

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

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Abstract: With changes in society and an increase in the number of older people in China, so too has this problem. Therefore, ensuring the travel safety, daily life assistance and emergency response of older people has become an urgent livelihood problem for all sectors of society. Traditional canes have only one function and can provide basic walking support; they do not meet all the various needs of modern older adults, such as safety alarms, emergency calls, flexible use in different situations, emotional support, etc. According to the three-tier experience model put forward by Donald Norman, this paper will carry out Interaction Design research on intelligent canes for older adults and consider the general characteristics of older people, namely physiological decline, changes in behaviour, and emotional and psychological needs. The main purpose of this paper is to help older people travel safely, and with this goal in mind, an interactive Design Scheme for elderly intelligent canes that meets their living conditions and complies with aging-friendly standards has been developed through theoretical classification, demand analysis, construction of the hierarchical design strategy, scheme practice and multi-dimensional usability evaluation.

Keywords: Smart Cane, Three-tier Experience Model, Age-friendly Design, Multi-modal Interaction are the keywords

1. Introduction

1.1 Research Background

In recent years, with the rapid development of intelligent sensing, Internet of Things communication, multi-modal feedback and other technologies, a strong technical foundation has been provided for the research and development of intelligent canes. Most of the intelligent products in the market today have a problem of focusing too much on stacking technical functions and neglecting real sensory experience, as well as the boundaries of operational ability and emotional and psychological needs of older adults; this can be seen from complex operation processes, poor grip feel, unclear feedback signals, large overall weight, etc. Thus, there are only a few actual users and little adoption among older people. Therefore, interactive Design research on intelligent canes for older people based on user experience and taking into account the physiological and psychological characteristics of older persons will have good practical and application value.

1.2 Research Status at Home and Abroad

Foreign research on intelligent canes, fall detection and walking aids started earlier, and good results have been obtained in sensing technology, algorithm model, human-computer interaction and clinical verification. Pei Di, Huang Jian, Nakagawa Shotaro and others (2014) have integrated the stability theory of the pressure centre with robot technology to develop an intelligent cane robot that is equipped with force sensors, laser rangefinders and plantar load sensors. Pedro Mouta, Nuno Ferrete Ribeiro and others (2019) have built an intelligent cane-based fall-detection system with an IMU and have compared three kinds of fall-detection algorithms: fixed multi-threshold, dynamic multi-threshold and machine learning. Some improvements have been made, and now the sensitivity and specificity of the algorithm are 96.90% and 98.98%, respectively; it can detect falls in an embedded real-time system accurately. Trujillo-León A., Vidal-Verdú F. and others (2021) added a Force-Sensing Resistor (FSR) to the handle and constructed a gait event detection system; based on the pressure distribution of the foot,

all periods in a person's walk, such as support and swing, can be recognised. Huang M. and Clancy E. (2022) have released an intelligent walker with an inertial sensor that can observe people's behaviour and detect falls. Panazan C.E. and Dulf E.H. (2024) have developed an intelligent cane with all kinds of sensors and environmental perception algorithms to help older people and people with poor eyesight better detect obstacles and live safely in crowded places. Moses Sung and others (2025) have developed an intelligent cane to help people with poor vision live safely.

Most of the foreign research has focused on technical accuracy, algorithm innovation and hardware integration, but it has paid less attention to localised age-friendly interactive design, emotional experience and family connection.

Research at home is closely related to China's pension system and the living standards of older people, so it focuses on functional implementation, the structure of ageing in place, multi-modal alarms and remote connection, etc., and is gradually integrating theories of user experience and interactive design. Guo Shujun and others (2017) have built a server and an Android mobile application to realise remote positioning, fall alarms, video recording and remote monitoring of the location of elderly people, and timely fall alerts. Xiong Shanbiao and others (2018) have developed a system based on the STM32 main chip, and with the help of sensors, fast and accurate satellite positioning can be achieved for real-time control and data processing of the safety of older people. Wang Yang (2020) has developed an intelligent cane for older people that has lights, GPS positioning, voice broadcasting, an emergency call function, etc. Deng Yuehui and Wang Tao (2024) have also developed an intelligent cane for older people to solve the problems of a slow response time, reduced vision, mobility difficulties and loss of balance in walking. Hu Kaisheng and others (2025) have put forward a Design Scheme for an intelligent blind guide cane based on AI voice interaction and ultrasonic ranging technology.

Although most of the domestic research has achieved good results in the areas of functional integration, engineering implementation and family linkage, there is still a lack of systematic application of classic theories, such as the Three-Tier Experience Model, to the interactive design of intelligent canes and the development of comprehensive usability verification; thus, this paper offers a new direction for innovation.

1.3 Research Design

Based on the above, this paper will use the method of literature research to collect theories and research results on topics such as aging populations, intelligent aids, interactive design, the Three-Tier Experience Model, etc., to provide a theoretical basis for this study; it will employ the method of user research to understand the physical and mental characteristics of older people, uncover their actual needs and required Design points in various situations; it will apply the method of design practice to develop Design Schemes, integrate functions, construct interactive logic and structure morphology at all levels according to the Three-Tier Experience Model; finally, with the help of the usability evaluation method, experts and older adults will carry out assessments and field tests to verify the experience and functional rationality of the product.

2. Related Theories and User Demand Research

2.1 Norman's Three-Tier Experience Model

Donald Norman's theory of emotional design divides the whole experience of users in their use of products into three related levels, from shallow to deep; it is a very typical theory that has had a wide impact on the field of interactive design. Visceral level refers to the fundamental intuitive sense of people; generally speaking, it is the first impression people have of a product, such as its appearance, feel, weight, visual feedback, sound, etc. Behaviour level refers to the functional experience that users obtain through the actual operation and use of products, and it is concerned with ease of use, operational efficiency, fault tolerance and functional practicality. A sense of reflection is a kind of high-level emotion and value experience that users have formed after using a product; generally, it includes feelings of safety, a sense of belonging, self-identity, emotional connection, long-term memory and brand consciousness. The three levels of experience are related and build on one another; together they form a person's general awareness and extended interest in using a product, and also provide an explicit theoretical basis for the interactive Design of this intelligent cane.

2.2 Physiological and Psychological Characteristics of Older Adults

2.2.1 Physiological attributes

Older people generally have weaker muscles and reduced hand-grip strength; they have poor limb coordination, reduced physical balance and stability in walking, are more prone to falling, etc. At the same time, the eyes of older people are also deteriorating; they are more sensitive to bright and dim light, can no longer see fine details and changes in their surroundings well, and their hearing has also decreased to some extent. They are less likely to perceive high-pitched and faint sounds, their nerves react more slowly, and their ability to learn and perform complex, multi-step operations has been greatly reduced. The changes in physiology mentioned above will directly affect how people use and accept smart products.

2.2.2 Psychological Traits

Older people are very concerned about safety and health psychologically; they feel anxious in unfamiliar places and during emergencies, and they are afraid of causing trouble for their children because of health problems. At the same time, most older people want to live independently and hope to be able to manage their own lives with dignity. Older people are more likely to feel resistant and afraid of complicated electronic products, so they prefer simple and intuitive operation that does not require learning. Emotionally, they desire the company and attention of family, so they are more willing to accept and rely on products that can give them a sense of security with their families; this is also a psychological need that should be taken into account in the design of intelligent canes.

2.3 Analysis of the Demand for Intelligent Canes for the Elderly

Given the physiological and psychological characteristics of older people, as well as their actual circumstances in daily life, such as going out, resting in the open air, seeking shade and shelter from rain, etc., five basic demands for intelligent canes have been identified: safety, function, interaction, physics and emotion. For the safety needs of older people, they hope that the product has a dependable safety guarantee function, such as fall detection, an automatic danger alarm, and timely help in case of an emergency; for functional requirements, the product should be able to support stable walking, provide a place to rest when tired from walking, and also have sunshade and rain protection in all kinds of weather. In terms of interaction requirements, it should have a simple operation logic, clear feedback signals, be immune to easy misoperation, and have a very low overall learning cost; for physical needs, it is hoped that the total weight is moderate, the volume is small and easy to carry, the grip area is non-slip, the hand-feel is good, and it should not be easily dropped while in use. Older people want to be able to live independently and safely, stay in touch with their families regularly, and have a sense of security and emotional support in their later years.

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

3.1 Design Strategy at the Visceral Level: Sensory Comfort, Intuition and Friendliness

Visceral level refers to the first, intuitive sense an older person has upon seeing, touching and feeling a product for the first time, and it is necessary to create a good first impression. Therefore, an all-encompassing plan for the sense of ageing-friendliness has been developed. It has a bend that fits the radius of the palm, is made of non-slip soft rubber, and is easy to hold and gentle to the touch. At the same time, an anti-fall wrist strap or a limit anti-fall device will be attached to prevent accidental falls of the cane. Lightweight high-strength materials are used for the whole body, and it has a small weight and volume; thus, it is convenient for older people to hold it for a long time and carry it every day. The warning light should have a high brightness, be gentle and not glaring to protect the eyes of older people, and the vibration feedback should have a moderate intensity so that older people can feel it easily and be notified promptly. Considering the aesthetic needs of older people, it should have a simple, unadorned and generous shape, and it should also improve the initial sense of usability for older adults.

3.2 Design Strategy at the Behavioural Level: Easy-to-use, Efficient, Safe and Reliable

Behavioural level refers to how people will use and feel about the product; it is the basic sense of

desire that people hope to obtain from smart canes. The first goal of the Design is to make it simple to operate, effective and safe. There is an automatic fall-detection algorithm in the product, and if an older person falls, it will sound an alarm; it does not need to be operated manually and can automatically call for help in the event of a fall. If it is determined that a warning needs to be issued, all three types of warnings (sound, light and vibration) will be activated at the same time to ensure that older people are informed promptly. When the cane is pressed, it will automatically connect to the guardian's mobile phone and send several repeated notifications according to the set rules to confirm that the information has been received. The entire operating logic is relatively simple, and as it only has a one-key start operation, it is unlikely to be used incorrectly. The three types of products are cane, a chair and an umbrella; they can be used to walk, sit, block the sun, etc. At the same time, it will maintain the stability of the system, promptly deal with problems, have good fault tolerance, and continuously improve the security for older people.

3.3 Design Strategy for Reflective Level: Emotional Peace, Warmth and Companionship

The aim of the above is to attract people's attention to the product, increase their sense of self-worth and dependence on it, and thus hope that the intelligent cane will be regarded as a "friend" rather than merely a "tool". Promptly inform people of any change in circumstances, ensure the safety of older persons, help them feel more at ease and confident during travel, build a stable and dependable guardian-link system, strengthen the emotional ties between older persons and their families, and reduce loneliness and anxiety about travel. The product can help older people live independently and safely in their later years, maintain their sense of self and dignity, reduce the burden on family caregivers, provide psychological support for families, and achieve the integration of functional needs with emotional and social needs; thus, an intelligent cane should not only have good functions but also touch hearts.

4. Interactive Design Practice of Intelligent Cane for the Elderly

4.1 Design Position

The main subjects of this intelligent cane for older adults are older people with reduced mobility who need help getting around, are very concerned about travel safety, and wish to live independently. The Design Concept is to prioritise safety, be age-friendly and easy to operate, have many functions, and offer emotional support for people of all ages. It should be able to detect falls automatically and send an emergency signal; it needs to be stable and reliable, have several operating modes, be user-friendly and secure, etc. The whole Design always considers the physical condition, daily life and emotional needs of older people, so it is truly age-friendly, simple to operate and warm.

4.2 General Functional Scheme Design

4.2.1 First Aid Functions

The first goal of an intelligent cane is to provide basic safety. An attitude sensor and an acceleration sensor can be employed to determine if there is a fault in the product, issue an automatic alarm, and thus realise intelligent fall detection. If there is a hazard, all three kinds of alarms will be triggered simultaneously to quickly notify older people through all sorts of channels. At the same time, an alarm notification and a status prompt will be sent to the guardian's mobile phone for early warning in bad weather.

4.2.2 Guardian Linkage Function

There is a Guardian Link for older people at home. The switch is in the ON position, and it will automatically connect to the mobile phone of the designated guardian; we no longer need to pair manually with the elderly person. Some repeated reminders will be sent out about the important status information so that guardians can be aware of it in advance. At the same time, continuous and stable status feedback will be provided to improve the reliability of remote care, give some peace of mind to the family members, and thus establish a secure communication path for older people and their families.

4.2.3 Some Auxiliary Functions

A few other uses for this product have also been added. It is a regular shape and has an even stress distribution, so it can help older people walk normally. When one is tired of walking, the portable seat

can be unfolded quickly for a short rest. The design of the umbrella module is to hide its function; thus, it can offer shade from the sun and also protect people from rain. Therefore, older people will be able to go out in good weather and achieve the goal of a "single cane for multiple uses" in all aspects of daily life.

4.2.4 Physical Age-Friendly Functions

The first two are suitable for the needs of older people. The total weight and size of the product are relatively small, so it will be more convenient for older people to carry and use. The Area of the handle is not uniform; it is easy to hold, and there is an anti-fall device. It has a good general shape and is durable; it is safe to use, and there are no loose parts or vibrations that could harm older people.

4.3 Interactive Process Design

The way people use the smart cane meets the demand for "simplicity, automation and clarity". Power on the system, and it will automatically connect to the guardian's mobile phone upon the start of cane movement, send an online status notification to the guardian, and no other operation needs to be carried out. The default walking support mode can be changed to the manual seat-rest mode normally, and by pressing one key, both the umbrella module and the seat-rest function can be turned on. If there is a fall or another dangerous situation, the system will detect and confirm it; then, three local reminders will be sent via voice, light and vibration, the alarm information will be automatically sent to the guardian, and repeated operations according to logic will be carried out to ensure an early emergency response. The product can show the connection status of the equipment, low-battery warnings, abnormal signals, and so on; thus, older people will be informed of any problems with the equipment in time.

4.4 Morphological and Structural Design

Ergonomics and aging-in-place are the main ideas of the form and structure design. It is curved, has a good feel in the hand, is non-slip rubber, and has an anti-fall wrist strap for better grip. Cane body is a strong, light material that can be folded and shaped in many ways; thus, it has good strength and portability. A seat frame is relatively portable, stable and reliable; it is a small item that does not take up much storage space. The umbrella module should be hidden and integrated, and it can be opened and closed by pressing one key. It is practical, durable and convenient for the people to use.

4.5 Multi-modal Feedback Design

All kinds of feedback have been modified according to the hearing and touch sensitivity of older people. A bright-light-emitting diode (LED) indicator will be used to show the current status clearly, and it is soft and does not cause glare. Speak softly but clearly at a moderate volume so that older people can hear you easily and know that you are talking to them. The amplitude of the vibration is small and constant; therefore, older people can feel it and judge their own health accurately through touch. The three types of feedback can help older people know the present state of the equipment in various places.

5. Conclusion and Outlook

5.1 Research Summary

Based on the theoretical foundation of the Three-Tier Experience Model, systematic research and practical design work have been carried out in this paper on an interactive intelligent cane for the basic need of safe travel for older people. The first is that the Three-Tier Experience Model can be applied to the Interaction Design of intelligent canes for older people to provide a scientific basis for the design of intelligent products that promote aging in place. Second, the Design Plan will cover the general requirements for fall prevention, multi-modal warning and guardian linkage, etc., to reduce the travel difficulties of older people. Thirdly, the intelligent cane is safe and convenient to use, comfortable, has a good emotional connotation, and can help older people live independently and happily in their later years.

5.2 Research Direction

There are still some defects in this study. The indices of the durability of the product structure and battery life have not been fully verified or optimised yet. In the future, based on the current Design, expanded functions such as health monitoring, voice control, intelligent obstacle avoidance, precise indoor and outdoor positioning, etc., will be gradually added to continuously improve the products and provide a more intelligent, portable, emotional and integrated way of life, and mass production and actual application will be promoted to offer safe, friendly and warm intelligent travel assistance for more elderly people.

References

- [1] Deng Yuehui,Wang Tao.Design and Application of Multifunctional Intelligent Cane Based on STM32F103RCT6.Industrial Control Computer, 2024,37(01):172-173+175.
- [2] Dong H,McGinley C,et al.Designing for designers.Insights into theknowledge users of inclusive design.Applied ergonomics,2015,46:284-291.
- [3] Hu Hong,Wu Yiyiing.Research on Aging-Design of Elderly Public Seats Based on Prosperity Experience Model.Design,2023,36(18):128-131.
- [4] Hu Kaisheng,Wang Xu.Intelligent Blind Guide Cane:Collaborative Design of AI Voice Interaction Core Technology and Ultrasonic Ranging.Science and Technology Innovation, 2025(16):219-222.
- [5] Kim K S,et al.Empirical research on an ecological interface design for improving situation awareness of operators in an advanced control room.Nuclear Engineering and Design,2012,253226-237.
- [6] Li Yongfeng,Liu Huanhuan,et al.User Experience Optimization Design Method of Elderly APP Based on Kano Model and Conjoint Analysis.Packaging Engineering,2021,42(02):77-85.
- [7] Moses Sung,Geun-Bae Jun,Da-Hyun Woo.Design of Intelligent Cane to Help Visually Impaired People Avoid Obstacles Effectively.Industrial Design,2025(10):14.
- [8] Stark M S,et al.A task to assess behavioral pattern separation (BPS) in humans: Data from healthy aging and mild cognitive impairment.Neuropsychologia,2013,51(12):2442-2449.
- [9] Wang Cuijie,et al.Classification of Interaction Modes for Interactive Devices and Research on the Influence of Display Attributes.Chinese Journal of Ergonomics,2011,17(03): 5-9.
- [10] Xiong Shanbiao,Ding Cunxin,Cai Mindong.Design of Multifunctional Intelligent Cane System Based on STM32.Shandong Industrial Technology, 2018(02):107.