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Research on Age-Friendly Design of Smart Lighting Products Based on Service Design

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Abstract: *Starting from the current research status and interaction issues of smart lighting products, this study explores smart lighting products based on service design methods and age-friendly design principles, aiming to address the issues of lack of safety, high operational redundancy, and inclusivity faced by elderly users when using these products. Through interviews, we gather information on the current situation and behavioral needs of elderly users. We utilize user personas and user journey maps, tools from service design methods, to construct various user models, identify key touchpoints, pain points, and opportunities. Prototype products are developed for usability verification. Service design methods enable us to explore the intelligent needs of the elderly throughout the entire process of using lighting products. The derived age-friendly design of smart lighting products is highly inclusive, satisfying the elderly's needs for smart lighting products while enhancing their satisfaction with these products. This study effectively addresses the age-friendly design issues of smart lighting products, improves the experience satisfaction of various elderly users when using smart lighting products, and provides practical evidence for the development of age-friendly design for smart lighting products.*

Keywords: *Service Design; Intelligent Lighting; Interaction Mode; Age-Friendly Design*

1. Introduction

The accelerating process of population aging is urgently giving rise to the demand for age-friendly smart lighting, while also posing severe technical and ethical challenges. According to statistics, as of 2023, the proportion of the population aged 60 and above in China has exceeded 21%, and among this group, 40% suffer from issues such as visual acuity decline and motor dysfunction. However, current smart lighting products on the market generally suffer from complex interaction methods and inadequate safety redundancy design, which fully exposes the systematic limitations of traditional design paradigms in user segmentation research. Therefore, this study employs service design methodology to reconstruct the full-process experience of elderly users. Specifically, by drawing user journey maps, the "cognition-operation-feedback-maintenance" behavior chain of elderly users in the process of using smart lighting is carefully deconstructed, thereby achieving personalized and emotional lighting solutions to create smart lighting product designs with greater emotional resonance and user satisfaction. This has important practical guiding significance for addressing the technical and ethical dilemmas faced by an aging society.

2. Research status and issues of intelligent lighting products

2.1 Research status of intelligent lighting products

The global aging trend has propelled the research on intelligent lighting for aging-friendly design to become a cross-disciplinary focus of human-computer interaction and inclusive design. Existing research revolves around three dimensions: physiological compensation, cognitive assistance, and emotional care. However, it faces challenges such as excessive technological dominance, insufficient cultural compatibility, and imbalanced system integration. People's first impression of things often stems from color. In the context of intelligent lighting, color is not only a visual effect of light but also an emotional language, significantly influencing personal emotions, physical and mental health, and living atmosphere [1]. Intelligent lighting scenarios allow users to preset and adjust lighting based on different activities, times, atmospheres, or personal preferences. Through intelligent controllers or mobile phone applications, users can create various scenarios and specify specific lighting settings, such as brightness, color

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temperature, and lighting combinations. These adjustments aim to further optimize the user experience, with the core being to provide the right light at the right time [2]. Social progress has enabled modern lighting fixtures to carry more spiritual and emotional significance beyond their illumination function, making them an indispensable part of people's current lives [3]. Immersive light and shadow artworks created by James Turrell, as well as series works by the Japanese light and shadow art team TeamLab, have created unique artistic lighting environments through emotional stimulation and mood regulation in indoor and outdoor settings. These works demonstrate the immense potential of light art in terms of psychological influence and emotional experience [4].

2.2 Aging-friendly issues of smart lighting products

In the current era of rapid development of smart lighting products, elderly user groups face numerous aging-related issues that urgently need to be addressed during use. The primary issue is the lack of safety. The elderly population experiences physical decline, with relatively slow movements and less responsive reactions. However, some current smart lighting products have significant deficiencies in safety design, such as the absence of safety redundancy designs like electric shock protection and fall emergency linkage, which undoubtedly pose potential safety hazards for elderly users. In the event of an accident, it could lead to serious consequences [1]. High operational redundancy also plagues elderly users. Smart lighting products often pursue functional diversity and intelligence, but complex interaction methods deter the elderly. Excessive operational steps, difficult-to-understand icons and instructions require elderly users to spend a lot of time and effort to learn and adapt, and may even affect their user experience due to operational errors [2]. Social progress has enabled modern lighting fixtures to carry more spiritual and emotional significance while still serving their lighting function, making them an indispensable part of people's current lives [3]. Immersive light and shadow artworks created by James Turrell, as well as series works by the Japanese light and shadow art team TeamLab, have created unique artistic light environments through emotional stimulation and mood regulation in indoor and outdoor settings. These works demonstrate the immense potential of light art in terms of psychological influence and emotional experience [4].

3. Age-friendly design based on service design approach

3.1 Principles of Age-Friendly Design and Methods of Service Design

In the design of intelligent lighting products for the elderly, it is necessary to follow a series of core principles and skillfully apply service design methods to effectively meet the special needs of elderly users.

In terms of age-friendly design principles, safety is of utmost importance. Given the decline in physiological functions of the elderly, products should be equipped with safety guarantee mechanisms such as anti-electric shock and fall emergency response, safeguarding the safety of elderly users from both hardware and software aspects. The principle of usability requires that product interactions be simple and intuitive, reducing complex operational steps, adopting large fonts, high-contrast interfaces, etc., to reduce the learning cost for the elderly. The principle of inclusivity emphasizes respecting the individual differences of elderly users, fully considering the needs of elderly people with different physical conditions and cognitive levels, and providing diversified functional options and operation modes.

The service design approach provides a systematic approach for age-friendly design. Through in-depth interviews, we gain a deep understanding of the current situation and behavioral needs of elderly users, providing precise basis for design. By utilizing user personas tools, we construct different types of elderly user models to clarify the characteristics of target users. With the help of user journey maps, we organize the entire process of elderly users from their initial contact with smart lighting products to the end of use, identifying key touchpoints, pain points, and opportunities. Based on this, we develop prototype products and conduct usability verification, continuously optimizing the design according to feedback. Combining age-friendly design principles with service design methods allows us to explore the intelligent needs of elderly users for smart lighting products throughout the entire process, designing more inclusive and user-friendly products to enhance the satisfaction of elderly users.

ISSN 2616-7433 Vol. 7, Issue 7: 22-28, DOI: 10.25236/FSST.2025.070704

3.2 Aging-friendly design process based on service design method

Both service design and age-friendly design are user-centered, aiming to meet user needs and enhance user experience. To better integrate age-friendly design principles into service design methods, this study proposes a design process, as shown in Figure 1. This process integrates the "Double Diamond Model" of service design with the age-friendly design process

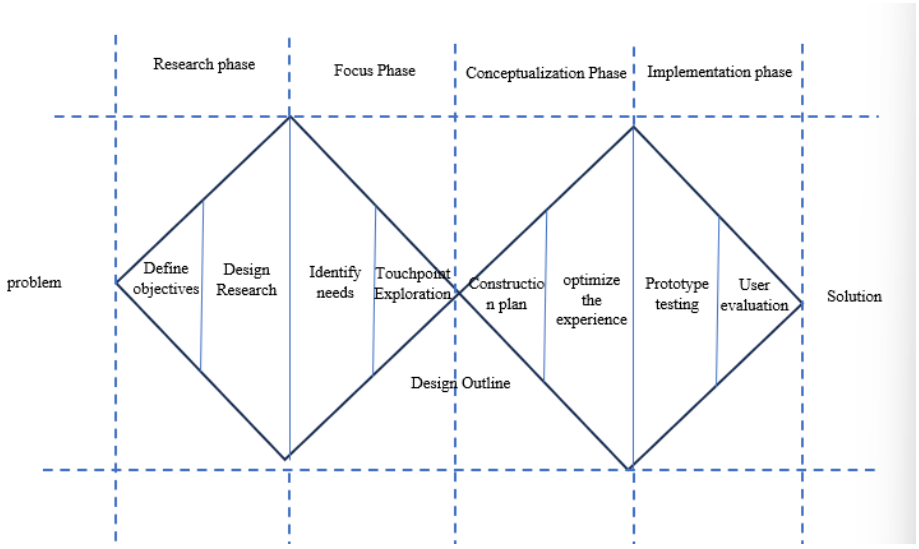

Fig.1 Flowchart of Age-Friendly Design Based on Service Design Method

4. Design Practice of Smart Lighting Products

4.1 User research

In the practice of aging-friendly design for smart lighting products, in-depth and comprehensive user research is a crucial step to accurately grasp the needs of elderly users and lay the foundation for design. This study adopts interviews as the primary research method, carefully selecting elderly users of different age groups, physical conditions, and life backgrounds as interviewees to ensure the diversity and representativeness of the sample. During the interviews, in-depth discussions were conducted around the lighting usage habits of elderly users in their daily lives, their cognition and experience with existing smart lighting products, the difficulties they encounter during use, and their expectations. Through interviews, it was found that elderly users generally reflect safety concerns with current smart lighting products, such as the lack of electric shock protection and emergency lighting functions; the complexity of operation, with too many buttons and cumbersome settings, which deter them; and the lack of inclusive design for elderly users with different physical abilities. At the same time, using the user personas tool from service design methodology, various typical elderly user models were constructed based on research data, including those with poor vision but able-bodied, and those with limited mobility but clear thinking. With the help of user journey maps, the entire process from elderly users' initial contact with smart lighting products to the end of use was carefully analyzed, accurately identifying key touchpoints, pain points, and potential opportunities (See Fig 2). These research findings provide a solid basis for formulating subsequent design strategies, ensuring that the designed smart lighting products can effectively meet the needs of elderly users.

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Fig.2 User Questionnaire

4.2 User persona construction and opportunity point mining

In the process of deeply exploring the needs of the elderly population, we focus on two core aspects: user persona construction and opportunity point mining. Relying on detailed user research data (See Fig 3), we have constructed a three-dimensional user persona system encompassing "physiology-behavior-culture" to accurately analyze the diverse characteristics of the elderly population. The elderly population is carefully divided into three typical clusters. The technologically conservative group mainly consists of solitary elderly people aged 75 and above, who experience significant physical degeneration in touch and vision. Behaviorally, they prefer familiar physical knob operations and have a high resistance to emerging health monitoring functions. Culturally, they adhere to traditional living habits. The functionally dependent group often suffers from mild cognitive impairment, and behaviorally, they rely heavily on voice interaction, but often have difficulty accurately waking up devices due to memory issues. The emotionally nostalgic group places great importance on cultural narratives in the light environment. Research shows that 83% of respondents have developed a deep emotional attachment to warm light color temperatures associated with old objects, which provides valuable entry points and directional guidance for product design and service optimization.

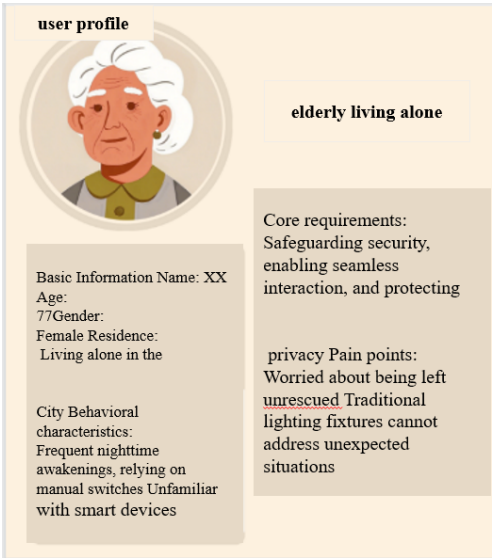

Fig.3 User persona

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Opportunity point mining focuses on four levels of breakthroughs:

1) Optimization of interaction design

Given the prevalent issue of visual decline among elderly users, they encounter difficulties in discerning minute elements and low-contrast information. Additionally, operational inconvenience poses a significant pain point during product usage. In light of this, the hardware design should feature a large-sized touch display to ensure clear visibility of displayed content. Furthermore, the use of high-contrast color combinations, such as vivid red-black and blue-white pairings, can enhance visual impact and facilitate recognition for elderly users. If physical buttons are employed, they should be sufficiently large in size and coated with anti-slip material to prevent accidental operations due to hand tremors. Additionally, distinct tactile feedback, such as slight indentations or protrusions, should be incorporated to allow elderly users to perceive the operational status through touch. In terms of operational processes, the principle of simplicity and ease of use should be adhered to, incorporating one-click operations or voice control functionalities. For instance, a dedicated "Common Mode" button can be set up, allowing elderly users to swiftly switch to their most frequently used lighting scenarios with a simple press, significantly reducing operational complexity and enabling seniors to easily grasp and enjoy the convenience brought by technology.

2) Enhanced security features

Enhancing security protection functions for users with mobility and cognitive impairments is a crucial design consideration. Due to limitations in physical function or cognitive ability, these two special user groups face numerous potential safety risks in daily life scenarios. Therefore, it is necessary to construct a comprehensive and effective security protection system specifically tailored to them. Specifically, advanced fall detection sensors can be installed in the user's activity area. These sensors utilize high-precision sensing technology and intelligent algorithms to monitor the user's body posture and movement trajectory in real time. Once a dangerous situation such as a fall is detected, the sensor will respond quickly and automatically activate the emergency lighting system to provide sufficient and appropriate lighting for the surrounding environment, avoiding secondary injuries caused by dim lighting. At the same time, the sensor will immediately send an alert containing key information such as the user's location and the time of the fall to a preset mobile terminal of a family member or a community service center, ensuring that relevant personnel are informed in a timely manner and can take rescue measures. The relevant design schematic can be seen in Fig 4.

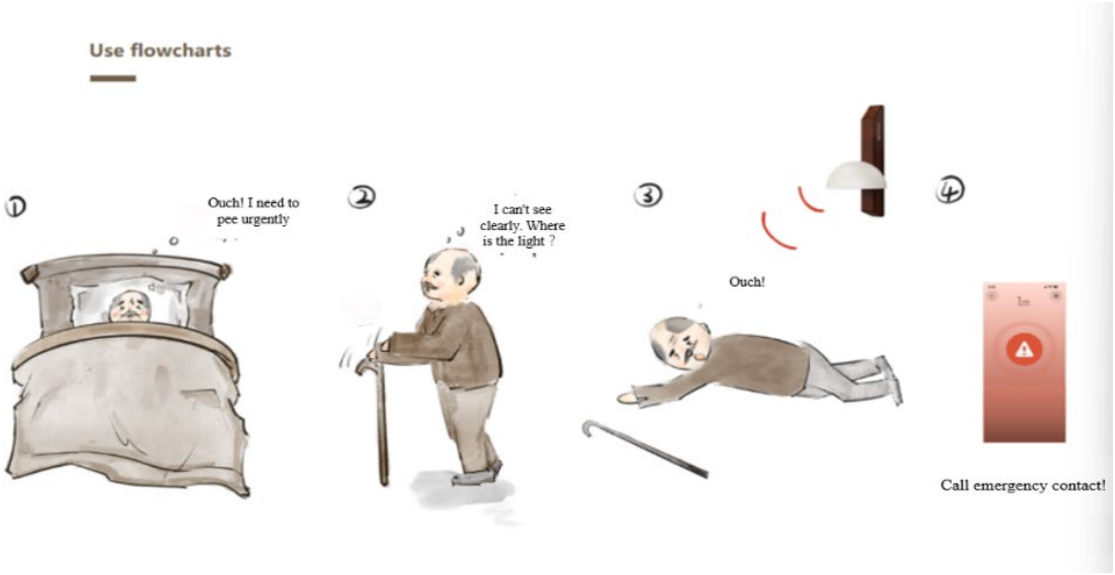

Fig.4 Flowchart

3) Personalized scene customization

In today's era of pursuing humanized and refined design, lighting design is no longer limited to simply achieving lighting functions. Instead, it requires a deep alignment with the living habits and personalized needs of different user groups, providing customized solutions. It aims to create the most suitable, comfortable, and intimate light environment for each user. For users with visual impairment, reading is an activity that requires clear light. A reading mode is specially designed, in which the lighting fixtures

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can output bright and evenly distributed light, effectively reducing shadows and glare in the reading area, avoiding the additional burden on the user's eyes caused by insufficient or unevenly distributed light, allowing users to read more easily and concentrately. For users with limited mobility, getting up in the dark at night poses many safety hazards. Therefore, a nighttime getting-up mode is designed. When the system detects the signal of the user getting up at night, it will automatically turn on the bedside lamp and hallway lamp, and precisely adjust the light brightness to an appropriate level, which will not affect the user's ability to fall asleep again due to excessively bright light, but also ensure that the user can see the surrounding environment clearly and ensure walking safety (See Fig5).

Fig.5 Schematic diagram of lighting fixtures

4) Intelligent interconnection and remote control

In today's era of rapid technological advancement and the increasing prevalence of the smart home concept, constructing a comprehensive and efficient smart home ecosystem has become pivotal in enhancing living quality and meeting diverse lifestyle needs. Among these, achieving interconnectivity between smart lighting products and other smart home devices stands as a core component in building this ecosystem. From a user experience perspective, this interconnectivity design brings immense convenience to the elderly user group. They no longer have to be constrained by traditional physical operation methods; instead, they can easily control lighting products remotely through a mobile app or smart speaker. Without having to worry about indoor lighting issues, children can remotely adjust the brightness, color temperature, and other parameters of indoor lighting through a mobile app based on the elderly's current activity scene, such as reading, resting, or dining, creating the most suitable lighting environment for them. Alternatively, the elderly themselves can also control the on/off and adjustment of lighting devices through simple voice commands using a smart speaker, greatly simplifying the operation process and enhancing the convenience of daily life. (See Fig6).

Fig.6 Schematic diagram of APP interaction4 Conclusion

ISSN 2616-7433 Vol. 7, Issue 7: 22-28, DOI: 10.25236/FSST.2025.070704

5. Conclusion

This study revolves around the aging-friendly design of smart lighting products, supported by service design methods and aging-friendly principles. It addresses the safety, operation, and inclusivity issues encountered by elderly users. Through interviews, we gain insights into their current situation and needs. By utilizing user personas and journey maps, we construct models to precisely identify key touchpoints, pain points, and opportunities. The usability verification of the prototype product demonstrates that the service design approach effectively taps into the smart needs of elderly users. The proposed solution is highly inclusive, meeting diverse needs and enhancing satisfaction. This study provides practical evidence for the aging-friendly design of smart lighting and serves as a reference for the aging-friendly research of other smart products. In the future, we will continue to deepen our research, promoting its development towards greater humanization and intelligence, allowing elderly users to enjoy the convenience of technology.

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