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Multi-sensory Design Empowering Natural Healing Landscape Design for the Elderly with Cognitive Impairment: An Empirical Study in the Chongqing Area

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ABSTRACT

Adopting an interdisciplinary perspective, this study focuses on the nature-based healing needs of the elderly with cognitive impairment and employs multi-sensory design as the core methodology to explore pathways for empowering healing environment art. A theoretical framework and a "Four-dimensional synergy + regional adaptation + elderly-friendly optimization" design strategy system were developed to align with the group characteristics and regional attributes of Chongqing. This system was implemented in an 860-square-meter outdoor courtyard. The results indicate that the strategy significantly enhances spatial cognition and emotional stability among the target group while reducing safety risks. The core value of this research lies in the deep integration of artistic expression and landscape health preservation, offering both theoretical support and a practical example for similar designs in the Southwest region.

Citation:

1 Theoretical Integration of Multi-sensory Design and Nature-based Healing Environments

1.1 Environmental Expression Logic of Multi-sensory Design

Multi-sensory design serves as the core design language for nature-based healing environments. It utilizes the environment as a medium to construct an artistic healing field through four-dimensional synergy of visual, tactile, olfactory, and auditory stimuli. This approach unifies aesthetic and therapeutic functions and represents a key aspect of interdisciplinary integration between landscape architecture and art design. Sensory stimuli are not isolated elements; instead, they must be organized into a coherent whole through spatial sequence(Wang & Liu, 2025).

Visual design focuses on color, form, and light and shadow, tailored to the group characteristics of individuals with cognitive impairment in the elderly. Color schemes primarily adopt a warm-dominant and cold-auxiliary approach, using the colors of plants and pavement to evoke memory and alleviate anxiety. Cool color systems are paired with evergreen plants to establish visual anchors. In terms of form, rigid lines are avoided, and groupings of native plants and natural materials are used to balance the sense of order with naturalness. Light and shadow are coordinated through both natural light and artificial lighting, creating mottled light and shadow during the day and enhancing boundaries at night with low-intensity warm light to convey a therapeutic atmosphere.

Tactile design focuses on the texture of natural materials and their functional roles, compensating for deficiencies in visual cognition. Pavement materials are selected based on function, incorporating anti-slip solid wood, frosted stone, and permeable concrete, with texture variation used to suggest spatial attributes. Touchable groups are formed through plant arrangements, selecting thornless and non-toxic, texturally rich varieties. In micro-plant spaces, wooden planter boxes, terracotta flower pots, and soil are combined to integrate plant interaction with tactile design.

Olfactory design centers on the seasonal allocation of aromatic plants and spatial layout to establish an implicit therapeutic system. Species such as banana shrub, gardenia, osmanthus, and wintersweet are arranged according to seasonal cycles, balancing therapeutic properties with recognizability. A concentration gradient is created based on function: high-concentration aromatic groups are placed in rest areas, low-concentration guidance is applied along passage routes, and regional aromatic plants serve as anchor points in the memory awakening area. Concentration levels are strictly controlled, and allergenic species are avoided.

Auditory design focuses on the integration of natural and artificial soundscapes to create a soothing environment. The natural soundscape is achieved through water features, the friction of bamboo and willow branches, and the attraction of birdsong by nectar plants. Artificial soundscapes adhere to the principle of low interference, with hidden speakers in rest spaces playing soft white noise to define differentiated soundscape spaces.

1.2 Design Translation of Natural Healing

The design translation of natural healing refers to the process of transforming the healing properties of natural elements into practical design techniques, thereby forming a "natural value – artistic design value – therapeutic value" closed loop. As the core medium, plants play a central role in this process, with their artistic empowerment serving as a key practice of interdisciplinary integration.

Plant community configuration is centered on healing functions and integrates artistic composition to construct an arbor-shrub-herb-vine multi-level structure. Native arbors form the upper structural skeleton, aromatic shrubs enrich the sensory experience at the middle level, and herbaceous layers provide the foundational base. Adhering to the principles of balance and recognizability, the design employs plant form and color, seasonal change, and iconic anchor points to create plant communities tailored to the needs of individuals with cognitive impairments.

The micro-plant healing space adopts a modular artistic layout that integrates planting, operation, and rest functions. The planting area is organized through zoning planning using artistic planter boxes. The operation area is equipped with easy-to-use tools, while the rest area encloses the planting area and is complemented by aromatic plants. Traditional garden techniques are simplified into participatory forms, combining therapeutic properties with cultural and artistic value.

The plant seasonal landscape centers on thematic design, creating dynamic scenes through variations in form, color, and scent across the four seasons. Flowering and shading plants are used in spring and summer, while colorful foliage, ornamental fruits, and aromatic plants are introduced in autumn and winter. This landscape narrative aids users in developing time perception. The design adheres to the "Nature-based, art-empowered" logic, prioritizing native and easy-to-maintain species, avoiding excessive decoration, and achieving a unified balance of naturalness, safety, and therapeutic properties.

1.3 Sensory Responses and Design Adaptation for the Elderly with Cognitive Impairment

The elderly with cognitive impairment often exhibit characteristics such as memory decline, spatial cognitive impairment, and sensory function degradation. Their environmental perception mode differs significantly from that of the healthy group, necessitating the development of a multi-sensory design adaptation mechanism based on sensory responses to accurately align sensory design with therapeutic needs. In interactive design for the elderly population, spatial narrative should be guided by carefully curated plant configuration to facilitate a psychological transformation from a daily state to a therapeutic state(Yang, 2025).

Due to the visual changes associated with aging, variations in the visual landscape design can stimulate the eyes of elderly individuals through external stimuli. These stimuli trigger a series of responses in the brain, subsequently leading to changes in physiological characteristics, most notably reflected in variations in pulse rate(Yin & Du, 2020). Visual response follows the "simplify, strengthen, anchor" strategy: simple plant groups and regular layouts are used to reduce redundancy; visual contrast is enhanced to emphasize focal points and boundaries; iconic plants or small-scale landscape features are placed at entrances and turning points, incorporating familiar symbols to establish visual anchors and trigger memory awakening.

Tactile sensation, as one of the most primitive and fundamental senses of human beings, serves as an auxiliary supplement to other sensory perceptions(Tang & Pan, 2018). Tactile design adheres to the "differentiation, safety, comfort" principle: natural materials with varying textures are selected to accommodate sensitivity differences; thornless and non-toxic plants and materials are chosen to ensure anti-slip pavement and anti-fall facilities; solid wood and natural stone are prioritized to enhance tactile feedback.

In terms of olfactory landscape, existing studies have found that the inhalation of volatile substances of spices through the sense of smell can contribute to disease prevention and relieve uncomfortable symptoms(Liu & Liu, 2006). Olfactory design centers on the principles of "familiarity, mildness, and pertinence": selecting common aromatic plants such as osmanthus and jasmine to evoke memory; maintaining a single and pure scent to avoid overload; and configuring sedative or awakening plants according to emotional needs to align with spatial function.

With age-related auditory changes, auditory landscape design plays a crucial role in influencing the physical and mental health of older adults(Song et al., 2019). Auditory adaptation follows the "low interference, regularity, comfort" principle: blocking noise and controlling artificial soundscape volume; constructing regular natural soundscapes such as running water and leaf friction to support time cognition; and enhancing mid-low frequency sound while avoiding high-frequency sharp sound.

Multi-sensory collaboration serves as the core logic, where element complementation compensates for the limitations of an insufficient single sense. This approach helps create an immersive environment while regulating stimulus intensity based on group cognitive level to prevent the onset of irritable mood.

1.4 Construction of the Interdisciplinary Design Model

The core logic of empowering nature-based healing environments through multi-sensory design lies in an interdisciplinary practice grounded in group sensory response patterns, employing multi-sensory art as the method, using plants as the medium, and environmental design as the pathway. This study establishes an "Input - transformation - output - feedback" closed-loop model that integrates multi-disciplinary theory, with the primary goal of translating theoretical frameworks into actionable design strategies.

The model progresses through four interrelated dimensions. Demand input identifies core needs and determines entry points through research. Artistic transformation converts these needs into three primary design pathways: single-sense, multi-sensory collaboration, and plant therapy. Therapeutic output constructs an evaluation system combining quantitative and qualitative methods. Optimization feedback enables immediate adjustment and long-term iteration logic, incorporating local culture and technical optimization plans. The innovation point of the model lies in achieving the triple integration of multi-sensory art and plant healing, theory and practice, and group needs and artistic expression.

1.5 International Frontier Research Comparison and Theoretical Expansion

The multi-sensory design framework of this study aligns with the international trend of person-centered care for the elderly with cognitive impairment, but also highlights regional characteristics based on the context of Southwest China. International studies have emphasized the role of multi-sensory stimulation in improving cognitive function, such as multi-sensory environment developed in the Netherlands, which has been proven to reduce agitation in elderly with dementia. However, most international studies focus on indoor environments, while this study extends the application to outdoor natural landscapes, which is more in line with the ecological needs of the elderly in China.

2 Design Requirements Analysis and Extraction of Core Entry Points

This chapter focuses on the "demand input" dimension of the interdisciplinary model. Drawing on specific research data—collected over a six-month follow-up period from 216 samples across three nursing homes and two community care centers in Chongqing, with an effective recovery rate of 92.1%—it dissects the core demands, constructs a transformation path, and extracts key entry points to achieve a seamless connection between theory and practice.

2.1 Anchoring Group Characteristics and Design Adaptation Requirements

With the acceleration of the global population aging process, elderly individuals are placing increasing demands on the safety, comfort, and health promotion function of their living environments(Cheng et al., 2026). Survey data indicate that among the elderly with cognitive impairment, the incidence rates of spatial disorientation, abnormal sensory sensitivity, and emotional anxiety are 78.2%, 73.6%, and 65.7%, respectively. Furthermore, environmental sensory adaptation exhibits a significant positive correlation with both cognitive arousal efficiency and emotional stability rate.

These findings clarify the analysis direction of taking sensory response as the core and artistic adaptation as the goal. The core of spatial cognitive needs lies in constructing a High Recognizability, Low Anxiety Space System. Among the samples, 82.4% experienced lost panic in complex spaces, and only 31.8% were able to Quickly Identify Traditional Landscape Boundaries, showing a clear preference for Regular Layouts. Design strategies should adopt Linear or Circular Regular Layouts and reinforce Identification through the "Plant + material" double anchor point. Functional zoning should be defined by the Differentiation of Pavement and Plant Groups.

Sensory experience needs stem from the phenomenon of Single Sensory Degradation, Multi-sensory Collaborative Compensation. Empirical data indicate that in Multi-sensory synergistic scenes, Cognitive Arousal Duration was reduced by 32.6%, while Emotional Stability Rate increased by 41.3%. The core requirements include Moderate Stimulation, Synergistic Complementarity, and Familiar Adaptation. Visual design should apply Low Redundancy, High Contrast Processing; tactile elements should feature Differentiated Texture; and olfactory and auditory stimuli should center on Natural Familiar Elements, with strict control over Stimulation Intensity.

Emotional regulation needs should be addressed by fostering a sense of belonging through the artistic expression of natural elements. A natural plant environment can extend the anxiety relief duration by 2.8 hours per day, while memory-related native plants and participatory scenes can enhance the therapeutic effect by 37.2% and 45.5%, respectively. The design should incorporate memory-related native plants, create micro-plant interaction spaces, and establish a four seasons theme landscape to promote positive emotions.

Safety guarantee needs represent the design baseline. Among incidents, 68.3% are attributed to insufficient ground anti-slip and blurred boundaries, while 29.5% are linked to improper plant selection. The design should focus on "implicit safety + artistic integration" by utilizing natural materials with an anti-slip coefficient ⩾ 0.6 and employing gentle slope transitions with a 1:12 gradient to mitigate risks. Thornless and non-toxic soft plants should be selected, facilities should be optimized, and emergency devices should be discreetly integrated into the landscape to achieve a unified approach to safety and aesthetics.

2.2 Demand Transformation and Core Design Entry Points

The core of demand transformation lies in accurately translating the four primary needs into a coherent design language, thereby establishing the "Demand ‑ Design Goal ‑ Artistic Technique ‑ Implementation Path" closed loop. This process distills four key entry points and anchors the strategic direction.

2.2.1 Transformation Path from Demand to Design

Spatial cognitive needs are addressed through a strategy integrating circulation optimization, dual anchor reinforcement, and boundary definition. The circulation system adopts a "Linear Main Line + Circular Supplement" configuration, with nodes placed every 30 to 40 meters. Dual anchor points are defined using native plants such as Ficus virens and Bougainvillea spectabilis, complemented by solid wood and blue-gray stone bases. Boundaries are articulated through soft plant enclosure, material definition, and light and shadow shaping coordination.

Sensory experience needs are translated into a strategy of four-dimensional synergy, intensity control, and scene integration. Visually, an earth tone palette serves as the base, with plant colors presenting a brightness difference of 30% to 40%. Tactile zones are divided into three types of texture areas. Olfactory elements are structured through the olfactory construction of a four seasons gradient aromatic system. Auditory design focuses on natural soundscapes, maintaining sound levels between 30 and 40 decibels.

The emotional regulation needs are translated into a strategy of "memory anchors + participatory space + seasonal narrative." Double memory groups are constructed using native plants. The participatory space adopts a modular layout, incorporating solid wood planting boxes with a height of 60 ‑ 70 cm, paired with adapted tools. Seasonal narrative is expressed through plant collocation to create a dynamic landscape.

The safety guarantee needs are addressed through a strategy of "implicit safety + elderly-friendly adaptation + artistic integration." Plants are strictly selected from safe categories. Facilities feature rounded corner treatment, while emergency channels and call devices are integrated into the landscape. Additionally, precise slope design ensures that the road longitudinal slope remains under 3%, with auxiliary facilities such as anti-slip strips provided accordingly(Sun & Zhang, 2024).

The transformation logic, implementation pathways, and regional adaptation points for each core demand can be systematically referenced in Table 1.

Table 1 Needs of Elderly People with Cognitive Impairment and Multi-Sensory Design Transformation Table

Core Demand Types	Key Survey Data Support	Design Objectives	Core Design Methods	Implementation Paths
Spatial Cognition Demand	78.2% of the subjects suffer from spatial disorientation; 82.4% tend to get lost in complex spaces; only 31.8% can quickly identify traditional landscape boundaries	Construction of a highly recognizable and low-anxiety spatial system	Regularized circulation design; Strengthening of "plant + material" dual anchor points; Artistic definition of boundaries	Linear main circulation + annular supplementary circulation, with nodes set every 30–40 meters; Selection of native plants such as Ficus virens and Bougainvillea spectabilis matched with natural material anchor points; Soft plant enclosure + material definition + light and shadow shaping
Sensory Experience Demand	73.6% have abnormal sensory sensitivity; cognitive arousal time is reduced by 32.6% and emotional stability rate is increased by 41.3% in multi-sensory coordinated scenarios	Moderate stimulation, synergistic complementarity, familiarity and adaptability	Four-dimensional sensory coordinated design; Stimulation intensity control; Scene integration	Visual contrast with 30%–40% brightness difference; Differentiated textures in tactile zones; Seasonal gradient fragrance in olfactory design; Low-interference soundscape with 30–40 decibels in auditory design
Emotional Regulation Demand	65.7% suffer from emotional anxiety; natural plant environments extend anxiety relief duration by 2.8 hours per day; the healing effect of participatory scenes is improved by 45.5%	Construction of psychological belonging and guidance of positive emotions	Creation of memory anchor points; Participatory space design; Seasonal narrative	Memory clusters of native plants; Interactive space with 60–70 cm high modular planters; Four-season themed plant landscape configuration
Safety Guarantee Demand	68.3% of accidents are caused by insufficient ground slip resistance or unclear boundaries; 29.5% are related to improper plant selection	Integration of implicit safety and artistic atmosphere	Application of anti-slip materials; Selection of safe plants; Elderly-friendly optimization of facilities; Artistic hiding of emergency functions	Natural materials with slip resistance coefficient ≥ 0.6 and 1:12 gentle slope; Thornless, non-toxic and soft plants; Facilities with rounded corners + hidden emergency devices

Research indicates that the recognition rate of traditional landscape boundaries is only 31.8%, which aligns with the baseline spatial orientation accuracy rate of 32.1% observed in the pre-renovation empirical study, thereby validating the representativeness of the sample. Table 1 presents the basic healing data of the multi-sensory synergy scene, serving as a reference for subsequent design interventions.

2.2.2 Core Design Entry Points

The four core design entry points are derived from the primary needs of the elderly with cognitive impairment and refined through interdisciplinary attributes. These serve as critical levers for implementing the design strategies discussed later. The spatial narrative entry point addresses spatial cognitive impairment by employing a strategy centered on a regularized moving line and a dual anchor point system. This is achieved through the integration of plants, paving, and light and shadow art to construct identifiable space, thereby establishing the foundation of spatial design.

The sensory compensation entry point directly addresses the characteristics of sensory degradation. By employing "Four-dimensional coordination + moderate stimulation," it compensates for the insufficiency of a single sense and enhances the healing experience, aligning with the multi-dimensional collaborative strategy. The memory awakening entry point centers on emotional regulation and integrates regional elements through "Native plants + participatory scene," providing a core conceptual framework for the emotion empowerment strategy.

The implicit safety entry point serves as the design baseline, achieving the landscape expression of safety functions through "Safety adaptation + artistic integration," thereby supporting the all-dimensional safety strategy. Together, the four key entry points form a cohesive "Function - Art - Healing" logic chain that runs through the entire design process.

3 Multi-sensory Design Strategy System

Building on the preceding theoretical framework and the four key entry points, this chapter establishes a strategy system of "Multi-sensory Collaboration + Regional Adaptation + Elderly-friendly Optimization." It focuses on the artistic expression of plant application, space creation, and material selection, aiming to enhance implementability and ensure functional unity.

3.1 Cognitive Adaptation Design Strategy Based on Spatial Narrative

Building upon the conclusion that 82.4% of the target group adapts well to regularized spaces, a low-anxiety space is created through the integration of "moving line narrative + dual anchor point design + boundary reinforcement". The circulation adopts a four-stage rhythm (entrance guidance - transition buffer - core interaction - rest and quiet) with a 1.8 - 2.2 m main path width. The entrance is planted with Ficus virens and paved with light gray frosted stone; the transition zone uses clumping bamboo and permeable concrete; the core area is a circular line surrounding a micro-plant zone.

The dual anchor points continue the "plants + materials" combination. Node anchor points are placed every 30 to 40 meters, with Bougainvillea spectabilis paired with solid wood flower ponds and wintersweet paired with stone flower pots to create memory points. Path anchor points are set at 15-meter intervals, using alternating solid wood strips and frosted stone, along with small aromatic groups, to enhance guidance. The boundaries are defined through a combination of soft plant enclosure, material edging, and light and shadow shaping coordination. Functional boundaries are delineated using groupings of Ophiopogon japonicus and Gardenia jasminoides paired with stone edging. Dynamic-static boundaries are softened through slight height differences and flexible plants to reduce spatial fragmentation. At night, low-illumination light strips are employed to enhance the moving line outline.

3.2 Multi-dimensional Collaborative Design Strategy Based on Sensory Compensation

Focusing on sensory compensation entry points and supported by data indicating a 41.3% improvement in emotional stability rate through multi-sensory collaboration, a four-dimensional collaborative field is constructed. Visually, the design adopts an earth tone base, combining dark pavement with light-colored herbs. Evergreen groups are paired with colorful foliage plants, with one to two core focuses maintained to avoid redundancy.

Tactile design emphasizes differentiated experiences. Passage routes incorporate a combination of anti-slip stone and solid wood strips. In the interaction area, fine gravel and a humus mixed layer are used alongside touchable plants. The rest area features a wooden platform complemented by cushions. An olfactory gradient system is established through strategic planting: high-branch osmanthus and Michelia figo groups are arranged in the rest area, while gardenia and jasmine cluster plantings are used in the interaction area. Aromatic potted plants are placed along the passage route, incorporating regional varieties such as Sichuan osmanthus to enhance sensory diversity.

A natural soundscape system is created to enrich the auditory experience. In the core area, a 30 cm high cascading water feature maintains water flow sound levels between 35 – 40 dB, complemented by aquatic plants. Along the circulation paths, bamboo and weeping willow are planted, accompanied by nectar source plants to attract birds. In the rest area, hidden speakers emit soft white noise at a volume not exceeding 30 dB.

3.3 Emotional Empowerment Design Strategy Based on Memory Arousal

Centered on the concept of "native plants + participatory scenes," the design reinforces a sense of belonging through plant groupings, participatory gardening, and cultural symbol translation. Plant memory anchor points are used to construct a "region + life" framework. A corridor lined with Ficus virens evokes the "old street memory," while Bougainvillea spectabilis climbing trellises create a "mountain city fireworks" atmosphere. Peach trees and gardenias, paired with signage featuring old family photographs, serve to awaken family memory.

Participatory gardening adopts a modular layout, divided into autonomous planting areas, assisted planting areas, and a harvest display area. The autonomous planting area features solid wood planter boxes with a height of 60 – 70 cm, filled with lightweight nutrient soil for cultivating easy-to-grow vegetables and herbs. The assisted planting area uses 40 cm high planter boxes paired with handrail operating tables. In the display area, wooden shelves are used to showcase the harvest, with surrounding rest seating and aromatic plants. The simplified integration of regional cultural symbols is reflected in the simplified transformation of the Diaojiaolou (stilted building) structure into planting frames and the old teahouse stone table into rest facilities. The inclusion of Pyracantha fortuneana and Serissa foetida potted plants further reinforces regional identity.

3.4 Elderly-friendly Integration Design Strategy Based on Implicit Safety

In response to data indicating that 68.3% of accidents stem from ground and boundary issues, the design employs four key approaches to achieve a unified balance between safety and spatial atmosphere. The ground pavement design utilizes natural materials with an anti-slip coefficient of ⩾0.6, arranged according to functional zoning. Transitions are implemented using gentle slopes with a 1:12 gradient. Light-colored stone edging is applied along the boundaries, and every 5 meters along circulation paths features stone groove anti-slip textures.

Plant selection follows the principles of being thornless, non-toxic, non-shedding, and easy to maintain. Arbor branch height is maintained at ⩾2.5 meters, and shrubs include soft varieties such as Gardenia jasminoides and jasmine. Facility optimization is based on ergonomics, with all facilities incorporating rounded corner treatment. Seating is designed with a height of 45 – 50 cm and equipped with handrails. In dangerous areas, low protective fences of 80 cm are combined with transparent plant screening. Emergency safety measures adopt a concealed design approach: 1.2-meter-wide emergency passages are paved with special texture stone; call devices are embedded in flower ponds at key nodes, with button height set at 1.1 meters and equipped with Braille. Emergency lighting is integrated with regular lighting.

3.5 Multi-strategy Collaboration and Regional Adaptation Design

Table2 systematically outlines the synergy among four major strategies, their key implementation points, and optimization measures tailored to regional adaptation in Chongqing. These strategies are interconnected through a design logic centered on sensory compensation, structured by spatial narrative, linked by memory awakening, and grounded in implicit safety, thereby achieving "one design with multiple layers of artistic value." Taking into account the subtropical monsoon climate and the cultural characteristics of Chongqing, plant selection prioritizes heat-resistant and moisture-resistant native varieties such as Ficus virens and camphor trees. The ground surface employs pervious materials in combination with vegetated swales. Facilities are designed using modular design principles, and multi-sensory elements are equipped with adjustable mechanisms to support operation and maintenance.

Table 2 Collaboration and Implementation Points Table of Core Strategies for Multi-sensory Design

Core Design Strategies	Core Objectives	Key Implementation Points	Regional Adaptation Optimization Measures (Chongqing)	Coordinated Correlation Logic
Spatial Narrative Strategy	Reduce spatial cognitive load and improve recognizability	Regular circulation structure (1.8–2.2m main corridor); 30–40m dual anchor points (plants + materials); soft boundary definition	Select native plants such as Ficus virens and Bougainvillea spectabilis; permeable concrete + solid wood pavement adapted to rainy climate	Provide a spatial framework for other strategies
Sensory Compensation Strategy	Make up for the deficiency of single sense and	Visual 30%–40% brightness difference; tactile zonal texture;	Supplement heat and humidity tolerant aromatic plants such as	Core functional strategy, linking space and emotion

Core Design Strategies	Core Objectives	Key Implementation Points	Regional Adaptation Optimization Measures (Chongqing)	Coordinated Correlation Logic
	strengthen experience	olfactory gradient fragrance; auditory 30–40dB natural soundscape	Cinnamomum wilsonii and Aglaia odorata; water feature landscape adapted to climate to enhance water sound therapy	
Memory Awakening Strategy	Strengthen emotional belonging and awaken past memories	Native plant memory clusters; modular participatory gardening; simplified translation of regional cultural symbols	Integrate regional elements such as Ficus virens corridors, simplified Diaojiaolou planters, and Diospyros cathayensis potted plants	Emotional link to improve spatial acceptance
Implicit Safety Strategy	Avoid risks and ensure elderly-friendly adaptation	Anti-slip materials (≥0.6); thornless and non-toxic plants; rounded-corner facilities; hidden emergency devices	Permeable ground materials + grassed swales for drainage; arbor branch height ≥2.5m adapted to terrain; Braille call devices adapted to the group	Bottom-line guarantee to support the implementation of other strategies

4 Design Demonstration and Effect Verification

This chapter presents an empirical study conducted in an 860-square-meter outdoor courtyard of an elderly cognitive impairment care center in Chongqing. By implementing the design strategy and following the process of "design implementation—effect verification—optimization and reflection," the study aims to validate the strategy's feasibility and therapeutic value, thereby achieving a closed loop between theory and practice.

4.1 Empirical Setting and Design Implementation

The 216 samples were recruited from 3 nursing homes and 2 community care centers in Chongqing, with the inclusion criteria: (1) aged 60 - 85 years; (2) diagnosed with mild to moderate cognitive impairment by a geriatrician using theDiagnostic and Statistical Manual of Mental Disorders (DSM-5) criteria; (3) able to walk independently or with a walker; (4) no severe visual, auditory, or motor impairment that would affect sensory perception. Theexclusion criteria: (1) severe cognitive impairment (MMSE score < 10); (2) acute mental illness or physical disease; (3) inability to cooperate with the assessment.

Among the 216 samples, 102 were male and 114 were female, with an average age of 72.3 ± 6.8 years. The cognitive impairment degree was classified as mild (MMSE score 20 - 26, n = 148) and moderate (MMSE score 10 - 19, n = 68). For the empirical study, 42 participants were selected using stratified random sampling to ensure the proportional distribution of age, gender, and cognitive impairment degree. The control group was set as the same participants in the pre-intervention period (self-control design), and the experimental group was the participants after the landscape renovation, with the observation period consistent for both groups (12 weeks).

The empirical study involved 42 patients aged 60 to 85 with cognitive impairments, all selected from the previously established research sample pool of 216 cases. The original site exhibited issues such as confused circulation, single sensory elements, prominent safety hazards, and a lack of regional characteristics, making it suitable for follow-up observation and regional adaptability verification.

The design plan focused on four key entry points. For spatial narrative, a 2.0-meter-wide main line was established within a 1.8 to 2.2-meter range, featuring row planting of Ficus virens and light gray stone paving. Every 35 meters, a "plant + material" dual anchor point was introduced, with Liriope spicata and Gardenia jasminoides groups forming a soft enclosure boundary. For sensory compensation, dark brown solid wood paving was paired with hosta plants (with a 35% brightness difference), and a fine gravel interaction area was integrated with tactile plants, complemented by gradient aroma and a 35 – 40 dB water feature soundscape. Memory recall was enhanced through a Ficus virens corridor, a simplified Diaojiaolou planting frame, 65 cm-high planting boxes, and Pyracantha fortuneana potted plants, reinforcing regional identity and interactive qualities. Implicit safety measures included stone materials with an anti-slip coefficient of 0.65, a 1:12 gentle slope, arbor branches at a height of 2.6 meters, and a hidden Braille call device, balancing safety with aesthetic considerations.

4.2 Measures & Analysis

4.2.1 Outcome Indicators and Measurement Tools

To ensure the reliability and replicability of the study, all outcome indicators were defined based on standardized scales and clinical assessment protocols, with detailed measurement tools and sources shown in Table 3.

Table 3 Outcome Indicators, Measurement Tools and Time Points

Indicator Category	Specific Indicator	Definition	Measurement Tool/Source	Time Points of Measurement
Spatial Cognition	Spatial Orientation Accuracy	The percentage of correct identification of spatial locations (entrance, activity zones, rest areas) by participants	Modified Environmental Orientation Assessment (EOA) for elderly with cognitive impairment	Pre-intervention (T0: 1 week before renovation); Post-intervention (T1: 12 weeks after renovation); Follow-up (T2: 24 weeks after renovation)
	Getting-lost Incidence Rate	The percentage of participants who experienced disorientation and required caregiver assistance within the space	On-site observation record sheet (validated by geriatric care experts)	T0; T1; T2
Cognitive & Emotional Function	Cognitive Arousal Duration	The time required for participants to complete a simple cognitive task (object	Stopwatch timing combined with Mini-Mental State Examination	T0; T1; T2

Indicator Category	Specific Indicator	Definition	Measurement Tool/Source	Time Points of Measurement
		recognition with plant cues)	(MMSE) auxiliary assessment	
	Emotional Stability Rate	The percentage of time participants maintained calm behavior (no irritability, restlessness) during 2-hour observation	Behavioral Rating Scale for Geriatric Patients (BRSGP)	T0; T1; T2
	SAS Anxiety Score	The score reflecting the severity of anxiety symptoms in participants, with higher scores indicating more severe anxiety	Self-Rating Anxiety Scale (SAS)	T0; T1; T2

4.2.2 Statistical Analysis of Outcome Indicators

SPSS 26.0 statistical software was used for data analysis, with $alpha = 0.05$ as the test level. Measurement data were expressed as $barxpms$, and paired t-test was used for comparison before and after intervention; count data were expressed as rate (%), and chi^2 test was used for comparison. All 42 participants completed the 24-week follow-up without loss to follow-up, ensuring the completeness and validity of the data. The specific statistical results of each indicator are shown in Table 4 and Table 5.

Table 4 Comparison of Measurement Data Indicators Before and After Intervention

Indicator	Pre-intervention (T0)	Post-intervention (T1)	Follow-up (T2)	t Value	P Value
Spatial Orientation Accuracy (%)	32.1 ± 8.5	68.3 ± 10.2	65.7 ± 9.8	15.362	< 0.001
Cognitive Arousal Duration (s)	89.6 ± 16.3	59.2 ± 12.7	61.5 ± 13.1	9.874	< 0.001
SAS Anxiety Score (points)	52.3 ± 7.6	41.5 ± 6.8	42.8 ± 7.1	7.925	< 0.001

Table 4 presents the statistical results of measurement data indicators. It can be seen that after the intervention (T1), the spatial orientation accuracy of the participants was significantly improved compared with that before the intervention (T0), the cognitive arousal duration was significantly shortened, and the SAS anxiety score was significantly reduced, with statistically significant differences ($P < 0.001$). During the follow-up period (T2), the indicators of the participants remained stable, without significant regression compared with T1, indicating that the multi-sensory natural healing landscape design has a lasting positive effect on improving the spatial cognitive ability and emotional state of the elderly with cognitive impairment.

Table 5 shows the statistical results of count data indicators (getting-lost incidence rate). Before the intervention, the getting-lost incidence rate of the participants was 69.0% (29/42); after the intervention, the getting-lost incidence rate was reduced to 14.3% (6/42); during the follow-up period, the getting-lost incidence rate was 16.7% (7/42). The difference between T1, T2 and T0 was statistically significant ($\chi^2 = 27.586, P < 0.001$; $\chi^2 = 24.892, P < 0.001$), indicating that the design strategy can effectively reduce the getting-lost risk of the target group and improve their spatial adaptability.

Table 5 Comparison of Getting-lost Incidence Rate Before and After Intervention

Indicator	Pre-intervention (T0)	Post-intervention (T1)	Follow-up (T2)	χ^2 Value	P Value
Getting-lost Incidence Rate	29(69.0)	6(14.3)	7(16.7)	27.586/24.892	< 0.001

4.2.3 Result Summary

The empirical results show that the multi-sensory natural healing landscape design strategy system constructed in this study can effectively improve the spatial cognitive ability, emotional stability and spatial adaptability of the elderly with cognitive impairment in Chongqing, and reduce the safety risks such as getting lost. Specifically, the spatial orientation accuracy of the participants increased by 36.2% after the intervention, the cognitive arousal duration was shortened by 30.4%, the SAS anxiety score decreased by 10.8 points, and the getting-lost incidence rate decreased by 54.7%. The follow-up results show that the therapeutic effect of the design is lasting, which verifies the feasibility, effectiveness and regional adaptability of the design strategy system.

4.3 Optimization and Reflection Based on Empirical Results

Combined with the empirical results and on-site observation, the design strategy is optimized and reflected to further improve the applicability and sustainability of the strategy. On the one hand, although the spatial orientation accuracy of the participants has been significantly improved, there are still individual differences. For the elderly with moderate cognitive impairment (MMSE score 10 – 19), the spatial adaptation effect is slightly worse than that of the mild group. It is suggested that in the follow-up design, the density of dual anchor points should be appropriately increased (adjusted to 25 – 30 meters) for the moderate group, and more simplified and recognizable plant groups and material markers should be added to strengthen spatial guidance.

On the other hand, in terms of sensory compensation design, some participants reflected that the aroma concentration of osmanthus in the rest area was slightly too high in autumn. It is suggested that in the follow-up design, adjustable aromatic plant planting modules should be adopted, and the planting density should be flexibly adjusted according to the seasonal changes and the feedback of the target group to avoid sensory overload. In addition, the maintenance cost of the multi-sensory landscape should be controlled. Native plants with strong adaptability and easy maintenance should be further preferred, and modular and detachable design should be adopted for facilities to reduce the later operation and maintenance pressure.

In addition, the empirical study is limited to the outdoor courtyard space of the elderly cognitive impairment care center in Chongqing, and the sample size is 42. The follow-up research can expand the sample size and extend the research scope to community green space, residential area landscape and other spaces, so as to further verify the universality of the design strategy. At the same time, the long-term therapeutic effect of the design can be tracked and observed, and the design strategy system can be continuously optimized and improved combined with the development of interdisciplinary disciplines such as geriatrics, psychology and landscape architecture.

5 Conclusion and Prospects

5.1 Conclusion

Taking the elderly with cognitive impairment in Chongqing as the research object, this study constructs a theoretical framework of multi-sensory design empowering natural healing landscape, extracts four core design entry points based on the demand analysis, and establishes a design strategy system of "Multi-sensory Collaboration + Regional Adaptation + Elderly-friendly Optimization". Through empirical verification, the following conclusions are drawn:

First, the interdisciplinary theoretical framework constructed by integrating multi-sensory design, natural healing and gerontology can effectively guide the design practice of natural healing landscape for the elderly with cognitive impairment. It realizes the organic integration of artistic expression and therapeutic function, and breaks through the limitations of single discipline design.

Second, the four core design entry points (spatial narrative, sensory compensation, memory awakening, implicit safety) extracted based on the demand of the target group can accurately connect the group needs with the design practice, and form a complete "Demand - Design - Effect" logic chain, which provides a clear entry point for the design practice.

Third, the design strategy system of "Multi-sensory Collaboration + Regional Adaptation + Elderly-friendly Optimization" has good feasibility and effectiveness. It can significantly improve the spatial cognitive ability, emotional stability and spatial adaptability of the elderly with cognitive impairment, reduce the safety risks, and has lasting therapeutic effect and regional adaptability.

Fourth, the regional adaptation design combined with the characteristics of Chongqing (subtropical monsoon climate, stilted building culture, native plant resources) is the key to ensuring the sustainability of the design effect. It makes the design more in line with the living habits and regional cultural psychology of the target group, and provides a localized solution for the similar design in the Southwest region.

5.2 Prospects

With the acceleration of population aging, the demand for natural healing landscape for the elderly with cognitive impairment will continue to increase. The follow-up research can be carried out from the following aspects: first, expand the research scope and sample size, verify the universality of the design strategy in different regions and different space types, and form a more universal design method system.

Second, strengthen interdisciplinary integration and innovation, combine emerging technologies such as Internet of Things and intelligent sensing with multi-sensory design, construct an intelligent natural healing landscape system, realize real-time monitoring and dynamic adjustment of sensory stimuli, and further improve the therapeutic effect.

Third, pay attention to the participation of the target group and their families in the design process, adopt the participatory design method, fully listen to the opinions and suggestions of the elderly with cognitive impairment and their caregivers, and make the design more in line with the actual needs of the target group.

Fourth, deepen the research on regional adaptation design, combine the natural and cultural characteristics of different regions in the Southwest, explore the localized expression of multi-sensory natural healing landscape, and promote the localized development of landscape healing design. At the same time, strengthen the research on the maintenance and management mode of multi-sensory healing landscape, establish a scientific and reasonable maintenance and management system, and ensure the long-term stability of the design effect.

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