Research on Elderly-Oriented Design of Pet Travel Products Based on Embodied Cognition Theory

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Abstract. Objective Aiming at the physical imbalance and safety risks caused by pets' sudden rushing when elderly users use traditional pet walking products, this paper analyzes the cognitive characteristics and usage demands of elderly users based on embodied cognition theory. It proposes elderly-oriented design strategies for pet travel products, so as to ensure the safety of the elderly when going out with pets and improve their well-being of keeping pets. Methods Firstly, scenario observation, user interview and other methods were adopted to conduct user journey analysis on the whole process of the elderly going out with pets, and systematically sort out user demands. Secondly, based on embodied cognition theory, this paper summarized the physiological perception and movement feedback characteristics of the elderly in the behaviors of going out with pets, and analyzed and classified travel demands. Finally, the Analytic Hierarchy Process (AHP) was used to quantitatively evaluate the weight of each user demand and determine the priority of user demands. On this basis, the elderly-oriented design principles for such products were put forward. Conclusion Understanding and analyzing the core demands of the elderly when going out with pets from the perspective of embodied cognition and proposing elderly-oriented design principles for pet travel products can provide reference ideas and practical paths for the design of similar products.

Keywords: Product Design, Elderly-oriented Design, Embodied Cognition, AHP

1. Introduction

By the end of 2025, China's total population reached 1,404.89 million, among which the population aged 60 and above was 323.38 million, accounting for 23.0% of the total population. The population aged 65 and above stood at 223.65 million, taking up 15.9% of the total population. China has entered a deeply aging society [1]. In 2025, China's pet consumption market grew steadily, and the consumption scale of urban pets (dogs and cats) reached 312.6 billion yuan. It is expected that China's pet consumption market will continue to expand in the future [2]. Existing studies have shown that pet ownership (especially dog keeping) can exert positive effects on the physical functions, physical health and mental health of the elderly [3-6]. Against the background of "raising pets in a parenting style", an increasing number of elderly people choose to keep pets to seek emotional companionship and relieve loneliness. According to market research, the elderly group shows strong willingness in pet consumption and possesses huge consumption potential of the silver economy, yet there is a notable gap in the pet product market targeting the elderly [7], leaving broad room for the development of elderly-oriented design of pet products.

A 2025 survey indicates that pet owners have a high demand for going out with pets, which accounts for 71% of pet owners. The pet travel market boasts great development potential [2]. Current mainstream pet travel products on the market mainly include pet leashes, pet backpacks, pet strollers and so on. There are also a type of relatively intelligent pet supplies, such as smart collars and anti-lost trackers [8, 9]. However, for short-distance outdoor travel scenarios, all existing products adopt traditional leash-based control modes [9]. Insufficient attention is paid to the human-pet collaborative safety brought by the uncertainty of pets' behaviors. Risks including tangling and loss of control caused by pets' sudden rushing due to "leash dependence" may threaten the outdoor safety of the elderly [10]. Virtual pet leash products retain the emotional bond between humans and pets while reducing the operational burden and potential safety hazards brought by physical leashes, putting forward innovative solutions for pet travel [11]. Nevertheless, these products only focus on functional realization and fail to take the particularity of elderly users in cognition, perception and physical functions into consideration [12, 13], resulting in inadequate elderly-oriented design.

In view of the above deficiencies in elderly-oriented design, it is of important practical significance and social value to sort out the perceptual characteristics of elderly users and analyze their real travel demands by applying embodied cognition theory, and further propose elderly-oriented design strategies for pet travel products.

2. Application of embodied cognition in elderly-oriented products

2.1. Research status of embodied cognition and elderly-oriented design

The core of elderly-oriented design is to fully consider various physiological and psychological demands of the elderly, improve their living ability and quality of life, and realize the optimization and innovation of product appearance, usage modes and interaction processes. Elderly-oriented design requires research on the characteristics of elderly users, which means an in-depth understanding of the demands faced by the elderly in daily life [14]. From the perspective of embodied cognition, the human body not only receives stimuli from the external environment, but also processes and constructs mental activities, and gives feedback and responses to the outside world. Due to the aging of various physical and mental functions, the elderly's ability to perceive the environment and interact with the outside world is limited and weakened to a certain extent, and their physiological and psychological characteristics will inevitably change accordingly [15]. Introducing the perspective of embodied cognition into elderly-oriented design can help designers better understand and analyze the cognitive and physical characteristics of the elderly, and assist designers in proposing more effective and user-friendly design strategies and methods for the elderly. Therefore, the application of embodied cognition theory in the research on elderly users' demands is of positive significance.

Recently, researchers have recognized the positive value of embodied cognition theory in guiding elderly-oriented design, and proposed elderly-oriented strategies and schemes for various types of products, covering spatial environment [16], interactive interfaces [17], product appliances [14, 18] and packaging design [19]. The above studies have formed a general methodology for elderly-oriented design combined with the connotation of embodied cognition theory, which is mainly reflected in three aspects. First, in view of the physiological degeneration of the elderly, multiple sensory feedback including vision, hearing and touch is strengthened. For example, designs such as enlarged fonts, high-contrast colors, enhanced tactile textures and voice prompts are adopted to compensate for the difficulties in product use caused by the decline of the elderly's physical functions. Second, conform to the physical experience and behavioral habits of the elderly, simplify operation procedures and human-computer interaction steps, and adopt intuitive guidance and unconscious operation modes to reduce the cognitive load and learning cost of the elderly when using new products. Third, based on humanistic considerations, elderly-oriented design should respect and attach importance to the emotional and psychological demands of the elderly, relieve their anxiety and frustration during use, and enhance their sense of security and self-efficacy. The above design strategies from the perspective of embodied cognition provide theoretical references and practical experience for the research on elderly-oriented design of pet travel products [14, 16-19].

2.2. Market research on pet travel products

With the rise of the pet economy and the silver economy, the elderly have become an important consumer group of pet products. Although a wide variety of pet travel products are available on the market, their overall design has the following deficiencies. First, insufficient consideration of diverse travel scenarios. Apart from traditional traction equipment, most pet travel products regard the behavior of people traveling with pets under static scenarios, and keep pets isolated inside carrying equipment. Their core function is to solve the problem of pet transportation and position transfer, such as pet backpacks, car crates, car mats and airline crates [8, 9]. A small number of innovative designs targeting the elderly traveling with pets, such as walking aids with pet carrying functions, only solve the problem of pet transportation. They fail to take more complex scenarios of free human-pet travel into account, nor do they address the issue of "dynamic human-pet interaction" [20]. Second, inadequate elderly-oriented design. The prominent problem of most current products lies in that traditional non-intelligent pet products ignore the physical degeneration of the elderly and fail to classify the demands of the elderly in detail. Meanwhile, the interactive design of many intelligent pet products relies on complex mobile application operation, which cannot adapt to the cognitive characteristics of elderly users and may lead to technophobia, making the products hard to be accepted and used effectively [13]. Third, the absence of guidance from embodied cognition theory. Essentially, the above two defects in product design result from ignoring the embodied cognitive characteristics of elderly users, as well as the failure to consider how the system composed of people, products and pets can realize free and safe travel in diverse and dynamic outdoor scenarios [12].

It can be concluded from the research on pet travel product design that existing travel products mainly focus on improving the travel convenience of pet owners, only a few products take human-pet interaction behaviors into account, and the elderly-oriented design is obviously insufficient. Therefore, it is an urgent practical need to systematically analyze the real demands of elderly users and put forward elderly-oriented design principles for pet travel supplies from the perspective of embodied cognition.

3. Theoretical overview

3.1. Embodied cognition theory

Traditional cognitive theory holds that cognition is disembodied and computable, and separated from modal perceptions such as brain perception (vision, hearing, etc.), physical movements (motor activities) and introspection (emotions) [21]. Embodied cognition refers to cognitive activities taking the human body as the main body, and emphasizes the vital role of the body in the cognitive process. Challenging the view of separating mind from body in traditional cognitive science, embodied cognition theory believes that cognition is rooted in the continuous interaction between the body and the environment. The physical attributes, perceptual experience and motor system of the body shape people's thinking and understanding modes [22]. According to relevant theoretical research summaries, the embodiment of cognition includes three connotations. First, the physical attributes of the body determine the modes and procedures of the cognitive process. Second, the content of cognition is provided by the body. Third, since the body exists in the environment, cognition, the body and the environment jointly form a dynamic coupling system [23].

3.2. Analytic hierarchy process

Common evaluation methods in design research include Analytic Hierarchy Process, Fuzzy Evaluation Method, Value Engineering Method and Artificial Neural Network Evaluation Method. In practical design application, appropriate evaluation methods should be selected according to different design contents and projects [24]. AHP is a widely used qualitative and quantitative combined decision-making analysis method for solving complex problems. It decomposes complex problems into multiple constituent factors and forms a hierarchical structure according to their dominant relationships. Then pairwise comparison is conducted to determine the weight of each indicator so as to assist decision-making [25]. The decision-making process of AHP combines qualitative analysis and subjective judgment, as well as the objectivity of quantitative analysis. In the demand analysis of elderly users traveling with pets, there are numerous interrelated user demands which are difficult to quantify. The construction of multi-level analysis structure model and the determination of weight values can realize relatively reasonable evaluation of demand weights [26].

3.3. Research framework

The elderly-oriented design of pet travel products is a complex systematic problem, especially the potential safety threats caused by traditional leash-type pet travel products when pets suddenly rush out of control. Therefore, understanding and analyzing the behavioral and cognitive characteristics as well as core demands of the elderly traveling with pets from the perspective of embodied cognition, and proposing elderly-oriented design principles for pet travel products are of great significance for guaranteeing the safety of elderly users when going out with pets. Firstly, scenario observation, user interview and other methods are adopted to conduct user journey analysis on the whole process of the elderly traveling with pets and sort out all their demands. Secondly, based on embodied cognition theory, the physiological perception and movement feedback of the elderly in the process of traveling with pets are analyzed, and demands are sorted and classified. Finally, AHP is applied to quantitatively evaluate user demands of products, confirm the priority of user demands, and further put forward elderly-oriented design principles.

4. Research process

4.1. User research

4.1.1. Physiological and psychological characteristics of the elderly from the perspective of embodied cognition

The core viewpoint of embodied cognition theory is that cognition is the product of the interaction among the body, perception and the environment. As the carrier and participant of cognition, the physical state of the body directly shapes individuals' perception of the world and behavioral decisions. Due to the degenerative changes of physiological functions, the elderly have unique physiological and psychological characteristics, and there is a significant correlation between physical and psychological changes, which provides important references for the elderly-oriented design of pet travel products.

The changes of the elderly's physical characteristics are mainly reflected in the dual decline of multi-channel perception and limb functions. In terms of sensory perception, their visual focusing ability and color difference recognition decrease, the field of vision narrows, and they are easily distracted by irrelevant visual stimuli. In terms of hearing, the ability to distinguish sound directions weakens, the sensitivity to high-frequency sounds reduces, and language recognition disorders may occur. In terms of touch, the number of sensitive touch points and sensory nerve fibers decreases, leading to dull perception of temperature and pressure as well as weakened positioning ability. In terms of limb functions, muscle strength declines with aging, accompanied by insufficient hand grip strength and weakened fine finger manipulation ability, as well as limited movement of upper limb joints. The joints of lower limbs become stiff, the flexion strength of instep is insufficient, resulting in slow walking speed and poor balance control ability. The flexibility of motor coordination also declines, making it difficult to respond to sudden movements. These characteristics make it hard for the elderly to accurately capture environmental information and pets' states when walking dogs, and they are prone to operational errors when using products. Therefore, elderly-oriented products should be designed with interactive structures and mechanisms friendly to the elderly [12, 27].

The psychological characteristics of the elderly are significantly affected by the decline of physical functions, presenting degenerated cognitive functions and fragile emotional states. On the cognitive level, the elderly have insufficient attention and are vulnerable to interference, with reduced ability to distinguish and integrate multi-channel information. Their spatial orientation ability weakens and the boundary diffusion effect appears, leading to deviation in estimating the distance between themselves and pets. They also have difficulties in mental rotation, failing to predict the moving track of pets in advance and responding slowly. On the emotional level, the decline of life autonomy tends to cause negative emotions such as anxiety and loneliness. The elderly have strong demands for safety and convenience, and meanwhile desire to gain respect and self-identity through walking dogs independently. In terms of social psychology, walking dogs is not only a physical activity, but also an important way to socialize with other pet owners. The elderly expect products to adapt to social scenarios and balance practicality and emotional identity [15].

To sum up, the physical and psychological characteristics of the elderly form a cycle of "physiological degeneration - cognitive deficit - behavioral disorder - negative emotion". The decline of physical perception and limb functions directly restricts the elderly's ability to operate products and adapt to the environment, while changes in cognition and emotions further reduce their willingness to act. Supported by embodied cognition theory, the elderly-oriented design of pet travel products should adapt to the sensory, limb and psychological characteristics of the elderly, so as to realize both practical functions and emotional adaptation.

4.1.2. User demand analysis based on user journey map

This research adopts the user journey map to sort out the whole process of elderly users using mainstream pet travel products represented by traditional leash products, so as to ensure that all design demands are fully taken into account. The research samples include 5 elderly people aged over 65 from first-tier and second-tier cities, covering two lifestyles: living alone and living with family members. Information collection combines in-depth interviews and behavioral observations to record the process of product operation and human-pet interaction in common outdoor activity areas for the elderly. According to the time sequence of each trip, the whole usage process of the above products by elderly users is divided into four stages: pre-travel preparation, normal use during travel, emergency response and end of travel. Each stage has different behaviors, emotions, pain points and demands, as shown in Figure 1.

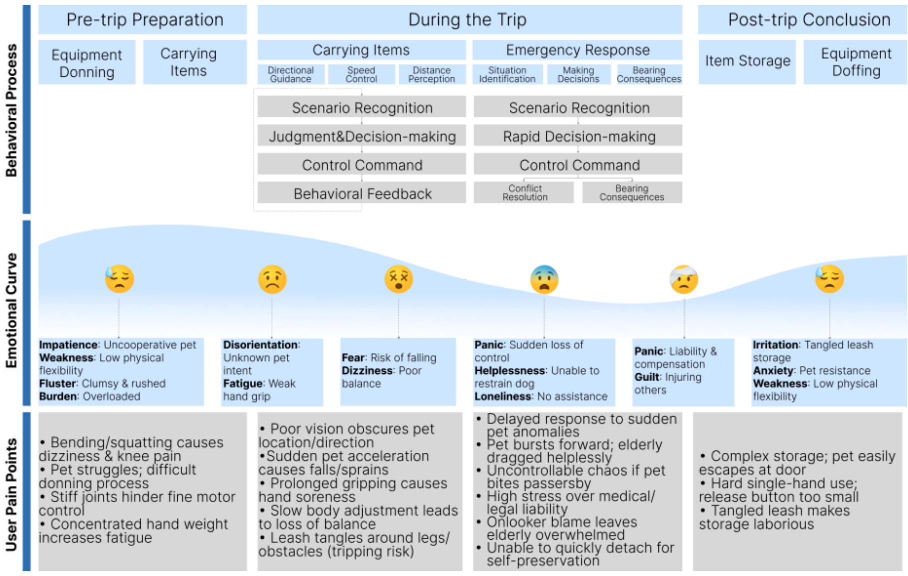

Figure 1. User journey map of pet travel products for elderly users

4.2. Classification of elderly-oriented demands for pet travel based on embodied cognition

Embodied cognition theory holds that the cognitive process does not merely occur in the brain, but is rooted in the interaction between the body and the environment, featuring physicality, dynamics and situationality. Under this theoretical framework, combined with the physical and mental characteristics of elderly pet owners and pain points in the scenarios of traveling with pets, the demands sorted out from the user journey map are classified into three layers: body perception, human-pet interaction and environment embedding. This classification ensures that all demands fully take the embodied cognitive characteristics of the elderly into consideration.

4.2.1. Body perception layer

The physicality of embodied cognition means that cognitive content is provided by the body, and physical form and sensorimotor activities are the foundation of cognition. The demands of the body perception layer follow this logic, conforming to the feature that the elderly's cognition relies on physical experience. This layer focuses on the direct feedback of pets' states perceived by the elderly's body, enabling the dynamic changes of pets to be transmitted through instinctive physical perceptions such as touch and stress, and reducing complex cognitive processing.

4.2.2. Human-pet interaction layer

Embodied cognition believes that cognition, the body and the environment form a dynamic unity, and interaction builds a closed loop linking the three. In real scenarios where the elderly travel with pets, the elderly do not interact with the external environment in isolation. Instead, they participate in travel activities as part of a system consisting of humans, pets and products. There are mutual influences within this system: the physical characteristics of the elderly determine the operation and feedback modes of products; product functions define the interaction modes between humans and pets; changes in pets' behaviors in turn affect the elderly's operational decisions and product response mechanisms. The human-pet interaction layer takes the real-time interaction within this system into account, integrates the dynamic coupling mechanism between the elderly's physical characteristics and pets' behavioral traits, and is equipped with emergency response capabilities to ensure safety and controllability under both normal and unexpected conditions.

4.2.3. Environment embedding layer

Embodied cognition advocates that cognition is not isolated from the environment, but closely bound up and interacts with external scenarios. Following this principle, the environment embedding layer focuses on the adaptive coupling between the human-pet system and travel scenarios, and realizes safe and stable regulation by adjusting interaction states according to environmental feedback in diverse scenarios.

All demands and their detailed descriptions are shown in Table 1.

Table 1. User demands and descriptions of pet travel products for elderly users

No.	Demand Name	Demand Description
A_1	Perception of Moving State	The elderly are unable to judge pets' moving states in real time. It is necessary to enhance their instant perception of pets' behaviors such as walking slowly, running fast and changing directions.
A_2	Perception of Traction Force	The elderly have limited physical tolerance. While perceiving changes of traction load, the products need to buffer the impact of sudden pulling force on the human body.
A_3	Guarantee of Grip Comfort	Due to the degradation of hand functions, the elderly are prone to physical fatigue after long-time gripping. It is required to improve grip comfort and reduce fatigue.
A_4	Feedback for Posture Adjustment	The elderly have weakened balance adjustment ability. It is necessary to perceive the change of pets' moving directions in advance to trigger preparation for physical balance adjustment.
A_5	Early Warning via Abnormal Physical Sensation	The elderly perceive pets' abnormal behaviors slowly. Intuitive physical feedback should be adopted to strengthen early warning of pets' abnormal states.
A_6	Distinct Marking of Key Information	The elderly have degraded visual functions. It is necessary to improve the recognizability of key product information and reduce the visual search burden.
A_7	Protection against Accidental Touch	The elderly are likely to touch products unintentionally. It is required to distinguish intentional operations from accidental touches and ensure accurate operation recognition.

Table 1. (continued)

B_1	Quick and Convenient Wearing	The elderly have difficulties in cooperating with pets to wear products. It is necessary to shorten the wearing time and reduce human-pet conflicts during the wearing process.
B_2	Instinct-oriented Control Operation	The elderly have declined ability of fine hand manipulation. It is required to convert physical movements into control intentions and eliminate complex operations.
B_3	Response Rhythm Adapted for the Elderly	The elderly have longer response time. The system response should conform to their response rhythm to avoid operational disconnection caused by mismatched response speed.
B_4	Dynamic Adjustment of Interaction Intensity	The elderly cannot maintain a fixed grip force continuously. The binding strength of traction and pets' range of activities need to be adjusted adaptively.
B_5	Buffering against Sudden Interaction	Pets' sudden rushing may pull the elderly over and cause injuries. The products need to absorb sudden impact and reduce the pulling force transmitted to the human body.
B_6	Simple Emergency Disconnection	The elderly have poor emergency handling ability. Physical connection between humans and pets should be released quickly without complex positioning or operational instructions.
C_1	Flexible Passage in Narrow Spaces	Leashes are easy to tangle in narrow spaces such as elevators and corridors. It is required to reduce tangling risks and ensure smooth passage.
C_2	Quick Distance Control in Crowded Areas	Human-pet separation and leash tangling are likely to occur in crowded places. It is necessary to shorten the distance between humans and pets rapidly.
C_3	Stable Traction on Complex Ground	Complex weather and terrain may lead to loss of traction control. It is required to guarantee control accuracy and product stability.
C_4	Visibility in Low-light Environments	The elderly have poor visual recognition ability in low-light conditions. The visibility of pet wearable devices and traction products should be improved.
C_5	Stability and Anti-interference in Emergency Environments	Sudden noises and other emergencies may cause pets to feel stressed. The system state should remain stable to reduce interference with the elderly's operation.
C_6	Rapid Restraint against Accidental Injuries	The elderly have difficulty making decisions and taking control when pets attack people in extreme cases. It is required to quickly limit pets' range of activities and isolate potential risks.

4.3. Demand weight analysis based on AHP

4.3.1. Construction of AHP model

This research adopts the Analytic Hierarchy Process to calculate and analyze the weight of user demands for traction tools used by the elderly when traveling with pets. According to the demand indicator system for the elderly traveling with pets established above, the AHP model is constructed as shown in Figure 2. The model consists of three layers. The goal layer is the weight evaluation of demands for traction tools used by the elderly traveling with pets (X). The criterion layer includes three primary indicators: Body Perception Layer (A), Human-pet Interaction Layer (B) and Environment Embedding Layer (C). The sub-criterion layer includes 19 secondary indicators from A1 to A7, B1 to B6 and C1 to C6.

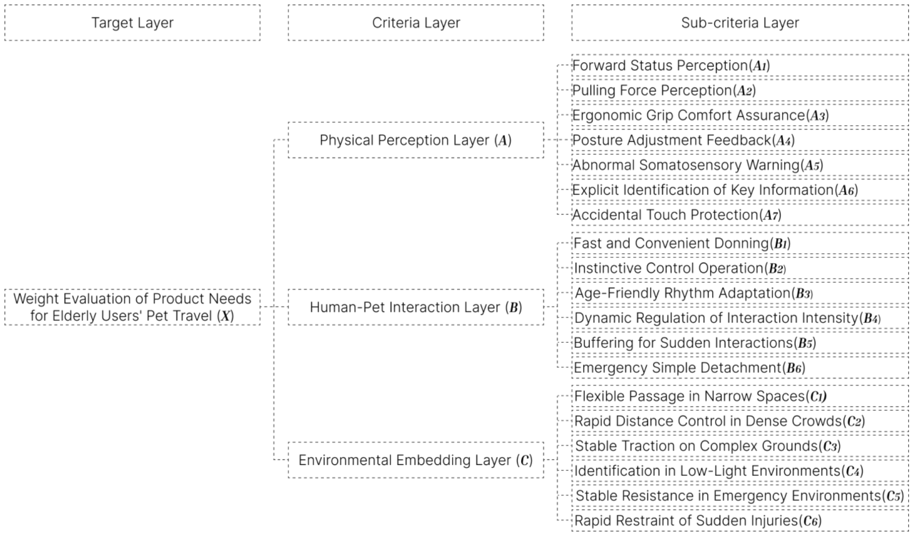

Figure 2. AHP model of user demands for pet travel products for elderly users

4.3.2. Construction of judgment matrix and weight calculation

To ensure the reliability of weight calculation results, a total of 8 experts were invited to fill in the judgment matrices, including 3 design experts with rich experience in elderly-oriented design, 3 medical experts and 2 staff members from community elderly care service institutions. The experts adopted the 1-9 scale method to score the importance of indicators in the criterion layer and sub-criterion layer through pairwise comparison. The scale definitions are as follows: 1 stands for equal importance, 3 for slightly important, 5 for obviously important, 7 for strongly important, 9 for extremely important, and 2, 4, 6, 8 represent intermediate values. After scoring, the geometric mean of all scores was taken as the basis for weight calculation. The calculation procedures are as follows:

4.3.2.1. Calculate the scale product of each layer

Suppose the judgment matrix of the criterion layer (or sub-criterion layer) is$\boldsymbol{A} = (a_{ij})_{n\times n}$, where a_{ij} represents the importance scale of the i -th indicator relative to the j -th indicator, and n is the number of indicators to be compared.

Calculate the scale product M_i of elements in each row:

$$M_i = \prod_{j=1}^{n} a_{ij} \quad \left(i = 1,2,\ldots,n\right)$$

Taking the criterion layer as an example, suppose the judgment matrix of pairwise comparison among Body Perception Layer (A), Human-pet Interaction Layer (B) and Environment Embedding Layer (C) is $\boldsymbol{A}_{3\times3}$, then the scale products of indicators in the criterion layer are M_A, M_B and M_C respectively.

4.3.2.2. Conduct geometric mean operation on the scale product of each layer

Calculate the n -th root of M_i, namely the geometric mean $\overline{W_i}$:

$$\overline{W_i} = \sqrt[n]{M_i} = \sqrt[n]{\prod_{j=1}^{n} a_{ij}} \quad \left(i = 1,2,\ldots,n\right)$$

This step converts the product result back to the geometric mean scale value consistent with the dimension of the original scale.

4.3.2.3. Calculate relative weights

Normalize the geometric mean $\overline{W_i}$ to obtain the relative weight W_i of each indicator:

$$W_i = \frac{\overline{W_i}}{\sum_{i=1}^{n} \overline{W_i}} \quad \left(i = 1,2,\ldots,n\right)$$

Thus $\sum_{i=1}^{n} W_i = 1$ is satisfied. The weights of the criterion layer are shown in the "Weight" column of Table 2 (A: 0.492, B: 0.233, C: 0.276). The local weights of secondary indicators A1~A7, B1~B6 and C1~C6 in the sub-criterion layer are calculated in the same way.

4.3.2.4. Calculate the maximum eigenvalue

Calculate the maximum eigenvalue $\lambda_{\max}$ of the judgment matrix $\boldsymbol{A}$ for subsequent consistency test:

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(\boldsymbol{AW})_i}{nW_i}$$

Where $\boldsymbol{W} = (W_1, W_2, \ldots, W_n)^T$ is the weight vector obtained in step (3), and $(\boldsymbol{AW})_i$ represents the i -th component of vector $\boldsymbol{AW}$, namely:

$$\left(\boldsymbol{AW}\right)_i = \sum_{j=1}^{n} a_{ij} W_j$$

4.3.2.5. Conduct consistency test

To verify the logical consistency of experts' judgments, Consistency Index (CI), Random Index (RI) and Consistency Ratio (CR) are introduced.

Consistency Index (CI):

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

Consistency Ratio (CR):

$$CR = \frac{CI}{RI}$$

RI refers to the average random consistency index. When $n = 3$, $RI = 0.52$; when $n = 6$, $RI = 1.24$; when $n = 7$, $RI = 1.36$. In this research, $n = 3$ for the criterion layer, and $n = 7$, $n = 6$, $n = 6$ for the three parts of the sub-criterion layer respectively.

After calculation, the Consistency Ratio (CR) of all judgment matrices in each layer is less than 0.1, which means all judgment matrices pass the consistency test and the weight distribution is reasonable and valid.

4.3.2.6. Overall hierarchical ranking

The comprehensive weight reflects the overall contribution degree of each secondary indicator to the general goal, which is calculated following the principle of overall hierarchical ranking:

$$W_{comprehensive,i} = W_{criterion} \times W_{local,i}$$

The calculation results of weights for the criterion layer and sub-criterion layer are shown in Table 2.

Table 2. Weight ranking of user demands for pet travel products for elderly users

Goal Layer	Criterion Layer	Weight	Sub-criterion Layer	Local Weight	Comprehensive Weight	Weight Ranking
X Weight Evaluation of Demands for Traction Tools Used by the Elderly Traveling with Pets	**A** Body Perception Layer	0.492	A_1 Perception of Moving State	0.099	0.048708	9
			A_2 Perception of Traction Force	0.097	0.047724	11
			A_3 Guarantee of Grip Comfort	0.115	0.05658	8
			A_4 Feedback for Posture Adjustment	0.099	0.048708	10
			A_5 Early Warning via Abnormal Physical Sensation	0.282	0.138744	1

Table 2. (continued)

X Weight Evaluation of Demands for Traction Tools Used by the Elderly Traveling with Pets	**A** Body Perception Layer	0.492	A_6 Distinct Marking of Key Information	0.139	0.068388	5
			A_7 Protection against Accidental Touch	0.168	0.082656	3
	B Human-pet Interaction Layer	0.233	B_1 Quick and Convenient Wearing	0.106	0.024698	16
			B_2 Instinct-oriented Control Operation	0.136	0.031688	14
			B_3 Response Rhythm Adapted for the Elderly	0.100	0.0233	17
			B_4 Dynamic Adjustment of Interaction Intensity	0.118	0.027494	15
			B_5 Buffering against Sudden Interaction	0.244	0.056852	7
			B_6 Simple Emergency Disconnection	0.296	0.068968	4
	C Environment Embedding Layer	0.276	C_1 Flexible Passage in Narrow Spaces	0.084	0.023184	18
			C_2 Quick Distance Control in Crowded Areas	0.163	0.044988	12
			C_3 Stable Traction on Complex Ground	0.118	0.032568	13
			C_4 Visibility in Low-light Environments	0.069	0.019044	19
			C_5 Stability and Anti-interference in Emergency Environments	0.218	0.060168	6
			C_6 Rapid Restraint against Accidental Injuries	0.347	0.095772	2

4.3.3. Analysis of weight results

4.3.3.1. Analysis of weights in the criterion layer

The weight ranking of the criterion layer is as follows: Body Perception Layer (A, 0.492), Environment Embedding Layer (C, 0.276), Human-pet Interaction Layer (B, 0.233). The Body Perception Layer has the highest weight, indicating that the elderly are most concerned about whether products can help them intuitively perceive pets' moving states through physical sensations. The cognition of the elderly highly relies on information received and perceived by the body, which is consistent with the connotation of embodied cognition theory. The Environment Embedding Layer ranks the second, reflecting that elderly users attach great importance to the adaptability of pet travel products in various complex scenarios. Common outdoor places for the elderly include parks, community roads and food markets. Whether products can maintain stable and controllable operation in complex scenarios is directly related to the travel safety and usage experience of elderly users. The Human-pet Interaction Layer has a relatively low weight, but it still has reference value. This layer mainly involves coordination functions such as buffering sudden interactions and emergency disconnection between humans and pets, which play a key role in guaranteeing the travel safety of the elderly under specific circumstances.

4.3.3.2. Analysis of weights in the sub-criterion layer

The top five indicators in terms of comprehensive weight are listed in order: A_5 Early Warning via Abnormal Physical Sensation (0.1387), C_6 Rapid Restraint against Accidental Injuries (0.0958), A_7 Protection against Accidental Touch (0.0827), B_6 Simple Emergency Disconnection (0.0690), A_6Distinct Marking of Key Information (0.0684).

A_5 Early Warning via Abnormal Physical Sensation ranks first in comprehensive weight, which means that the elderly have the strongest demand for perceiving pets' abnormal behaviors in advance. Due to the decline of vision, hearing and other senses, the elderly cannot detect pets' behavioral changes in a timely manner. Delivering early warning signals through senses such as touch with relatively intact perception can help the elderly get prepared in advance to cope with dangers such as pets' sudden rushing. C_6 Rapid Restraint against Accidental Injuries ranks the second, which reflects the elderly's awareness of preventing extreme safety risks. In extreme cases where pets suddenly attack others, the ability to quickly control and isolate risks is their top safety demand. A_7 Protection against Accidental Touch ranks the third, showing that the elderly pay much attention to operational accuracy. The decline of the elderly's fine hand manipulation ability leads to a high probability of accidental touches. Distinguishing intentional operations from unintended touches can reduce potential safety hazards caused by operational errors. B_6 Simple Emergency Disconnection ranks the fourth, and this demand works synergistically with C_6 Rapid Restraint against Accidental Injuries. When encountering emergencies such as pets' sudden rushing, releasing the physical connection between humans and pets without complex operations can provide the elderly with a rapid emergency avoidance solution.

A_6 Distinct Marking of Key Information ranks the fifth, reflecting the elderly's basic requirement for the recognizability of product information. Adopting designs such as high-contrast colors, enlarged icons or tactile raised points can enhance the recognizability of product information, reduce the elderly's visual search burden and improve operational efficiency and accuracy.

4.3.3.3. Summary of demand distribution characteristics

Among the top 10 indicators in comprehensive weight, 5 belong to the Body Perception Layer (A_5, A_7, A_6, A_3, A_1 and A_4 with tied ranking), 3 belong to the Environment Embedding Layer (C_6, C_5, C_2), and 2 belong to the Human-pet Interaction Layer (B_6, B_5). It proves that physical perception is the core demand of the elderly, and environmental adaptability as well as human-pet interaction safety are also indispensable parts of travel experience.

In addition, indicators including B_1 Quick and Convenient Wearing, B_3 Response Rhythm Adapted for the Elderly, C_1 Flexible Passage in Narrow Spaces and C_4 Visibility in Low-light Environments have relatively low comprehensive weights. However, low weight does not mean these demands are unimportant. Instead, it indicates that in the priority judgment of elderly users, safety guarantee demands such as abnormal behavior early warning and anti-accidental touch have higher urgency than efficiency and convenience demands. In the complete product experience, efficiency and convenience demands, together with safety guarantee demands, jointly affect users' usage experience. This finding suggests that designers should take safety as the primary design goal during product development, and optimize operational convenience and environmental adaptability on the premise of ensuring safety and reliability.

4.4. Elderly-oriented design principles

Based on the above weight calculation results, this paper puts forward four elderly-oriented design principles for pet travel products.

4.4.1. Body priority principle: construct a "perception-action-feedback" closed loop

Embodied cognition theory emphasizes the core position of the body in the cognitive process, and the AHP weight analysis also verifies that demands of the Body Perception Layer are the most concerned dimension for elderly users. The Body Priority Principle requires product design to center on the physical perception and motor ability of the elderly, and build a complete closed loop of "receiving signals by the body - taking actions by the body - receiving action feedback by the body".

Specifically, products should preferentially transmit key information through the elderly's relatively intact tactile perception, converting dynamic information such as pets' moving states, changes of pulling force and abnormal behaviors into physical sensory signals including vibration and stress changes at the grip part, so as to reduce reliance on degenerated senses such as vision and hearing. Meanwhile, the interactive operation modes should be designed based on the elderly's instinctive movements such as grip reflex and limb direction. Natural movements derived from traditional dog walking behaviors such as "tightening the grip" and "swinging the arm" can be converted into control commands to lower learning cost and cognitive load. The high weight ranking of A_5 Early Warning via Abnormal Physical Sensation and A_7 Protection against Accidental Touch verifies the rationality and necessity of this principle from the perspective of data.

4.4.1.1. Safety guarantee principle: establish a multi-level protection mechanism

Safety guarantee is the top priority of elderly-oriented product design. According to the AHP weight analysis, three of the top five indicators in comprehensive weight are directly related to safety guarantee functions, namely A5 Early Warning via Abnormal Physical Sensation, C_6 Rapid Restraint against Accidental Injuries and B_6 Simple Emergency Disconnection, which fully demonstrates the vital importance of product safety for elderly users.

The Safety Guarantee Principle requires establishing a multi-level protection mechanism covering early warning, buffering and disconnection. At the early warning stage, products detect changes of pets' behaviors and deliver early warning information to users through physical sensory signals before dangerous behaviors such as sudden rushing occur. At the buffering stage, buffer structures are equipped to absorb kinetic energy generated by pets' sudden rushing and reduce the strong pulling force transmitted to the human body. At the disconnection stage, an emergency separation mechanism is designed to instantly release the physical connection between humans and pets without complex positioning under extreme conditions. The three stages form a progressive product safety protection system, providing safety protection for the elderly respectively during the gestation, occurrence and out-of-control stages of dangers.

4.4.2. Environment adaptation principle: improve adaptability to diverse scenarios

The elderly travel with pets in various scenarios, including park trails, community roads, food markets, elevators and corridors. Different scenarios put forward different performance requirements for products. In the AHP weight analysis, the Environment Embedding Layer ranks the second. Among its indicators, C_6 Rapid Restraint against Accidental Injuries, C_5 Stability and Anti-interference in Emergency Environments and C_2 Quick Distance Control in Crowded Areas have relatively high weights, reflecting the elderly's comprehensive demands for the stability and scenario adaptability of products.

The Environment Adaptation Principle requires products to have stable traction performance in complex environments, anti-tangling ability for passage in narrow spaces, rapid distance adjustment function in crowded places and anti-interference ability in sudden emergency environments. To be specific, products should ensure traction stability on slippery, uneven, soft and other complex road surfaces, eliminate leash tangling risks in narrow and crowded environments, and realize rapid adjustment of the distance between humans and pets.

4.4.3. Emotional care principle: balance functional practicality and psychological adaptation

It is worth noting that the elderly's outdoor activities are not merely physical exercises, but also carry multiple psychological demands including social interaction and self-actualization. The demands for "pleasant usage experience" and "social identity" mentioned repeatedly in user interviews are not included in the statistical analysis and weight calculation of functional demands due to their complex causes and multiple social influencing factors, yet they reflect the implicit value of humanistic care in elderly-oriented product design.

The Emotional Care Principle requires products to take the elderly's psychological demands into account while ensuring practical functions. Specific implementations are as follows. In terms of vision, adopt warm and soft colors and rounded shapes to deliver a safe and friendly impression. In terms of interaction, provide clear feedback and appropriate response rhythm to enhance the elderly's sense of control and self-confidence. In terms of social attributes, the product shape should consider the elderly's usage experience in public scenarios and avoid medical or disability-oriented appearances which may cause psychological rejection. Combining functions with emotional care helps the elderly gain a sense of security, independence and happiness when traveling with pets.

5. Conclusion

Supported by embodied cognition theory and adopting AHP as the weight measurement tool, this research systematically analyzes and quantitatively evaluates the user demands of the elderly for pet travel products, and puts forward referable elderly-oriented design principles.

The main contributions of this research are as follows. Firstly, a demand analysis framework for the elderly based on embodied cognition theory is constructed. Different from previous studies that only focused on the physiological characteristics of the elderly, this research incorporates three layers including body perception, human-pet interaction and environment embedding into the demand analysis framework. Secondly, AHP is adopted for quantitative evaluation and priority ranking of user demands, clarifying the priority of the elderly's demands in safety guarantee and physical perception. Finally, four elderly-oriented design principles including Body Priority, Safety Guarantee, Environment Adaptation and Emotional Care are proposed, forming a complete design strategy system from theory to practice. It can provide methodological guidance and directional reference for the design and development of pet travel products and other outdoor elderly-oriented products.

This research still has limitations and needs to be further improved in the future. In terms of sample selection, the sample size is limited, and expanding the sample scale will improve the universality of the research results. Besides, the user survey of the elderly is mainly conducted in first-tier and second-tier cities with limited geographical coverage. Further research can supplement demand surveys and differentiated research on the elderly in different regions. In terms of research methods, this research mainly uses AHP for demand weight evaluation. More scientific evaluation methods can be introduced in the future to form a more complete product development process. In terms of technology application, with the development of multimodal perception and haptic feedback technology, continuous exploration is needed to make intelligent technology truly serve the elderly's travel demands.

It is hoped that this research can arouse the attention of academic circles and the industry to the demands of the "silver-haired pet-raising" group, promote the elderly-oriented transformation of pet travel products, provide practical support for the elderly to travel safely, and enable more elderly people to gain health and happiness accompanied by pets.

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