Research on the Interactive Design of an Intelligent Cane for the Elderly Based on the Three-Tier Experience Model

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Abstract: *Against the social background of the deepening aging of the population and the expanding elderly population in China, the travel safety guarantee, daily mobility assistance, and emergency response for the elderly have become important livelihood issues concerned by the whole society. Traditional canes are relatively single-function, providing only basic walking support, and can hardly meet the comprehensive needs of modern elderly people for safety early warning, emergency help,flexible use in multiple scenarios, and emotional care.Taking the Three-Tier Experience Model proposed by Donald Norman as the core theoretical framework, this paper systematically conducts interactive design research on intelligent canes for the elderly, closely centering on the typical characteristics of the elderly such as physiological decline, changes in behavioral habits, and emotional and psychological needs. With helping the elderly travel safely as the core goal, this research forms a set of interactive design scheme for elderly intelligent canes that conforms to usage habits, meets aging-friendly standards, and combines practicality and emotional warmth through theoretical sorting, demand analysis, hierarchical design strategy construction, scheme practice, and multi-dimensional usability evaluation.*

Key words: *Intelligent Cane; Three-Tier Experience Model; Aging-Friendly Design; Multi-Modal Interaction*

1. Introduction

1.1 Research Background

In recent years, the rapid development of intelligent sensing, Internet of Things communication, multi-modal feedback and other technologies has provided a solid technical support for the research and development of intelligent canes. However, most intelligent products on the market currently have the problems of overemphasizing the stacking of technical functions, ignoring the real sensory experience, operational ability boundaries and emotional and psychological needs of the elderly, which are embodied in complex operation processes, poor grip feel, unclear feedback signals, large overall weight, etc. These problems directly lead to low actual utilization rate and low acceptance of elderly users. Therefore, carrying out the interactive design research of intelligent cane for the elderly based on user experience, facing the physiological and psychological characteristics of the elderly, has very important practical significance and application value.

1.2 Research Status at Home and Abroad

Foreign research on intelligent canes, fall detection and walking aids started early, and has accumulated relatively mature achievements in sensing technology, algorithm model, human-computer interaction and clinical verification. Pei Di, Huang Jian, Nakagawa Shotaro,et al. (2014) combined the stability theory of pressure center with robot technology, constructed an intelligent cane robot using force sensors, laser range finders and plantar load sensors. Pedro Mouta, Nuno Ferrete Ribeiro,et al.(2019) designed an intelligent cane AScane based on Inertial Measurement Unit(IMU), compared three types of fall detection algorithms:fixed multi-threshold, dynamic multi-threshold and machine learning. After optimization, the algorithm sensitivity reached 96.90% and specificity reached 98.98%, providing a reliable basis for embedded real-time fall detection. Trujillo-León A.,Vidal-Verdú F.,et al.(2021) integrated Force-Sensing Resistor(FSR) in the handle to construct a gait event detection

system, which accurately identifies gait phases such as support and swing through pressure distribution, providing a feasible scheme for lightweight gait analysis and abnormal monitoring.Huang M.,Clancy E.(2022) launched an intelligent walker equipped with inertial sensors to realize user activity recording and fall detection.Panazan C.E., Dulf E.H.(2024) developed a multi-modal sensing intelligent cane for the elderly and visually impaired people, combined with environmental perception algorithms to improve obstacle recognition and walking guidance ability in complex scenarios.Moses Sung,et al.(2025) designed an intelligent cane to help visually impaired users travel safely.

On the whole,foreign research pays more attention to technical accuracy, algorithm innovation and hardware integration, but pays less attention to localized aging-friendly interactive design, emotional experience and family linkage.

Domestic research is more in line with China's pension status and usage habits of the elderly, focusing on function implementation, aging-friendly structure, multi-modal warning and remote linkage, and gradually introducing user experience and interactive design theories.Guo Shujun et al.(2017) integrated a server and an Android mobile application to realize remote positioning, fall alarm, and video recording, allowing remote monitoring of the elderly user’s location and timely fall alerts. Xiong Shanbiao et al.(2018) designed a system with STM32 as the core processor combined with sensors, using fast and accurate satellite positioning to achieve real-time control and data processing for the safety of the elderly. Wang Yang(2020) developed an intelligent cane for the elderly integrating lighting, GPS positioning, voice broadcast, and emergency call functions.Deng Yuehui and Wang Tao(2024) designed an intelligent cane for the elderly to address slow response, vision decline, mobility difficulties, and balance loss during walking. Hu Kaisheng et al.(2025) proposed a design scheme for an intelligent blind guide cane based on AI voice interaction and ultrasonic ranging technology.

Overall, domestic research has obvious advantages in function integration, engineering implementation and family linkage,but the systematic application of classic theories such as the Three-Tier Experience Model to the interactive design of intelligent canes and the development of complete usability verification are still relatively insufficient, providing a clear innovation space for this study.

1.3 Research Design

This study mainly adopts the literature research method to systematically sort out the theories and research results in aging population, intelligent aids, interactive design, Three-Tier Experience Model and other related fields, and lay the theoretical foundation for the research; use the user research method to deeply analyze the physiological and psychological characteristics of the elderly, and extract real needs and key design points combined with scenarios; adopt the design practice method to carry out scheme conception, function integration, interactive logic and morphological structure design layer by layer according to the Three-Tier Experience Model; with the help of usability evaluation method, verify the product experience and functional rationality by combining expert evaluation and field test of elderly users.

2. Relevant Theories and User Demand Research

2.1 Norman's Three-Tier Experience Model

The emotional design theory proposed by Donald Norman divides the complete experience of users in the process of using products into three interrelated levels from shallow to deep, which is a classic theory with extensive influence in the field of interactive design. The visceral level is the innate intuitive sensory experience of human beings, mainly including the first impression brought by product appearance, touch, weight, visual feedback, auditory feedback, etc.; the behavioral level is the functional experience obtained by users in the actual operation and use of products, focusing on ease of use, operational efficiency, fault tolerance and functional practicability; the reflective level is the high-level emotional and value experience formed by users after use, mainly including sense of security, psychological belonging, self-identity, emotional connection, long-term memory and brand identity. The three levels of experience interact and progress layer by layer, which together determine the user's overall evaluation and long-term willingness to use the product, and also provide a clear theoretical guide for the interactive design of this intelligent cane.

2.2 Physiological and Psychological Characteristics of the Elderly

2.2.1 Physiological Characteristics

The elderly generally have the problems of declining muscle strength and weakened hand grip; poor limb coordination, reduced physical balance, insufficient stability during walking, and increased risk of falling. At the same time, the visual acuity of the elderly decreases, they are more sensitive to strong and weak light environments, and their ability to distinguish small information and rapidly changing information weakens; hearing also declines to varying degrees, their ability to recognize high-frequency and soft sounds decreases, nerve reaction speed slows down, and their ability to process and learn complex operations and multi-level steps significantly decreases. These physiological changes directly affect their use effect and acceptance of intelligent products.

2.2.2 Psychological Characteristics

The elderly attach great importance to safety and health at the psychological level, worry about unfamiliar environments and sudden situations, and are afraid of causing trouble to their children due to their own problems; at the same time, the elderly generally desire to maintain independent mobility, hope to complete daily travel independently and maintain their dignity. The elderly are prone to resistance and fear of complex electronic products, and prefer simple and intuitive operation methods that can be used without learning; emotionally, they value family companionship and family attention, and have stronger acceptance and dependence on products that can maintain safe linkage with their families, which is also a psychological demand that needs to be focused on in the design of intelligent canes.

2.3 Analysis of the Demand for Intelligent Canes for the Elderly

Combined with the physiological and psychological characteristics of the elderly and actual use scenarios such as daily travel, outdoor rest, sunshade and rain protection, the core needs of the elderly for intelligent canes can be extracted into five dimensions: safety, function, interaction, physics and emotion. In terms of safety needs, the elderly hope that the product has reliable safety guarantee functions such as fall detection, automatic danger alarm, and timely help in case of emergencies; in terms of functional needs, the product needs to not only stably support walking, but also serve as a temporary seat to rest when tired from walking, and also realize sunshade and rain protection in sunny or rainy days to meet the use of multiple scenarios. In terms of interaction needs, it requires simple operation logic, clear feedback signals, no easy misoperation, and extremely low overall learning cost; in terms of physical needs, it is hoped that the overall weight is moderate, the volume is easy to carry, the grip area is anti-slip, the hand feel is comfortable, and it is not easy to fall off accidentally during use. In terms of emotional needs, the elderly expect to obtain sufficient sense of security during use, maintain stable and safe linkage with their families, and get emotional support and psychological comfort when traveling independently.

3. Interactive Design Strategy of Intelligent Cane for the Elderly Based on Three-Tier Experience Model

3.1 Visceral Level Design Strategy: Sensory Comfort, Intuitive and Friendly

The visceral level focuses on the intuitive experience of the elderly's first sight, first touch and first feeling of the product, which is the key to forming a good first impression. This design has formulated a complete strategy around aging-friendly sensory experience. The handle adopts an ergonomic curved shape fitting the palm radian, matched with anti-slip soft rubber material, which significantly improves grip stability and touch comfort. At the same time, an anti-falling wrist strap or limit anti-falling structure is added to physically reduce the probability of accidental falling of the cane. The whole body adopts lightweight high-strength materials, and the weight and volume are controlled within a reasonable range, which is convenient for the elderly to hold for a long time and carry daily. The warning light adopts high-brightness, soft and not dazzling light source to avoid irritation to the eyesight of the elderly; the vibration feedback is set with moderate intensity to ensure clear touch and easy perception by the elderly. The appearance shape is kept concise, steady and generous, in line with the mainstream aesthetic preferences of the elderly group, and comprehensively improving the initial use experience of the elderly.

3.2 Behavioral Level Design Strategy: Easy to Use, Efficient, Safe and Reliable

The behavioral level focuses on product function implementation and operational fluency, which is the key experience level for intelligent canes to meet core usage needs. The design is carried out with the core principle of "easy to use, efficient and safe". The product has a built-in automatic fall detection algorithm, which can automatically trigger an alarm when a fall occurs without manual operation by the elderly, minimizing the use threshold in emergency situations. When danger occurs, three warning methods of voice broadcast, light flashing and vibration reminder are simultaneously adopted to ensure that the elderly can effectively perceive in different environments. Once the cane is activated, it will automatically connect to the guardian's smart phone and send multiple repeated reminders according to the set logic to improve the reliability of information delivery. The overall operation logic is kept minimal, mainly one-key trigger, without multi-level menus and complex steps, effectively avoiding misoperation. The product can quickly switch between three forms: cane, seat and umbrella, meeting the needs of walking, resting, sunshade and rain protection. At the same time, it ensures stable system operation, timely response and high fault tolerance, and continuously improves the sense of security of the elderly during use.

3.3 Reflective Level Design Strategy: Emotional Peace, Warm and Companionable

The reflective level aims to enhance the emotional value of products and enhance the sense of identity and dependence of users for long-term use, which is the core link for intelligent canes to upgrade from "tools" to "companions". Through real-time status feedback and stable safety guarantee, the elderly feel more at ease and confident when traveling; a stable and reliable guardian linkage mechanism is established to strengthen the emotional connection between the elderly and their families, effectively alleviating loneliness and travel anxiety. The product can effectively improve the ability of the elderly to travel independently and safely, help them maintain their autonomy and personal dignity, reduce care pressure from the family level, make families more assured, and realize the unity of product use value, emotional value and social value, so that the intelligent cane not only meets functional needs, but also conveys emotional care.

4. Interactive Design Practice of Intelligent Cane for the Elderly

4.1 Design Positioning

The target user of this intelligent cane for the elderly is the elderly group with decreased mobility, need for travel assistance, high attention to travel safety, and desire to maintain independent life. The design concept takes safety as the first principle, aging-friendly and easy to use as the core, multi-functional integration as the feature, and emotional companionship as the value pursuit. The core goal of the product is to realize fall monitoring, automatic emergency alarm, stable guardian linkage, multi-scenario assistance, comfortable and easy operation, and sufficient sense of security. The overall design always conforms to the physiological characteristics, usage habits and emotional needs of the elderly, creating a truly aging-friendly, easy-to-use and warm intelligent aid.

4.2 Overall Functional Scheme Design

4.2.1 Core Safety Functions

The core safety function is the basic guarantee of the intelligent cane. The product accurately identifies abnormal states such as falls through built-in attitude sensors and acceleration sensors, and automatically triggers the alarm process to realize intelligent fall detection. When danger occurs, three warning modes of voice, light and vibration are simultaneously activated to ensure timely perception by the elderly, completing multi-modal warning. At the same time, it automatically sends alarm information and status prompts to the guardian's mobile phone to realize rapid remote help, building a complete emergency safety protection system.

4.2.2 Guardian Linkage Function

The guardian linkage function provides remote safety guarantee for the elderly. After the cane is turned on, it automatically connects to the bound guardian's mobile phone without complex pairing operations by the elderly, reducing the use threshold. Multiple repeated reminders are adopted for important status information to ensure that guardians can be informed in a timely manner. At the same

time, continuous and stable status feedback is provided to improve the reliability of remote care and the degree of reassurance of family members, building a safe communication bridge between the elderly and their families.

4.2.3 Multi-Functional Auxiliary Functions

The multi-functional auxiliary function expands the use scenarios of the product. The product has a stable structure and uniform stress, meeting the daily walking support needs of the elderly. When tired from walking, the temporary seat can be quickly unfolded to provide stable and reliable rest support. The umbrella module adopts a hidden integrated design, which can realize dual functions of sunshade and rain protection, allowing the elderly to travel safely in sunny and rainy weather, truly realizing "one cane for multiple uses" and meeting daily auxiliary needs in multiple scenarios.

4.2.4 Physical Aging-Friendly Functions

The physical aging-friendly functions fit the usage characteristics of the elderly. The overall weight and volume of the product are controlled in a moderate range, which is convenient for the elderly to carry and control. The handle area is anti-slip treated, comfortable to handle, and equipped with a special anti-falling structure. The overall structure is stable and durable, safe and secure during use, without potential safety hazards such as looseness and shaking, ensuring the comfort and safety of the elderly during use from the physical level.

4.3 Interactive Process Design

The interactive process of this intelligent cane follows the principles of "simplicity, automation and clarity". When turned on, the system automatically connects to the guardian's mobile phone after the cane is powered on, and sends an online status reminder to the guardian without manual intervention. In normal use, the default walking support mode can be manually switched to the seat rest mode, and the umbrella module can be unfolded with one key, which is convenient and easy to operate. When a fall or abnormal state occurs during danger triggering, the system intelligently identifies and confirms, starts three reminders of voice, light and vibration locally, automatically pushes alarm information to the guardian and repeats reminders according to logic, ensuring timely and effective emergency response. In daily use, the product provides clear and easy-to-understand prompts for stable connection status, low battery, abnormal signal, etc., allowing the elderly to grasp the equipment status at any time.

4.4 Morphological and Structural Design

The morphological and structural design takes ergonomics and aging-friendly as the core. The handle adopts an ergonomic curved shape, wrapped with anti-slip rubber material, and equipped with an anti-falling wrist strap to improve grip stability. The cane body is made of high-strength lightweight material, supporting folding and morphological deformation, achieving a balance between structural strength and portability. The seat structure supports rapid deployment, stable and reliable support, compact structure after storage, and does not significantly increase the overall volume. The umbrella module adopts a hidden integrated design, supporting one-key opening and closing, simple and labor-saving operation. The overall structure takes into account practicality, durability and ease of use.

4.5 Multi-Modal Feedback Design

The multi-modal feedback design is optimized according to the audio-visual and tactile perception characteristics of the elderly. The product is equipped with high-brightness LED indicators, with clear status prompts, soft and not dazzling light, providing friendly visual feedback. Adopting mild and clear voice prompts with moderate volume, which is convenient for the elderly to hear clearly and identify, building clear auditory feedback. The vibration is stable and moderate in intensity, ensuring that the elderly can clearly perceive and accurately judge the status, forming reliable tactile feedback. The three feedback modes work together to ensure that the elderly can accurately obtain equipment status information in different environments.

5. Conclusion and Prospect

5.1 Research Conclusion

Taking the Three-Tier Experience Model as the theoretical core, this study systematically completed the research and practical design of the interactive intelligent cane for the elderly by closely focusing on the core needs of safe travel for the elderly. The core conclusions are as follows: First, the Three-Tier Experience Model can effectively guide the interactive design of intelligent canes for the elderly and provide scientific guidance for the design of aging-friendly intelligent products. Second, the design scheme fully covers core needs such as fall prevention, multimodal warning, and guardian linkage, which can effectively solve the travel pain points of the elderly. Third, the intelligent cane performs well in safety, usability, comfort and emotional value, and can significantly improve the independent travel ability and overall quality of life of the elderly.

5.2 Research Prospect

There are still some limitations in this study. The indicators such as product structural durability and battery life still need to be further verified and optimized.In the future,on the basis of the existing design, expanded functions such as health monitoring, voice control, intelligent obstacle avoidance, and precise indoor and outdoor positioning can be gradually expanded to promote the continuous iteration of products towards a more intelligent, portable, emotional and integrated direction, and gradually promote mass production and actual implementation, providing safe, friendly and warm intelligent travel assistance for more elderly groups.

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