to other the elderly and work staff here.	-3	-2	-1	0	1	2	3

3 Your rating of the mood of this activity area:

	-3 -2 -1 0 1 2 3	
Passive		**Active**
Uncontrolled		**Controlled**

	-3	-2	-1	0	1	2	3	
Depressed								**Satisfield**
Unhappy								**Happy**
Restless								**Comfortable**
Angry								**Glad**
Fevered								**Peaceful**
Unexcited								**Excited**
Stimulated								**Relax**
Drowsy								**Awakened**
Passive								**Active**
Uncontrolled								**Controlled**

Thank you for your participation!

APPENDIX D Publications and Outreach

Journal papers in peer-reviewed journals

- Mu, J., & Kang, J. (2017). Zhongying Yanglao Sheshi Tixi yu Kongjian Sheji Bijiao Yanjiu [Comparative study on the system and space design of pension facilities between China and Britain]. *Architectural Journal (3)*. doi:10.3969/j.issn.0529-1399.2017.03.015 https://doi.org/10.3969/j.issn.0529-1399.2017.03.015
- Mu, J., Kang, J., & Zhang, S. (2017). Yingguo Baozhangxing Laonian Gongyu Tedian ji Fazhan dui Woguo de Qifa [The characteristics and development of the sheltered elderly apartment in the UK and Its Enlightenment to China]. *World Architecture, 000(011):89-95.* https://doi.org/ CNKI:SUN:SJZJ.0.2017-11-019
- Wu, Y., Meng, Q., Li, L., & Mu, J. (2019). Interaction between Sound and Thermal Influences on Patient Comfort in the Hospitals of China's Northern Heating Region. *Applied Sciences, (SCI), 9*(24), 5551. https://doi.org/10.3390/app9245551
- Mu,J, Kang, J.*, Wu, Y.. Acoustic environment of comprehensive activity spaces in nursing homes: A case study in Harbin, China. Applied Acoustics. 2021, 177(24):107932. https://www.sciencedirect.com/science/article/abs/pii/S0003682X21000256
- Wu, Y., Kang, J., & Mu,J,*. Assessment and simulation of evacuation in large railway stations. Building Simulation, 2021(6). https://link.springer.com/article/10.1007/s12273-020-0754-7
- Mu, J., Kang, J. Quality of life in elderly housing based on a structural equation model *Journal of Housing and the Built environment*（under review)
- Mu, J., Kang, J. Indoor Environmental Quality of Residential Aged Care Facilities in Cold Regions. *Science of Total Environment*（under review)
- Mu, J., Kang, J. Impacts of Indoor Audio Environment on the Physical and Mental Health, Mood, and Behaviour of Senior Adults in Senior Care Facilities Under the Intervention of Different Ambient Factors. *Indoor and Built Environment*（under review)