

Research on the Intelligent Design of Aging-Friendly Living Spaces Empowered by Digital Technologies

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Abstract: *With the intensification of population aging, the design of elderly-friendly living spaces has increasingly become a societal focal point. Traditional designs for elderly living spaces often prioritize functionality and safety, while the integration of digital technology opens up new possibilities for enhancing the quality of life for the elderly. This paper aims to investigate the intelligent design of elderly living spaces empowered by digital technology, exploring how digital innovations can improve the living experience for older individuals from an interior design perspective. The research begins by analyzing the physiological and psychological needs of the elderly, and then combines the application of digital technology with principles of interior design to propose a series of intelligent design strategies. Finally, through case studies and user experience testing, the effectiveness and practicality of these design strategies are validated.*

Keywords: *Elderly design; Smart living; Digital technology; Interior design; User experience*

1. Introduction

With the ongoing global trend of population aging, the living conditions of the elderly have gradually become a hot topic of concern across various sectors of society. The design of elderly-friendly living spaces should not only meet the basic life needs of older individuals but also address their psychological well-being to enhance their overall quality of life. The development of digital technology provides a new perspective and approach, enabling the effective integration of interior design with smart technology to create more humane and intelligent living environments for the elderly. This paper aims to explore the concept of intelligent design for elderly living spaces empowered by digital advancements, focusing on interior design details and striving to create a more comfortable, convenient, and secure living environment.

2. Interior Design Principles for Elderly-Friendly Living Spaces

2.1 Considering the Physiological Characteristics of the Elderly

In the design of elderly-friendly living spaces, thorough consideration of the physiological characteristics of the elderly is a fundamental prerequisite. With age, individuals experience varying degrees of decline in visual acuity, hearing, motor abilities, and cognitive functions. To meet the physiological needs of the elderly, interior design must adopt a people-centric approach, ensuring safety, convenience, and comfort.^[1]

First and foremost, safety is a core consideration in elderly-friendly design. Designers need to ensure that all home environments are barrier-free, especially with non-slip materials on the floor, such as non-slip tiles or additional non-slip pads, to reduce the risk of slipping accidents. Thresholds should be lowered or completely flat to avoid tripping, particularly crucial for elderly individuals using mobility aids or wheelchairs. Additionally, indoor corridors should be spacious enough for safe use of mobility aids or wheelchairs by the elderly.

In terms of lighting design, intense direct light sources should be avoided to reduce glare and shadows. Adequate indirect lighting should be ensured to allow the elderly to clearly see environmental details at any time. Specifically, night lights or motion-sensor lights should be provided for safe guidance during nighttime activities.

The selection and arrangement of furniture should also reflect human-centric design. Bed and chair heights should facilitate easy standing up and sitting down, considering potential knee joint issues.

Furniture should predominantly feature rounded edges to reduce the risk of collisions. Furthermore, the height of cabinets and shelves should allow easy access for the elderly, avoiding the need for excessive reaching or bending. Drawer and cabinet doors should have minimal opening resistance to accommodate weakened hand strength in the elderly.^[2]

To ensure the comfort of the living environment, the temperature control system should be easy to understand and operate. Underfloor heating and air conditioning temperature adjustments should be automatic or controllable remotely to adapt to the elderly's sensitivity to temperature changes. Additionally, considering the potentially fragile skin of the elderly, indoor humidity should be maintained at an appropriate level.

Special attention should be given to the bathroom, where toilet height should be moderate for easy standing up and sitting down. The bathroom should have non-slip floors and an emergency call button. Grab bars should be installed near the bathtub, shower, and toilet. To meet the diverse needs of elderly individuals with different physical conditions, bathing facilities should offer flexibility for both sitting and standing, achievable through adjustable equipment heights or the installation of removable seats.

By implementing these specific interior design principles, potential safety hazards in elderly living spaces can be effectively reduced, enhancing their living comfort and making their lives more convenient and enjoyable.^[3]

2.2 Addressing the Psychological and Social Needs of the Elderly

The design of elderly-friendly living spaces not only needs to meet the physical needs of the elderly but also must fully consider their psychological and social needs. A good living environment should promote the mental health and social activities of the elderly, which is crucial for improving their quality of life, enhancing social interactions, and slowing cognitive decline.

Design should make full use of public and semi-public spaces to encourage communication and interaction among the elderly. For example, apartment buildings can be designed with shared activity rooms, reading rooms, or game rooms to invite residents to participate in collective activities. Interior layouts should ensure sufficient open spaces and leisure areas, such as spacious balconies or reading corners with comfortable seating, allowing residents to invite friends or family for visits.

Interior design should also take into account the arrangement of individual private spaces, providing privacy and personal time for the elderly. Designers can use clever space planning, such as using screens, bookshelves, or plants to divide interior areas, creating an environment suitable for both personal relaxation, hobbies, and convenient socialization.^[4]

Colors have a direct impact on emotions. Interior design should choose colors that evoke positive emotions and memories. Warm tones, such as soft yellows or oranges, can create a cozy atmosphere. Additionally, material selection should prioritize texture and comfort, such as using wooden elements and fabrics to add warmth and comfort.

Design should pay special attention to potential cognitive impairments, using visual cues to help them identify spatial functions. For example, different colors or patterns can be used to identify different room doors, or simple symbol signs can be placed at key locations.

Utilizing smart technology can help the elderly stay connected to the outside world, such as smart phones and video communication devices that make it easier for them to communicate with family and friends. In addition, smart calendars and reminder systems can help the elderly remember social activities and important events, reducing the embarrassment and inconvenience of forgetfulness.

Interior design should respect the religious beliefs and cultural customs of the elderly, providing spaces for religious activities and cultural celebrations. For example, a corner can be reserved for placing religious idols or a small reading area for religious books.

Through the implementation of these design principles, a living environment is created for the elderly that not only meets their social needs but also provides a psychologically comfortable living space, effectively increasing their happiness and life satisfaction.

2.3 Integrating Smart Technology to Enhance Independence

When designing elderly-friendly living spaces, the integration of smart technology can significantly enhance the independence of the elderly. With the development of the Internet of Things, artificial

intelligence, and smart home devices, interior design is no longer limited to traditional construction and layout but can use intelligent means to help the elderly better control their living environment and improve their quality of life.^[5]

The integration of smart technology can first be reflected in the basic control of the home environment. Through voice control or touch screen systems, the elderly can easily adjust lighting, curtains, indoor temperature, etc., without the need to get up or perform complex operations. For example, at night, all lights can be turned off with a voice command, or the air conditioning temperature can be adjusted using a tablet while in bed. Such designs are both convenient and reduce the risk of falls and touches.

In functional spaces with a higher degree of functionality, such as the kitchen and bathroom, smart technology also plays a crucial role. Smart refrigerators can remind the elderly of food storage conditions and expiration dates, while smart stoves can automatically adjust firepower and shut off on a timer, reducing the risk of accidents due to operational errors. Smart toilet seats, barrier-free shower rooms, and faucets with automatic temperature control can make these spaces safer and more convenient for the elderly.

Emergency response systems are also a crucial component of smart home design. Emergency buttons or wearable devices can promptly notify family members or medical service providers when the elderly encounter sudden situations. These systems are usually connected to phones or the internet, ensuring rapid assistance in emergency situations.

Health monitoring is also an indispensable function of smart homes. Smartwatches and health monitoring devices can track the elderly's heart rate, blood pressure, and sleep quality, detecting early signs of health issues and sending reminders to users or family doctors through applications. Smart mattresses can even monitor breathing and body movement during sleep to prevent potential health risks.

The integration of smart technology in elderly design not only improves the safety and convenience of living spaces but, more importantly, enhances the control and confidence of the elderly in their lives. Such an environment supports the elderly in enjoying independent, dignified, and comfortable lives with as little external assistance as possible. Through the intelligent living environment, we not only provide convenience for the elderly but also add a guarantee for their happy lives.^[6]

3. Application of Digital Technology in Elderly-Friendly Interior Design

3.1 Smart Home Systems

In the field of interior design for elderly-friendly living spaces, smart home systems not only provide comfort but also play a crucial role in ensuring the safety and independent living capabilities of the elderly. Smart home systems integrate subsystems such as lighting, temperature control, security, and entertainment to create an intelligent environment that responds to the specific needs of residents, especially tailored to the elderly population.

The core of smart home systems lies in achieving automatic adjustments and personalized settings for the environment. For example, environmental sensors monitoring indoor lighting and temperature allow smart curtains and air conditioning to automatically adjust to maintain a comfortable living environment. This automated adjustment not only considers energy efficiency but also ensures comfort, eliminating discomfort caused by the elderly forgetting to manually adjust settings.

In the design principles of control systems, convenience, reliability, and user-friendliness are paramount. The control system should be easy to understand and operate, avoiding complex interfaces and redundant steps to reduce frustration and inconvenience for the elderly due to technological barriers. For instance, a straightforward main interface can display all basic control options, such as light switches and temperature adjustments, while advanced settings can be hidden in sub-menus, maintaining a simple interface without sacrificing functionality.

User-friendly interface design catering to the elderly is another key aspect of the successful implementation of smart home systems. High-contrast displays and large fonts assist visually impaired elderly individuals in reading information more easily. Buttons on touchscreens should be designed larger for easy touch and operation. Additionally, the application of voice recognition technology, such as smart assistants and voice commands, allows users to control home devices through simple verbal

communication, especially suitable for elderly individuals with limited hand functionality.

Among various interaction methods, voice control becomes the preferred choice in user interface design for the elderly due to its intuitiveness and convenience. Through integration with virtual assistants like Alexa or Google Assistant, the elderly can easily perform daily tasks such as setting alarms, checking the weather, playing music, or tuning in to radio stations. The simplicity of these functions is well-suited to the operating habits of elderly users.

As technology advances, these smart home systems continue to be optimized to better adapt to the physical and cognitive changes of the elderly. Future smart home systems will become more personalized, capable of learning user behavior and automatically adjusting the home environment based on these patterns, providing the elderly with a more intelligent, comfortable, and secure living space. Through the application of these technologies, elderly-friendly interior design continues to transcend traditional boundaries, moving towards higher goals of life quality.

3.2 Environmental Monitoring and Health Management

In the design of elderly-friendly living spaces, the importance of environmental monitoring and health management cannot be overlooked. As individuals age, the elderly become more sensitive to factors such as temperature, humidity, lighting, and air quality in their living environment. Therefore, interior design must incorporate advanced environmental monitoring technology to ensure living spaces meet the physiological needs of the elderly and contribute to their overall health.

Environmental monitoring systems use a range of sensors to collect real-time data on indoor and outdoor environmental conditions. For example, temperature and humidity sensors can monitor indoor climate conditions, ensuring they remain within a comfortable range. Smart lighting systems can adjust brightness based on indoor light intensity and residents' activity patterns, meeting physiological needs while conserving energy. Air quality sensors can detect pollutant levels indoors and, in conjunction with air purification systems, promptly eliminate harmful substances, ensuring fresh air.

These environmental monitoring systems are typically connected to a central control system, which can automatically adjust relevant devices such as air conditioners, humidifiers, and purifiers through intelligent algorithms to maintain the optimal indoor environment. Additionally, the system can provide real-time feedback on environmental conditions to the elderly through mobile devices, allowing them to make manual adjustments based on personal preferences, increasing the interactivity and personalization of the living space.

Simultaneously, the integration of health management features is an indispensable part of intelligent elderly-friendly interior design. Through mattress sensors, wearable devices, or home-installed health monitoring devices, the elderly can track vital signs such as heart rate, blood pressure, sleep quality, and activity level. This data is transmitted wirelessly to a central system, where artificial intelligence algorithms analyze the information to identify health trends and potential issues.

Real-time feedback and alert systems for health data are crucial tools to ensure that the elderly receive timely care. The system can immediately alert the elderly or their caregivers upon detecting abnormal indicators, allowing for a rapid response to potential health issues. This warning mechanism is particularly important in preventing emergencies such as falls or cardiovascular events, not only saving lives but also significantly enhancing the independent living capabilities of the elderly.

Through such intelligent design, the indoor environment becomes not only a comfortable living space for the elderly but also a robust support for their health management. The comprehensive application of environmental monitoring and health management systems greatly improves the quality and safety of elderly living, exemplifying modern interior design's development toward intelligence and humanization.

3.3 Assistive and Interactive Technologies

The integration of assistive and interactive technologies into elderly-friendly living spaces provides a more humane living experience and ensures safety for the elderly. The advancement of information technology brings convenience to the lives of the elderly and enriches their social activities.

Voice and touch interaction technologies are particularly suitable for the elderly. Devices such as smart speakers simplify the need for physical operations through voice commands, which is crucial for elderly individuals with limited mobility or visual impairments. Touch technology enhances visibility

and usability through large icons and simplified interfaces.

Virtual assistants can perform information queries, task scheduling, and provide personalized health management and emergency contact services. Their learning capabilities make services more personalized. Social platforms and video call tools are essential for independently living elderly individuals, helping them maintain a sense of social participation and emotional well-being.

For emergency situations such as falls, emergency call systems can automatically notify contacts or medical institutions, enhancing residential safety. The integration of these technologies not only facilitates the lives of the elderly but also improves their quality of life and safety. As technology advances, we can expect future living spaces to be more intelligent and humane, making elderly life more fulfilling and free.

4. Innovative Design Strategies and Implementation

4.1 Application of Innovative Technologies in Design

The application of innovative technologies in design is a crucial step in achieving the intelligence of elderly-friendly living spaces. With the continuous maturity of technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI), they have begun to play a role in interior design, creating more intelligent, comfortable, and secure living environments.

Firstly, the application of IoT technology enables various devices and systems in living spaces to connect and collaborate, such as smart lighting, temperature control systems, and security monitoring devices. Through unified management by a central control system, the elderly can easily control various devices in their homes, and all operations can be completed through simple voice commands or touchscreen interactions. IoT not only enhances operational convenience but also, through the accumulation and analysis of data, provides possibilities for personalized services.

Secondly, big data analysis can help designers understand the living habits and needs of the elderly, providing more precise design solutions. Through collected data, we can better optimize spatial layouts, such as adjusting furniture arrangements based on the elderly's activity patterns or determining the installation locations of certain devices based on frequency of use. Big data can also assist in energy consumption management, supporting the creation of a green and energy-efficient living environment.

The application of artificial intelligence in elderly-friendly interior design brings unprecedented intelligent services to living spaces. For example, by learning the behavioral patterns of the elderly, artificial intelligence can timely remind them to take medication, schedule doctor appointments, and even issue alerts in case of detected anomalies. Further applications, such as virtual reality technology, can provide immersive fitness and entertainment experiences for the elderly while also being utilized for cognitive training and memory maintenance.

Finally, with the emergence of new materials and technologies, future interior design will pay more attention to health and environmental protection. Smart windows can adjust light transmittance, self-cleaning floors and walls contribute to reduced maintenance work, and the application of these innovative technologies will make elderly-friendly interior design more intelligent and humane.

4.2 Sustainable Development Strategies for Smart Design

Sustainable development strategies for smart design aim to meet current needs without compromising the ability of future generations to meet their own needs. The design of elderly-friendly living spaces, while pursuing intelligence and comfort, also needs to consider environmental impact and resource efficiency.

Firstly, sustainable design should consider the use of environmentally friendly materials that are renewable or at least recyclable. Applying these materials in interior design can reduce environmental damage and ensure indoor air quality, providing a healthier living environment for the elderly.

Secondly, energy efficiency is another crucial aspect. Through efficient energy management systems, such as smart temperature control and lighting systems, energy waste can be significantly reduced. Devices in elderly-friendly interior design should be selected based on high energy efficiency ratings and precisely controlled through intelligent systems to ensure energy usage only when needed.

Furthermore, sustainable development strategies for smart design should include detailed

observation and research of the daily activities of the elderly. Design should allow for multifunctionality and flexibility of space to adapt to the changing needs of the elderly over time. For example, movable partition walls and adjustable furniture can be reconfigured as needed.

Lastly, the design process should adopt a life cycle assessment approach, comprehensively evaluating the environmental impact from raw material acquisition to the final disposal of the product. Based on this assessment, designers can identify and implement strategies that maximize the reduction of environmental impact. For instance, enhancing indoor environments by adding green plants and natural light not only enhances aesthetics and health but also helps regulate indoor temperatures, reducing energy consumption.

In summary, sustainable development strategies for smart design are not only reflected in the application of technology but, more importantly, involve considering environmental impact and the effective use of resources at every stage of the design to ensure its long-term sustainability.

5. Conclusion

This study, from the perspective of digital technology, explores how the livability of elderly-friendly living spaces can be enhanced through smart design. The research indicates that the judicious application of smart home systems, environmental monitoring technology, and human-computer interaction design can significantly improve the living experience of older adults. Additionally, it emphasizes the importance of continuous innovation and the implementation of sustainable strategies in design practice to ensure that designs meet the needs of contemporary elderly individuals while considering resource efficiency and environmental protection. In summary, smart design not only creates a living space for the elderly but also fosters a caring, convenient, and secure living environment.

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