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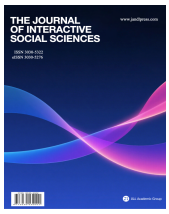

A Study on the Design of Portable Hand Exercise Toys for the Elderly Based on Multisensory Interaction

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ABSTRACT

Against the backdrop of an aging population and the continuous development of the silver economy, the design of products for the elderly is gradually shifting from single-function compensation to a balanced emphasis on health support, emotional care, and life experiences. Addressing the declining hand dexterity, reduced sensory sensitivity, and daily emotional comfort needs of the elderly, this paper explores the design concepts and practical approaches for portable hand exercise toys for the elderly, using multisensory interaction as a starting point. Through literature analysis, needs assessment, and design practice, this study identifies the needs of elderly users regarding light hand activities, clear sensory feedback, psychological companionship, and low-burden usage. Based on these findings, four design principles are proposed: usability, comfort, multisensory coordination, and portability. Building on this foundation, the study conducts design practices centered on portable hand exercise toys for the elderly, exploring ways to integrate hand activities, multisensory feedback, and everyday play experiences. This study aims to transform relatively mechanical hand exercises into natural, low-intensity, and sustainable daily play experiences, providing a reference for the experience design of age-friendly toys and products.

1. Research Background

Population aging has become a critical issue with long-term and structural implications for China's social development. Data released by the National Bureau of Statistics in 2024 indicates that by the end of 2023, China's population aged 60 and above stood at 296.97 million, accounting for 21.1% of the total population; the population aged 65 and above reached 216.76 million, representing 15.4% of the total population. This demographic shift indicates that the elderly population is no longer a small, specialized group requiring specific services, but rather a significant

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demographic that profoundly impacts public services, the health industry, consumer markets, and approaches to social governance. As the elderly population continues to grow, issues such as senior products, rehabilitation aids, health management, emotional support, and daily companionship are gradually shifting from individual family concerns to systemic societal issues.Older adults are not merely recipients of care, but rather a significant user group with a desire for an active life, emotional needs, aesthetic preferences, and spending power (Bloom et al., 2015).

The "Healthy China 2030" Plan Outline proposes strengthening the development of integrated medical institutions for rehabilitation, geriatric medicine, long-term care, chronic disease management, and palliative care, and promoting a shift in health services from disease treatment to full-lifecycle health management (Central Committee of the Communist Party of China and State Council, 2016). This policy indicates that issues of elderly health should not be limited to the treatment of disease but must also focus on prevention, rehabilitation, companionship, and health promotion in daily life. The “Opinions on Strengthening Aging-Related Work in the New Era” further emphasizes the need to establish a coordinated system of home-based, community-based, and institutional care services that integrates medical care with health and wellness support, thereby enhancing the quality of life and health support for the elderly (Central Committee of the Communist Party of China and State Council, 2021).As the silver economy enters a phase of accelerated development, the "Opinions on Developing the Silver Economy and Enhancing the Well-being of the Elderly" issued by the General Office of the State Council (2024) proposes, from the perspective of industrial innovation, that the supply of products for the elderly should be expanded, and promising industries such as smart health and elderly care, rehabilitation assistive devices, and age-friendly renovations should be cultivated. It is evident that the design of products for the elderly is gradually shifting from basic care-oriented offerings to health-supportive, experiential, and lifestyle-oriented solutions.

Against this social backdrop, hand exercise products hold clear practical significance. The hands are a vital body part for older adults in performing daily activities; actions such as holding a cup, unscrewing a bottle cap, buttoning a shirt, zipping a jacket, retrieving medication, and using a mobile phone all rely on finger dexterity, grip stability, and motor coordination. As people age, hand strength, fine motor control, and motor coordination may all decline, thereby affecting older adults’ convenience, autonomy, and sense of self-efficacy (Carmeli et al., 2003; Ranganathan et al., 2001). Hand exercise is therefore not merely localized physical training but is closely linked to older adults’ quality of life, psychological well-being, and daily independence.

Most existing hand exercise products for the elderly focus on types such as grip balls, finger strength trainers, massage balls, hand rehabilitation devices, and electric massagers. While these products can meet strength training or localized relief needs to some extent, they also suffer from issues such as a monotonous user experience, lack of engagement, and a strong resemblance to medical devices.Product experience depends not only on functional effectiveness but also on users’ comprehensive perceptions across aesthetic perception, meaning interpretation, and emotional response (Desmet & Hekkert, 2007).For elderly users, products that overemphasize training and rehabilitation can reinforce psychological associations with aging, illness, and disability, thereby reducing their willingness to use them actively. In contrast, transforming hand exercises into everyday play activities helps alleviate the psychological burden on the elderly, making the exercise process more natural, relaxed, and sustainable.

Based on the above context, hand exercise toys for the elderly differ from traditional medical

rehabilitation devices and are not merely entertainment toys; rather, they are hybrid products situated between age-friendly toys, wellness products, and everyday play items. By combining low-intensity hand activities, multisensory feedback, portable designs, and emotionally soothing experiences, these products can more naturally integrate into the daily lives of older adults—whether at home, in the community, while waiting at a clinic, during walks, or before bedtime.

2. Research Significance

From a theoretical perspective, this study contributes to broadening the research perspective on age-friendly product design. Existing research on products for the elderly has largely focused on safety protection, functional compensation, and daily living assistance, with limited discussion of product design from the perspectives of multisensory interaction and psychological care. Hand exercise products for the elderly do not merely address the decline in finger mobility; they also involve sensory stimulation, emotional comfort, and active participation in the daily lives of older adults. Multisensory product experiences emphasize the synergistic role of visual, tactile, auditory, and olfactory information in product perception and emotional judgment, providing a theoretical basis for shifting elderly-friendly toy design from a single-function orientation to an experience- and care-oriented approach (Schifferstein & Spence, 2008).At the same time, it further enriches the theoretical framework of elderly toy design, ensuring that such products are no longer simply viewed as entertainment items, but rather as important design mediators that connect physical activity, sensory feedback, psychological comfort, and daily companionship.

From a practical perspective, this study can serve as a reference for the design and development of portable hand exercise products for the elderly. Currently, common hand exercise products on the market are primarily grip balls, massagers, and finger strength trainers, which generally suffer from issues such as monotonous product forms, tedious usage processes, and a lack of sustained appeal. To address these shortcomings, this study proposes a design approach centered on portability, low physical burden, and multisensory feedback, enabling older adults to naturally use the product in daily scenarios such as leisure at home, outdoor activities, and relaxation before bed.User experience research emphasizes that a product's practicality, enjoyment, and contextual experience collectively influence users' acceptance and continued use of the product (Hassenzahl & Tractinsky, 2006). This design helps reduce older adults' psychological resistance to exercise products, transforming hand exercises from a passive task into a casual, everyday activity, and offers insights for innovation in senior-friendly products within the context of the silver economy.

3. Research Content and Methods

This study addresses the question: "How can multisensory interaction be used to improve the user experience of portable hand-exercise toys for the elderly?" The research comprises three aspects: First, against the social backdrop of population aging, the silver economy, and innovation in age-friendly products, we analyze the necessity of shifting elderly hand-exercise products from single-function training toward daily play, sensory feedback, and emotional care; Second, based on theories of multisensory interaction, emotional design, inclusive design, and age-friendly design, we identify the specific needs of elderly users regarding hand mobility, sensory recognition, psychological comfort, and low-effort usability; Third, we conduct design practices focusing on product form, functional modules, age-friendly details, multisensory feedback, and usage scenarios to develop a conceptual design that is portable, user-friendly, and seamlessly integrated into daily life.

This study primarily employs literature analysis, needs synthesis, and design practice. First, through literature analysis, we review relevant research on multisensory interaction, emotional design, inclusive design, and aging-related factors to establish a theoretical foundation for product design. Second, by integrating the physical capabilities, sensory changes, psychological states, and daily behavioral characteristics of older adults, we synthesized their usage needs and translated these into design requirements such as ease of recognition, ease of operation, comfortable grip, clear feedback, and portability. Finally, through design practice, we translated these requirements into product positioning, functional modules, and multisensory interaction schemes. This paper constitutes design research and conceptual exploration, focusing on proposing design concepts and product implementation pathways; it does not make judgments regarding the product's medical rehabilitation efficacy.

3.1 Relevant Theories and Design Rationale

3.1.1 Overview of Multisensory Interaction Design

Multisensory interaction is a key topic in product experience and human-computer interaction research. It does not simply involve the superimposition of sensory stimuli—such as visual, auditory, tactile, and olfactory inputs—onto a product. Rather, it involves the synergistic relationship among different sensory channels to enable users to perceive the product's functions, context, and meaning holistically. Human experience is not generated by a single sense in isolation but is formed through the collective participation of multiple sensory cues, including visual, auditory, tactile, and olfactory inputs. In experience design, the coordinated organization of different sensory elements also influences users' understanding of a product's state, contextual atmosphere, and usage significance (Spence, 2020; Xu et al., 2025).This perspective suggests that a product is not a static object but rather a medium through which humans interact with their environment. Users' understanding of a product derives not only from its visual form but also from the tactile feedback of materials, auditory cues during operation, situational associations evoked by scent, and experiential memories formed through physical movements.

From a design perspective, multisensory interaction is not merely a mode of interaction but also a method of organizing experiences grounded in bodily experience. Product experiences typically encompass multiple dimensions such as aesthetics, meaning, and emotion, and cues from vision, hearing, touch, and smell collectively influence users' judgments of space, products, and the atmosphere of a scene (Desmet & Hekkert, 2007; Spence, 2020).Multisensory interaction establishes connections across these layers, transforming products from "usable tools" into "objects that can be perceived, responded to, and emotionally connected with." Thus, multisensory interaction is not merely superficial formal innovation but a systematic design approach grounded in users' bodily perceptions, environmental relationships, and contextual meanings. Particularly in the design of age-friendly products, multisensory interaction must avoid overstimulation and excessive formal elements. Instead, it should utilize gentle tactile sensations, clear sounds, low-stimulus visual feedback, and subtle scents to reduce cognitive load, enhance operational confirmation, and improve the product's approachability and likelihood of sustained use in daily life.

3.1.2 Design Philosophy for Age-Friendly Design

Age-friendly design refers to a design philosophy that involves the targeted optimization of products, spaces, services, and information systems in response to changes in older adults' physical functions, sensory abilities, cognitive processes, psychological states, and living environments, making them better suited to their capabilities and daily needs. It does not simply involve making

products larger, lighter, or softer, nor does it mean adding "senior-specific" features to existing products. Rather, it enables older adults to participate in daily life more naturally and with greater dignity by lowering operational barriers, enhancing recognition and feedback, and improving safety and comfort. Inclusive design emphasizes that the design process should proactively incorporate the experiences and limitations of users with diverse abilities, rather than focusing solely on the "standard user" (Newell & Gregor, 2000).Thus, age-friendly design is a design approach that has evolved gradually from the foundations of accessible design, universal design, inclusive design, and gerontology research.

Concepts closely related to age-friendly design primarily include barrier-free design, universal design, inclusive design, and senior-friendly design. Accessible design initially focused more on removing barriers for people with disabilities in terms of spatial mobility, facility use, and information access, emphasizing "accessibility, reachability, and usability"; universal design further emphasizes that, regardless of age, ability, or identity differences, more people should be able to use the same product or environment equally; inclusive design, on the other hand, focuses more on differences in user abilities and usage contexts, advocating for the proactive identification of barriers and needs among different groups during the design process. Design that accounts for ability differences does not merely compensate for users' limitations; rather, it requires organizing interaction methods and product feedback around the abilities users retain (Wobbrock et al., 2011). In contrast, age-friendly design focuses more on the physical, cognitive, and psychological changes experienced by older adults, incorporating both the safety principles of accessible design and the concepts of fairness, usability, and dignity from universal and inclusive design.

From a deeper perspective of design value, age-friendly design is also closely linked to active aging, healthy aging, and the development of an age-friendly society. Differences in how older users engage with technology and products are often related to factors such as cognitive abilities, self-efficacy, anxiety levels, and prior usage experience (Czaja et al., 2006).This indicates that age-friendly design should not be limited to localized functional optimization but should focus on cognitive load and behavioral adaptation throughout the entire product usage process. Consequently, the essence of age-friendly design is not to label older adults as a "special group," but rather to help them maintain autonomy, emotional dignity, and participation in daily life despite changes in their capabilities through more human-centered, inclusive, and life-integrated design approaches. For portable hand exercise toys for the elderly, the principles of age-friendly design provide a foundational basis for product sizing, operational methods, sensory feedback, and situational adaptation.

3.1.3 Current Status of Hand Exercise Products for the Elderly

Existing hand exercise products for the elderly can be broadly categorized into three types. The first category consists of strength-training products, such as grip balls, resistance bands, and finger strength trainers, which are primarily used to enhance hand strength and joint mobility. The second category includes massage and relaxation products, such as massage balls, hand massagers, and heat-therapy gloves, which are mainly used to relieve hand fatigue or promote localized relaxation. The third category consists of rehabilitation training products, such as finger rehabilitation devices and hand function training boards, which are often used for post-surgical rehabilitation or functional impairment training. While these products serve a specific purpose in certain scenarios, they share common issues: their functional objectives are relatively narrow, the usage process tends to be mechanical, and they lack sufficient integration with the daily emotions and living environments of the elderly.

Current hand exercise products for the elderly primarily face three issues. First, most products emphasize training outcomes while neglecting the elderly users' intrinsic motivation to use them. Many products focus their design on grip strength enhancement, joint mobility, or localized massage; while these meet certain functional needs, the usage process often feels mechanical. The value of a product experience stems not only from task completion but also from the sense of meaning, pleasure, and self-expression derived during use. User experience research indicates that a product's ability to evoke positive emotions and contextual value influences users' perception of its significance (Hassenzahl, 2008). For older adults, hand exercise products that offer only repetitive pressing, gripping, or stretching motions are likely to be set aside after short-term use; conversely, products that incorporate elements of exploration, fun, and emotional comfort can help stimulate older adults' willingness to continue using them.

Second, existing products tend to be mechanical, functional, and limited in scope. Many hand-training products can only perform a single type of exercise—such as squeezing, stretching, or rotating—making it difficult to meet the diverse hand activity needs of older adults. Additionally, some products are bulky or require fixed placement on surfaces like desks or bedside tables, rendering them unsuitable for the fragmented daily routines of older adults. Interaction design research related to older users also indicates that a product's usability depends not only on individual functions but also on operational pathways, informational cues, adaptation to physical capabilities, and usage contexts (Nurgalieva et al., 2019). Therefore, designs that are compact, portable, and low-effort better align with the daily rhythms of older adults and are more conducive to frequent use.

Third, existing products still do not make full use of multisensory stimulation. Most products rely primarily on tactile or haptic feedback, with few incorporating sound, lighting effects, scent, and mood-soothing experiences into their overall design. Multisensory product design emphasizes the interactive effects between different sensory cues, positing that visual, auditory, and tactile cues collectively influence users' judgments regarding product quality, operational status, and experiential value (Maki & Yanagisawa, 2019).To enhance the long-term value of hand exercise products for the elderly, they should not merely meet the basic goal of "being able to train," but also address the experiential goals of "willingness to use," "ease of use," and "frequent use." Through the synergistic design of tactile textures, gentle sounds, low-intensity lighting, and natural scents, hand activities can be transformed from a single training behavior into a comprehensive experience that more closely resembles everyday manipulation and emotional relaxation.

In summary, the future development of hand exercise products for older adults should not be confined to a single-function training logic but should shift toward integrating physical activity, sensory feedback, psychological comfort, and real-life scenarios. The core of healthy aging lies in developing and maintaining functional abilities in older adults. From this perspective, age-friendly products should not only help older adults compensate for functional decline but also support their continued daily participation, mobility independence, and confidence in life. Although portable hand exercise toys are not medical devices, they can serve as a complementary product form that helps older adults maintain daily functions, enrich their life experiences, and enhance their sense of active participation through light hand movements, multisensory stimulation, and psychological comfort and companionship.

3.2 Analysis of Elderly User Needs e

3.2.1 Demand for Light Activities Amid Hand Function Decline

Hand function is closely linked to older adults' ability to perform activities of daily living. As they age, some older adults experience issues such as weakened grip strength, stiff fingers, reduced joint mobility, and diminished motor coordination, which in turn affect daily activities such as holding a cup, unscrewing bottle caps, buttoning clothes, zipping up zippers, taking medication, and using a mobile phone. Recent studies on the relationship between grip strength and quality of life in older adults indicate a dose-response relationship between grip strength levels and physical health dimensions; insufficient grip strength can impair physical function and the maintenance of quality of life (Meng et al., 2024).Although hand movements are localized activities, they directly relate to older adults' convenience in daily life, mobility autonomy, and sense of self-efficacy. When familiar daily movements gradually become laborious, older adults not only face physical inconveniences but may also experience feelings of frustration and a sense of declining ability.

Compared to high-intensity, task-oriented training methods, older adults require support through low-intensity, sustained, and daily-life-integrated hand activities. Many hand activities do not occur during dedicated training sessions but are incorporated into daily routines such as watching TV, chatting, taking a walk or resting, waiting in a clinic, and relaxing before bed. Thus, the need for hand activities among older adults emphasizes natural participation and long-term maintenance rather than short-term intensive training. The needs of older adults also vary: some prioritize grip stability, others focus on finger dexterity, while still others hope to alleviate stiffness, tension, and the lack of hand activity that comes from prolonged sitting or waiting through light movement. Therefore, hand activity needs among older adults are characterized by low intensity, diversity, and situational adaptability.

3.2.2 The Need for Clear Feedback Amid Changes in Sensory Abilities

The sensory abilities of older adults undergo varying degrees of change with age. Declining visual recognition may affect their ability to discern fine details, low-contrast information, and changes in status; reduced tactile sensitivity may weaken their perception of material hardness, surface texture, pressure levels, and motion feedback; and changes in hearing may also reduce the reliability of their reception of auditory cues. Age-related sensory and motor changes affect the processes of information acquisition, motor control, and feedback confirmation between older adults and products (Charness & Boot, 2009). Changes in sensory abilities do not mean that older adults are unable to perform tasks; rather, they indicate a greater reliance on clear, direct, and multi-channel feedback.

During daily use, clear feedback helps older adults confirm the results of their actions, reducing uncertainty and hesitation. If feedback is too weak, cues are ambiguous, or results are unclear, older adults may become concerned about operating errors, which in turn reduces their confidence in continuing to use the product. At the same time, older adults' need for sensory feedback does not equate to a need for strong stimuli. Excessively bright lighting, shrill sounds, overly firm tactile sensations, or overpowering odors can all cause discomfort. Feedback methods best suited for older adults should be gentle, clear, and consistent, providing them with an experience that is understandable, verifiable, and controllable during the perception process.

3.2.3 Needs for Psychological Comfort and Companionship in Situations of Solitude and Waiting

The needs of older adults stem not only from changes in physical function but are also related to their daily rhythms, social roles, and psychological states. After retirement, changes in social participation, reduced time spent with family, and decreased social interaction can lead some older

adults to experience boredom, restlessness, a sense of emptiness, or mild anxiety in situations such as being alone, waiting, or before bedtime. Recent research on social isolation and loneliness among the elderly indicates that reduced social connections, decreased interaction frequency, and weakened support networks can have adverse effects on their emotional state, mental health, and quality of life (Donovan & Blazer, 2020). While such psychological states typically do not warrant medical intervention, they do represent genuine needs for emotional comfort and daily companionship in everyday life.

Repetitive hand movements serve to divert attention. Actions such as pressing, sliding, rolling, and rotating can shift older adults' focus from abstract emotional sensations to concrete physical activities and tactile perceptions, thereby fostering a sense of stability and calm. Olfactory stimuli and natural scents are also frequently used to create relaxing experiences. Among these, the scent of lavender has been extensively linked in research to nervous system relaxation, sleep, and emotional regulation (Koulivand et al., 2013).This psychological comfort and companionship does not necessarily rely on complex verbal communication or intelligent systems; rather, it can be gradually established through physical movements, sensory feedback, and sustained interpersonal relationships. For older users, whether an object possesses inherent appeal and can be repeatedly used in everyday moments often reflects its true practical value more than its mere functional capabilities.

3.2.4 Low-Burden Usage Needs in Everyday Life Scenarios

The usage needs of older adults are distinctly characterized by their everyday nature and fragmented nature. Many needs do not arise in specialized settings but are distributed across everyday spaces such as living rooms, bedrooms, community rest areas, hospital waiting rooms, bus stops, and during walks. Recent research on the adoption of health technologies by older adults indicates that whether a product or technology is used consistently is closely related to factors such as operational complexity, comprehensibility, accessibility, user confidence, and suitability for the usage context (Bertolazzi et al., 2024).Consequently, older adults prefer items that can be easily picked up, operated with one hand, placed effortlessly, and stored conveniently. If an item is too bulky, structurally complex, or requires fixed installation, device connections, or extensive reading of instructions, it increases the cost of use and diminishes the willingness to use it.

The need for low-burden usability is primarily reflected in three dimensions: cognitive, physical, and maintenance. Cognitively, older adults prefer intuitive, clear, and easy-to-understand operating methods, avoiding complex rules, frequent task switching, and multi-level settings. Physically, the weight, size, grip, and operating force of items should be adapted to the physical condition of older adults to avoid causing additional strain. In terms of maintenance, older adults require everyday items that are easy to clean, easy to store, durable, and do not require frequent maintenance. It is evident that the demand for low-burden usability fundamentally reflects the elderly's comprehensive needs for convenience, a sense of security, stability, and autonomy in daily activities.

3.3 Product Design Positioning and Design Principles

3.3.1 Product Design Positioning

Portable hand exercise toys for the elderly should be distinguished from professional rehabilitation equipment and should not be simplistically regarded as ordinary recreational toys. Their core positioning is as follows: targeting primarily elderly individuals with basic self-care abilities, grounded in low-intensity hand activities, and supported by multisensory feedback.

Through portable, low-burden, and life-integrated design, the product aims to become an age-friendly play item that seamlessly integrates into everyday life.

This product is primarily intended for older adults who experience reduced hand dexterity, weakened grip stability, and an increased need for sensory feedback, or who have mild emotional comfort needs during periods of solitude or waiting. Such users typically do not require specialized, high-intensity training equipment, but they do have needs to maintain the frequency of hand activity, relieve hand stiffness caused by prolonged sitting, divert their attention, and receive moderate sensory stimulation. Therefore, the product should not emphasize “therapeutic” or “corrective” attributes but rather support daily activities in a gentle, natural manner.

In terms of product attributes, this design should fall between hand activity aids, age-friendly toys, and everyday companions. On one hand, it needs to provide some guidance for hand movement, enabling older adults to perform low-intensity hand actions through pressing, sliding, flicking, and rolling. On the other hand, it must offer an experience that is playful, tactile, and inviting for repeated interaction, avoiding neglect due to overly narrow functionality or an overly mechanical feel. In other words, the product’s value lies not merely in “whether it can provide training,” but rather in whether it can encourage older adults to voluntarily pick it up, use it consistently, and integrate it naturally into their daily routines.

The product is suitable for fragmented scenarios such as leisure at home, time spent in the community, waiting in a doctor’s office, commuting, and relaxing before bed. These scenarios are characterized by irregular timing, dispersed locations, and low-intensity activities, which necessitate that the product be compact, portable, easy to learn, and ready for immediate use. Elderly users should not need to make complex preparations to use the product, nor should they be required to visit specialized facilities or follow strict procedures. The product should exist as naturally as everyday small objects, allowing hand movements to occur in a stress-free state.

In summary, the product design objectives can be summarized in three aspects: First, lower the barriers to understanding and operation, enabling older adults to quickly identify functions based on the product’s form and tactile cues; second, establish gentle yet clear multisensory feedback to enhance the sense of confirmation during operation and the enjoyment of handling the product; third, enhance the product’s integration into daily life, allowing it to adapt to fragmented scenarios such as home, community, waiting rooms, travel, and bedtime. Consequently, product design should achieve a harmonious integration of functionality, user experience, and contextual use.

3.3.2 Product Design Principles

(1) Usability Principle

Usability is the fundamental principle in the design of portable hand exercise toys for the elderly. Since older adults may experience varying degrees of change in visual recognition, motor control, and information processing speed, products should avoid complex structures, hidden functions, and multi-step operational logic as much as possible. The method of use should primarily rely on intuitive physical interaction, allowing older adults to naturally understand the basic operational path when interacting with the product.

In practical design, functional areas should be clearly distinguishable. Different operational

zones can be differentiated through variations in shape, material, textured surfaces, or spatial relationships, allowing older adults to determine their purpose through sight and touch. For older users, clearly knowing "where to press," "where to slide," and "where to grip" is more important than the number of complex functions. Products should not rely excessively on textual instructions or abstract symbols but should convey usage through their physical form. Operational feedback should also be unambiguous. During use, older adults need to confirm whether an action has been completed, whether the applied force is appropriate, and whether the operation was successful. If product feedback is too weak or the results are unclear, it can easily lead to hesitation and uncertainty. Through moderate damping, slight spring back, soft sounds, or changes in state, the sense of operational confirmation can be enhanced, providing older adults with a stable and controllable experience during use.

(2) Comfort Principle

Comfort relates not only to the physical experience of contact with the product but also influences older adults' psychological acceptance. Hand exercise toys require prolonged contact with the palms, fingers, and skin; therefore, the product's dimensions, weight, edge treatment, material hardness, and surface texture should all align with the usage characteristics of older adults. Products that are too heavy, too hard, too slippery, or have overly sharp edges may increase the burden of use and even lead to rejection. In terms of form design, products should avoid sharp angles and overly complex shapes, favoring rounded, full-bodied forms that are easy to grip. Dimensions should not be too large, so as not to hinder one-handed use; nor should they be too small, to ensure the elderly can maintain a stable grip. Material selection should balance skin-friendliness, slip resistance, and ease of cleaning, allowing users to feel safe, stable, and comfortable upon contact.

Psychological comfort is equally important. If products for the elderly appear overly mechanical, medical, or exercise-oriented, they can reinforce older adults' sense of physical decline. In contrast, gentle colors, approachable shapes, and everyday product semantics are more effective at reducing psychological distance. For portable hand exercise toys designed for the elderly, comfort is not merely a matter of tactile sensation; it is also a key factor in whether the product is naturally accepted.

(3) Principle of Multisensory Synergy

Multisensory synergy is a core principle of this design. As older users may experience diminished cognitive abilities in individual sensory channels, products must utilize complementary feedback from multiple senses—including touch, sight, sound, and smell. Multisensory synergy does not simply involve adding sensory elements; rather, it establishes clear relationships between different feedback channels around a single usage process, thereby enhancing the product's perceptibility and the continuity of the user experience. Sensory research indicates that cues from vision, hearing, touch, and smell can influence people's perceptual judgments of products, environments, and behavioral outcomes (Krishna, 2012). Tactile feedback should serve as the primary feedback channel. Through manual contact with products, older adults can directly perceive variations in material hardness, surface texture, pressure required, sliding resistance, and rebound. Visual feedback can be used to provide supplementary status cues, such as soft lighting effects or color changes; auditory feedback can enhance the sense of action confirmation through subtle sounds; and olfactory feedback can create a soothing atmosphere in specific scenarios.

Different senses should complement one another rather than interfere with each other.

It is important to emphasize that multisensory design for older adults should control the intensity of stimuli. Excessively bright lights, loud sounds, overpowering scents, or overly firm textures can all diminish user comfort. A more appropriate approach is to employ gentle, stable, and low-intensity sensory feedback, ensuring that older adults experience clarity without feeling overwhelmed during use. The ultimate goal of multisensory coordination is to enhance a product's comprehensibility, approachability, and likelihood of continued use.

(4) Portability Principle

Portability is a key prerequisite for such products to integrate into the daily lives of older adults. Their usage needs are often scattered across various daily activities and do not occur exclusively in specialized training settings. Therefore, products should be compact, lightweight, and easy to store, allowing older adults to access them at any time—whether at home, in the community, in hospital waiting areas, or while out and about. Portability implies not only a small footprint but also the ability to carry the product effortlessly, activate it quickly, and store it safely. The product's structure should be as compact as possible, avoiding exposed sharp edges or small parts that could easily come loose. The overall weight should be within a range that allows older adults to hold it with one hand for extended periods, and the surface should have a certain degree of slip resistance to reduce the risk of dropping.

Additionally, portable products should prioritize ease of maintenance. Older adults typically prefer everyday items that are easy to clean, require minimal upkeep, and are durable. If a product necessitates frequent disassembly, complex maintenance, or reliance on external devices, it increases the burden of use and reduces the likelihood of continued use. Therefore, the principle of portability should encompass size control, structural safety, convenient storage, and simplified maintenance, ensuring the product truly adapts to the daily rhythms of older adults.

3.4 Design Practice of Portable Hand Exercise Toys for the Elderly

(1) Product Concept Description

Addressing issues such as declining hand mobility, increased need for sensory feedback, and the need for daily emotional relief among the elderly, this study proposes a portable, pocket-sized multisensory hand exercise toy. Unlike professional rehabilitation equipment, this design does not emphasize high-intensity training or medical treatment functions; instead, it transforms light hand activities into natural, low-burden, and repeatable daily play behaviors. In scenarios such as leisure at home, community activities, waiting in a clinic, or relaxing before bed, the elderly can engage in hand activities through pressing, sliding, flicking, rolling, and smelling, receiving clear feedback and a sense of emotional stability in the process.

In terms of overall form, the design features a pocket-sized cube structure that fits comfortably in the palm. Its compact size makes it easy to carry in a pocket, handbag, or store in a bedside drawer (Fig. 1). Each of the six surfaces corresponds to a distinct functional module, which not only maximizes the product's spatial efficiency but also ensures that each operational area is relatively independent, making it easier for older adults to identify and remember them. Compared to traditional hand training products such as grip balls and finger exercisers, this design places greater emphasis on "toy-like" and "life-integrated" experiential features. Users are not required to

follow a fixed training routine but can independently choose different ways to interact with the device based on their current physical condition and emotional needs. As a result, hand exercise is no longer a task-oriented training activity but becomes a daily behavior that can be performed casually and explored freely.

Figure 1: Overall rendering of the portable hand exercise toy for the elderly

This solution primarily addresses needs on three levels. Physically, it helps older adults maintain hand activity frequency through low-intensity actions such as pressing, sliding, flicking, and rolling, thereby alleviating discomfort caused by finger stiffness and slowed movements. Sensory-wise, a combination of different materials, textures, resistance, sounds, lighting effects, and scents creates multi-channel feedback, making the usage process easier to perceive and confirm. Psychologically, the product's soft form, repetitive interactions, and sustained tactile engagement mitigate the mechanical feel of traditional rehabilitation devices. This reduces older adults' psychological resistance to concepts like "rehabilitation" and "training," allowing the product to integrate more naturally into daily life. It is important to note that this product does not replace medical rehabilitation training; rather, it serves as a daily assistive, age-friendly product designed to help older adults maintain hand mobility and a sense of participation in daily life in a relaxed state.

(2) Functional Modules and Age-Friendly Design Details

The functional modules are designed around the usage characteristics of the elderly: "easy to pick up, direct operation, and clear feedback." A vertical silicone slider is positioned on the front of the product, allowing users to slide their thumb or index finger up and down. This action generates moderate resistance and a subtle audible click, providing immediate feedback on the operation. This design not only helps mobilize finger joints but also enhances the sense of rhythm and enjoyment during use. The raised buttons on the side of the front panel and the small joystick provide distinct modes of operation: the former is suitable for repeated pressing, while the latter allows for slight forward, backward, left, and right movements, thereby engaging the thumb, index finger, and metacarpophalangeal joints (Figure 2).The ring-shaped slider on the right emphasizes circular sliding and localized pressing, guiding older adults to perform more precise finger control movements. It also provides visual cues through subtle changes in the light-sensitive silicone on its surface (Figure 3).

Figure 2: Front Press and Slide Module Figure 3: Right-Side Ring Slider Module

The functional design of the tactile layer places greater emphasis on material differentiation and perceptual discrimination. Four slow-rebound buttons with distinct textures are positioned on the left side of the product, creating soft, raised, rough, and smooth tactile sensations, respectively. This provides older adults with rich yet non-overwhelming tactile feedback during touching and pressing (Fig. 4).The stainless steel roller module on the back is designed for gentle rolling, providing moderate tactile stimulation on the back of the hand, arms, and other areas to help users reduce the urge to scratch directly (Fig. 5). This feature is primarily intended as a daily comfort aid and should not be interpreted as medical treatment. The slow-rebound silicone push buttons on the top are suitable for repeated pressing in quiet environments; the lights change in brightness after pressing, enhancing the sense of operational confirmation. The concealed aromatherapy compartment at the base can hold natural scent materials such as dried tangerine peel, lavender, or dried flowers, creating a soothing atmosphere during bedtime relaxation, moments of restlessness, or when spending time alone (Fig. 6, Fig. 7).

Fig. 4 Left-side multi-textured tactile module Fig. 5 Rear rollerball relaxation module

Fig. 6 Top-mounted pressure light Fig. 7 Bottom Aromatherapy Chamber

Age-friendly design details are primarily reflected in scale, form, materials, and safety considerations. The overall shape adopts a pocket-like structure that fits comfortably in the palm; the size should not be too large to ensure that older adults can hold it steadily with one hand. Edges

should be rounded to prevent sharp corners from causing discomfort or injuries. Contact surfaces should use skin-friendly, non-slip, soft, and easy-to-clean materials to maintain comfort during prolonged use.Different functional zones can be distinguished through variations in form, material, texture, and position, reducing the need for text labels and complex learning processes so that older adults can intuitively determine how to operate the device through touch. Structurally, small parts that are prone to falling off should be avoided, and the pressure required for buttons, sliding resistance, the smoothness of rollers, and the force needed to open and close the aroma chamber should be carefully controlled to ensure the product is easy to operate while providing stability and a sense of security.The overall design does not pursue complex smart features but instead enhances older adults' willingness to actively use the product through clear, low-effort physical interactions.

(3) Multisensory Interaction Experience and Usage Scenarios

Multisensory coordination is the key feature that distinguishes this solution from traditional hand exercise products. Tactile feedback serves as the primary interaction channel, integrated across multiple modules including silicone sliders, raised buttons, joysticks, ring-shaped tracks, slow-return buttons, and stainless steel rollers. As older adults touch, press, slide, and roll these elements, they can perceive variations in firmness, texture, temperature, and resistance. This feedback not only helps users confirm the results of their actions but also enriches the hand-movement process, making it more engaging and sustainable. Research on cross-modal experiences indicates that when multiple sensory cues co-occur within a single product, they influence users' overall judgments regarding the product's status, quality, and usage context (Spence, 2011).Auditory feedback primarily comes from the subtle sounds produced when sliding the slider; the sound intensity should remain gentle, providing action confirmation without disturbing others. Visual feedback is achieved through light-sensitive silicone and press-activated lights, primarily serving to indicate status and regulate mood. The olfactory experience is provided by a concealed aroma chamber; natural scents help create a relaxing atmosphere before sleep, during rest, and when feeling agitated.

The various sensory elements are not simply superimposed but should form a coordinated relationship centered on the actual usage scenarios of older adults. Tactile feedback handles primary operations, sound aids in action confirmation, lighting provides gentle cues, and scent creates an emotional backdrop. If any single sensory stimulus is too intense, it may actually cause stress during use. Therefore, multisensory design for older adults should control stimulus intensity, emphasizing gentleness, stability, and comprehensibility. Particularly in quiet settings such as before bedtime or while waiting in a clinic, overly bright lights, loud sounds, or strong scents can reduce comfort. A more appropriate approach is to ensure that sensory feedback remains low-stimulus, highly recognizable, and sustainable, providing older adults with a stable and undisturbed experience during use.

When watching TV, listening to the radio, chatting, or resting, older adults can easily pick up the product to press and slide it. In these situations, the product does not require the user to focus intensely but rather helps them perform low-intensity hand activities in a relaxed state (Figure 8). In community settings, the product can serve as a small, portable item for use during walks, rest breaks, or neighborhood interactions; it takes up little space and does not give off a strong impression of being a medical device. In waiting rooms or while waiting for public transportation, repetitive pressing, sliding, and rolling motions can divert attention and alleviate the restlessness associated with waiting (Fig. 9). At bedtime, the slow-rebound press buttons, soft lighting, and

aroma chamber can be used in combination to help users enter a relaxed state through a slow rhythm, gentle tactile sensations, and natural scents.

Figure 8: Usage scenario in a home leisure setting

Overall, this solution aims to transform "passive training" into "active play" and "single-function products" into "companion-style lifestyle accessories." Its value lies not in enhancing a specific training metric, but in enabling older adults to engage in physical activity, receive sensory stimulation, and experience emotional relief with minimal burden through a portable design, modular functions, and multisensory feedback. Compared to traditional hand-exercise products, this design downplays medical and mechanical connotations, placing greater emphasis on approachability, naturalness, and the potential for everyday use. For age-friendly toy design, this approach offers a concrete practical reference for shifting silver-generation products from functional compensation toward experiential care.

Fig. 9 Usage scenario in an outdoor portable setting

4. Conclusion

This study adopts a multisensory interaction perspective to address issues such as hand function decline, reduced sensory sensitivity, daily emotional distress (including loneliness and irritability), and changes in cognitive and motor abilities among the elderly. It proposes a design solution for a portable hand exercise toy for seniors. The research indicates that hand exercise products for the elderly should not only focus on training intensity and functional compensation but also prioritize the product's perceptibility, playfulness, companionship, and value for everyday use.

Theoretically, by integrating multisensory interaction with age-friendly design, this study proposes a design approach that progresses from physical activity to sensory experience and ultimately to emotional comfort. The synergy of tactile, auditory, visual, and olfactory stimuli can transform monotonous hand exercises into a gentler, more natural, and more sustainable interactive experience. Elderly users are not merely passive recipients of care, nor are they users who pursue only functional efficiency; rather, they are complete individuals with emotional, aesthetic, and experiential needs.

In practical terms, the product design integrates hand movement, multisensory stimulation, emotional comfort, and daily assistance through modules such as silicone sliders, raised buttons, joysticks, ring-shaped tracks, multi-textured slow-return buttons, stainless steel rollers, and a concealed aromatherapy chamber. The design focuses not on replacing user behavior with complex technology, but on guiding older adults to actively engage through low-effort physical interactions. This design approach better aligns with the usage characteristics of older adults, which are characterized by fragmented, everyday use and low learning curves.

The study still has certain limitations. The current proposal is primarily in the conceptual design and prototyping stages; key parameters such as product dimensions, weight, actuation force, sliding resistance, light brightness, and acceptance of the aromatherapy feature still need to be validated through testing with real elderly users. Acceptance of the product may vary among older adults of different ages, physical conditions, lifestyle habits, and sensory abilities; future research should expand the user sample and conduct stratified evaluations. The product's rolling ball and aromatherapy functions should be clearly defined as daily-life aids and should not be interpreted as medical treatments.

In the future, portable hand exercise toys for the elderly can be further developed by integrating them with community-based elderly care, home-based wellness, and senior consumer scenarios. On one hand, modular designs can be used to create different versions tailored to various needs, such as light hand exercises, pre-sleep relaxation, and emotional comfort; on the other hand, , lightweight smart features—such as exercise count reminders, family interaction, or community activity tracking—can be explored without increasing the burden on elderly users. Overall, the design of portable hand exercise toys for the elderly based on multisensory interaction offers a viable path for senior products to transition from functional compensation to experiential care, and provides new design insights for product innovation tailored to the elderly in the context of the silver economy.

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