

Enhancing Elderly Rehabilitation Outcomes through Customized Restorative Virtual Environments in Nursing Home

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Abstract

Virtual restoration environments used in nursing home rehab programs demonstrate potential as a solution to boost physical along with cognitive and emotional healing in elderly patients. Restorative virtual environments which replicate soothing natural elements along with interactive spaces and personal virtual experiences help individuals experience less anxiety and better participation and enhanced therapeutic results. The newly developed design method corrects the limits of standard rehabilitation practice by providing customized virtual experiences which build determination among users and help them become stronger. The combination of environmental psychology approaches with rehabilitation science knowledge enables the development of restorative virtual environments that are expected to enhance nursing home service quality thus improving resident quality of life and functional abilities.

Keywords: Robotics, Skilled Nursing Facilities, Physical Engagement, Cognitive Stimulation, Social Interaction, Elderly Care, Rehabilitation Technology, Assistive Robots, Quality of Life, Healthcare Innovation.

1.Introduction

Healthcare challenges multiply because aging meets physical health requirements and mental wellbeing status. With age comes physical deterioration which prevents people from continuing regular exercise and natural environment appreciation so essential to their overall wellness(1). The barriers to independence and restorative experiences become most challenging in nursing home environments because its residents often must overcome several restricts. Modern virtual reality technology introduces valuable solutions to overcome these problems by creating totally realistic nature-based encounters as additional support for conventional rehabilitation practices.

The body of older adults progressively deteriorates when they remain inactive according to research that demonstrates how muscle strength diminishes more rapidly during periods of sitting. Physiological factors create a cycle that causes problems since reduced physical activity becomes harder because of balance issues and weaker strength and coordination and arthritis and other conditions. Philadelphia nursing home residents experience diminished access to nature and outdoor environments although these elements deliver multiple health advantages to people. The lack of both physical mobility and natural environment contact results in major negative effects on residents' quality of life and recovery results.

Research shows that nature contact leads to positive health effects throughout all aspects of human well-being. Multiple studies show natural environments trigger relaxation in people while simultaneously elevating mood levels and mental performance and decreasing stress-centered biological indicators and positively influencing mental health. Studies show that nature environments function as influential behavior change factors because people exercise better both in and because of seeing natural settings(2). Personal interactions with natural settings established a convincing logic behind using natural features in rehabilitation programs for elderly patients.

Virtual environments (VEs) serve as technological tools which link human requirements for personal space to real-life functional barriers. VEs achieve functionality through linking physical movements to virtual responses to offer experiences that are unavailable to nursing home residents limited by health-related disabilities. Through virtual technology users can have controlled and risk-free nature encounters without actual travel impediments. New technological capacities allow VEs to develop completed platforms that support nature encounters in ways similar to standing directly in natural environments for recreation and stress relief.

Holistic mental recovery through restorative environments stems from research within environmental psychology although Kaplan and his colleagues proved decisive in defining natural factors which restore psychological health. The four essential elements that make up restoration include "being away" to provide psychological distance from daily life stresses, "extent" that creates a complex and cohesive environment and "fascination" which means

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effortless attention capture as well as "compatibility" that connects the virtual space to individual goals. Virtual environment developers can use these principles as guidelines to create restorative experiences that help older adults deal with physical needs.

Nursing home residents participating in previous studies showed marked increased physical exercise motivation when exercise equipment received enhancements through virtual environment addition. Beautiful landscapes during exercise creates an interesting sensory adventure which converts monotonous workouts into journeys of exploration. Virtual nature scenes shown during exercise lead elderly participants to extend their exercise times and develop stronger internal drive to exercise regularly. The enhanced experiences provide standard rehabilitation benefits in combination with psychological aspects that promote better adherence and enjoyable experiences.

Developing successful restorative virtual environments (RVEs) requires researchers to establish the environmental features that create the strongest impact on user perception. The psychological impacts of real-world natural environments have been thoroughly researched but scientists understand very little concerning their digital translation especially when addressing the perceptual necessities of older adults(3). The design process needs to handle technical aspects for virtual experience generation while incorporating psychological principles responsible for restoration. Designing optimal RVEs demands researchers to strike a balance between technical implementation feasibility and psychological effectiveness by considering visual realism standards and selection of content and spatial arrangements and sensory involvement.

Exclusive design complications of RVE systems emerge from the specific needs of elderly users who exhibit cognitive impairment and physical limitations combined with their minimal technological expertise. Successful implementation of accessible engaging content depends on deliberate thought towards interface development with movement structures in combination with cognitive loading and content familiarity. Users need to easily navigate their environments while also experiencing richness that delivers the powerful therapeutic experience.

The increased healthcare facility interest in VR technology for rehabilitation leads to the needed creation of evidence-based design standards. Research on the combination between physical engagement and psychological restoration effects of virtual environments must evaluate their most effective features and methods to establish better deployment strategies. Multi-disciplinary guidelines need to incorporate knowledge from environmental psychology alongside gerontology and physical therapy with computer science and user experience design principles in order to develop therapy-based virtual experiences.

Well-designed RVEs have purposes that span beyond recovery from physical therapy since they help elderly people experience diminished depression levels and gain more social connections while maintaining cognitive abilities and gaining independence. These technologies enable residents in care facilities to experience diverse stimulating settings which beyond their reach which shifts residential care from restrictiveness to inclusive world exploration.

2. Theoretical Foundations of Restorative Virtual Environments

Theoretical Foundations of Restorative Virtual Environments

Multiple related theoretical frameworks support restorative virtual environment development (RVEs) for elderly care facilities because they explain how natural settings affect human body functions and emotional reactions. Designing virtual experiences requires a thorough understanding of these foundations since they form the basis for creating experiences that duplicate beneficial nature factors while addressing requirements of older adults in residential care facilities.

Attention Restoration Theory

The Attention Restoration Theory of Kaplan serves as a mainstream explanatory system to determine mental benefits from nature exposure. This theory maintains that directed attention which powers concentration during work hours becomes progressively less available as people use it continuously until their mental capabilities decline. People recover attentional abilities in natural surroundings through four defining characteristics of restorative experiences.

Psychological separation from everyday mental needs including standards and daily schedules represents the first aspect of restorative experiences(4). The frequent lack of change in nursing home environments generally causes major problems for the residents who cannot break from their institutionalized spaces. Virtual platforms generate a feeling of actual displacement that enables residents to explore different exciting yet new physical landscapes over

their current spaces.

The second part of the definition refers to "extent" which illustrates how an environment achieves psychological wholeness to present itself as a separate "whole other world." To achieve its restorative impact an effective environment needs enough substance along with precise details which draw focus and create total absorption of users' attention. Virtual environments need to achieve a proper balance between complicated elements and coherent organization which provides enough visual and sensory content for immersive engagement but keeps an unified design and rational structure.

As the third essential element of nature's restorative qualities the environment demonstrates its ability to maintain attention without demanding conscious subjectively provided effort from individuals. Soft fascination occurs in nature through peaceful elements such as leaf rustling, flowing water and dappled sunlight which both attract attention gently and allow the mind to contemplate. Elective fascination stands distinct from hard fascination which can be found in dangerous or energetic situations. Designing spaces with several soft fascination elements suite elderly users because they reduce cognitive fatigue while bettering their attention capabilities.

The final component, "compatibility," refers to the alignment between the environment and an individual's purposes or inclinations. The restorative environment provides facilities for personal goals and experiences even when these require minimal effort or dilemma resolution. Rehabilitation-focused RVEs require user interfaces which provide natural operation and serve therapy requirements by avoiding excessive cognitive load.

Theory	Key Concepts	Implications for RVE Design
Attention Restoration Theory (ART)	Nature restores directed attention through psychological separation, extent, soft fascination, and compatibility.	Create immersive, coherent worlds with gentle, absorbing features and low cognitive demand.
Stress Reduction Theory (SRT)	Nature exposure reduces stress via evolutionary responses to safe, resource-rich environments.	Include calming elements like water, greenery, open spaces, and horizons.
Embodied Cognition and Presence Theory	Physical sensations and presence shape environmental understanding and engagement.	Provide intuitive interfaces, simulate movement and interaction to enhance "reembodiment."

TABLE 1 Theoretical Foundations of Restorative Virtual Environments

Stress Reduction Theory

The Stress Reduction Theory together with ART explains how natural environments react to human psychological stress using evolutionary responses that identify certain landscape features. Research indicates that humans naturally respond favorably to environments which in the past demonstrated safety and resource availability by mixing open space with water features as well as visible horizons and green vegetation.

Participating in nature scenes triggers observable changes within the body which lower blood pressure and decrease muscle tension and minimize cortisol release and increase immune system capability. Short contacts with nature starting within minutes after exposure indicate that elderly people living in institutions could receive important stress relief from both real and virtual outdoor experiences due to their combined health-related and institutional stresses.

Embodied Cognition and Presence Theory

Virtual environments achieve success through their content and user feeling of presence much more than content alone. Mouse and Teeters (2021) investigated how design elements affect the subjectively felt sense of being present most commonly known as immersion(5). Elderly users need specific attention regarding sensory stimulation and user interface elements along with mental accessibility in order to achieve a sense of being present.

Research in embodied cognition shows that people understand their environment by merging their body experiences with their possible actions. Virtual environments offer older people with restricted mobility the chance to experience vicarious embodied sensations which replicate body movement alongside exploration together with environmental interaction although these things could prove inaccessible under regular conditions. Through virtual experiences older adults can potentially experience "reembodiment" which helps preserve their spatial understanding of

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environments even when physical abilities decrease.

These theoretical models build a strong framework to showcase how virtual natural environments deliver benefits to senior citizen users. To be effective RVEs need to distance users mentally from institutional environments and provide complete sensory perceptions with a directional flow while offering gentle interactions that require minimal work from users and connect to their abilities and objectives while featuring ancestor-related landforms and enabling users to feel physically present inside the virtual environment.

3. Design Methodology for Therapeutic Virtual Environments

The development of restorative virtual environments (RVEs) for elderly users demands both technical and psychological design elements that fulfill user needs. A detailed approach to create nursing home resident-specific RVEs emerges in this part which incorporates content choices alongside spatial planning and deployment methods.

Content Selection and Prioritization

Studies of environmental preferences demonstrate that selected natural elements such as water features lead to positive reactions among different population groups. Research indicates that water features are essential for restorative experiences because they generate strong psychological reactions alongside physiological responses when persons encounter flowing water elements or still water features(6). Water activates several sensory pathways with sounds and sight as well as movement to deliver soothing preoccupation and deep absorption.

Environmentally various plant life at multiple scales stands as a key structural element that people prefer in their recreational areas. Nearby flowers along with bushes together with ground cover offer detailed views at short distances while medium-range trees and distant forests establish depth factors and structural elements. Studies regarding color psychology demonstrate elderly individuals commonly prefer landscapes dominated by natural greens and blues during different seasons because they provide both natural beauty and fresh visual attractions throughout the year.

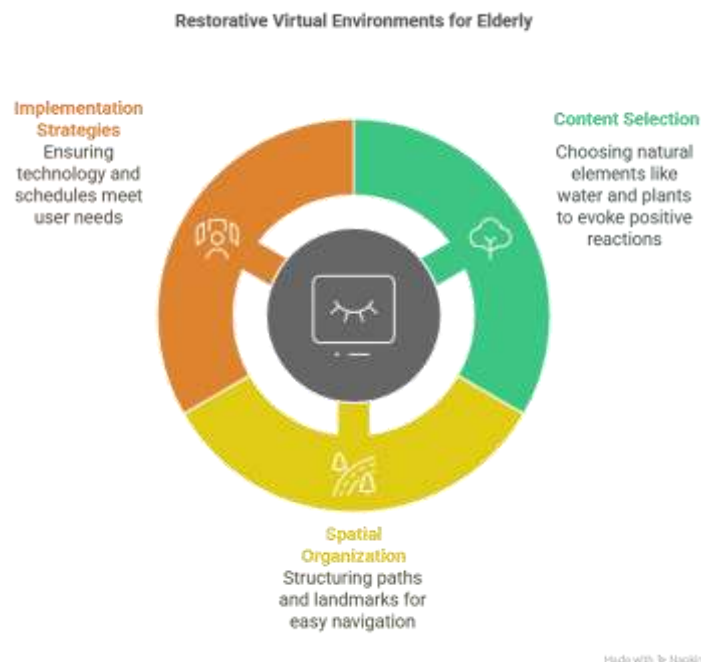


FIGURE 1 Restorative Virtual Environments for Elderly

Non-threatening wildlife species such as birds and small animals generate the perception of an actual living space. It is vital to manage the integration methods related to these elements because they risk creating performance issues for elderly users through too much fluidity or lack of predictability. Their ability to create perception of presence works for everyone including those with different vision levels since they activate sounds independent of visual

requirements.

Spatial Organization and Navigation Design

The way an RVE is spatially structured determines the way it allows users to navigate through it along with its capacity to provide restorative effects. A proper path design stands as a crucial aspect since it dictates the temporal user path throughout the environment(7). The combination of both curving paths which provide intermittent sightline changes and straight paths which enable continuous view observation leads research to suggest that anticipation grows and people become more inclined to explore. Path width together with how stable they feel while navigating is essential for elderly individuals because perilous-looking paths often create mental distress instead of relaxation.

Research on environmental cognition directs landmark placement in methods that assist users to maintain their spatial orientation and develop mental maps of their surroundings. Many users demonstrate through research that prominent elements of natural nature such as distinctive trees or rock formations or waterfalls can work just as well as reference locations even though they preserve the original natural ambiance.

The principle of "prospect and refuge" from landscape preference theory guides space design to achieve areas which provide protection alongside connection to their environments. Viewpoints together with clearings as well as elevated positions are high-prospect areas that enable wide vistas and overview perception yet refuge areas like groves or garden nooks and sheltered spaces establish protective and intimate experiences. These spatial types present in alternation generate experiential rhythm as well as diversity and fulfill various psychological requirements.

The spatial layout of environmental spaces must be designed for elderly users based on their cognitive accessibility requirements. Structural arrangements that present clear hierarchies achieve most success for elderly users including those with impairments of cognition. However the integrated system requires an approach which layers complex elements inside a structure that is easily understandable to users.

Implementation Strategies for Elderly Users

The establishment of RVEs in nursing facilities needs exclusive oversight for both system design aspects and staff involvement. Technology solutions used for displays need to meet both deep immersion needs and operational requirements which include simplicity in use along with durability and interoperability with medical devices. Therapy practices should use large screens instead of head-mounted displays because the larger screens offer practicality through staff monitoring abilities during resident therapy sessions.

The design of interfaces for elderly users keeps it basic and predictable through controls which adapt to physical skills and low exposure to technology(8). Users find automatic navigation systems through presets as middle-ground because these systems let people explore paths independently though they need no advanced movement skills.

Schedule design for sessions needs to adjust its speed according to the mental abilities and endurance levels of elderly users. The research shows spaced shorter visits deliver greater advantages than periodic longer durations and users obtain optimal results from 15 to 20 minutes engagement intervals. Environmental complexity introduces gradually to patients during therapy sessions which improves their familiarity progression thereby decreasing cognitive load but sustaining their interest in multiple sessions.

Personalization features in VR platforms offer the most important advantage of increased patient engagement and treatment effectiveness. Software that lets users choose among diversified environmental styles matches personality types and emotional states. Advanced version implementations of nursing homes would utilize personal historical elements including previous lived settings and architectural layouts to develop stronger resident to virtual environment ties.

Careful application of design principles in RVEs creates meaningful natural interactions for elderly users with restricted movements in nursing home settings which provides several psychological along with physical well-being advantages that identical to open-air nature encounters.

4. Experimental Implementation and User Studies

The development of four different restorative virtual environments (RVEs) occurred within a nursing home facility to evaluate methodology effectiveness and measure user preference changes among residents. This section details

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the implementation approach alongside both the individual environmental traits and the results generated by user research assessments of environmental elements.

RVE Development and Technical Implementation

The development of all environments occurred through Unity 4 Pro game engine because it provided balanced functionality between visuals, physical simulation and performance enhancement features. The system operated on standard computing equipment attached to large-screen display screens and head-mounted displays for different stages of research evaluation(9). The development of special interfaces enabled the synchronization of bike pedaling using stationary equipment with virtual corridor progression.

The audio system received special focus since spatial sound designers placed environmental sounds such as wind, water, and birdsong correctly throughout the three-dimensional space. A combination of modalities was adopted through which users received matched perceptual feedback between their visual and auditory senses to create immersion. The motion picture presentation received performance optimization to achieve continuous frame rates while executing complicated visual elements because variations in quality would affect the immersive quality and possibly generate discomfort for senior users.

The Four RVE Designs

The designers created four unique environments that uphold basic restorative environment principles through their individual designs. Each setting had a distinctive name including Lake Park, Mountain Top, Winter Forest, and Country Side with unique attributes for landscapes and emotional ambiance and ways to navigate through them.

Lake Park functioned as a metropolitan nature sanctuary just like Central Park in New York City which displayed neat wild specimens beside skyline landmarks. The extensive brick pathways at Lake Park required users to cross various bridges over its extensive central lake. The design incorporated decorative fencing together with old-style lanterns and ornate seating areas and numerous tree and flower types. Most park wildlife consisted of pigeons which would occasionally return to rest and then fly away. Multiple gentle curve and junction structures composed the path system which enabled multiple path combinations across the environmental area. The site design showcased a nature-inspired atmosphere that achieved perfect landscape views through countless water viewpoints.

Visitors enjoyed dramatic mountain views that included enormous cliffs alongside picture-perfect sceneries and elevated elevation contours. The paved path followed vertical stone cliffs before leading visitors into caves and across the three monumental stone bridges which crossed extensive natural gaps. The area contained only basic human-made barriers such as wooden fences and hard-to-reach cliff houses along with abandoned construction sites that served story purposes in the path experience. Natural elements prevailed throughout the landscape including eagles flying above the trail and sparrows, multiple waterfalls alongside a lake at high altitude. Except for lower junction frequency the path system achieved dynamic viewing angles through its substantial elevation changes which made visitors feel accomplished as they reached the viewpoints.

As the minimalistic environment of Country Side wrapped around a peaceful lakeside the visitors walked in circles. Despite its small dimensions the area presented various attractive proximal elements which included plants of different kinds alongside rocks and flower displays. The bridge remained small while the houses appeared medium in size and a group of big willow trees formed major landmarks. The place focused on peaceful encounters with nature while maintaining a unified rural appearance in all its sections.

The wintertime atmosphere in Winter Forest revealed itself through its snowy landscapes and tight spaces that enclosed visitors within the domain. Part of the trail system ran through thick pine forests but opened into fewer areas along the way. The artificial installations featured wooden dwellings together with decorative barriers and garden lights and brick walls with decorated arches. Visual effects in the form of falling snowflakes together with torch light helped keep the ambiance dynamic in spite of the constrained color palette. The path's curves along with the enclosures of fog reduced distant views allowing a person to concentrate on what lay closest to them as they uncovered new things around each turn.

User Study Design and Methods

At Akaciegården nursing home in Denmark researchers carried out multiple research studies to measure user responses toward the implemented RVEs from a ten-month period. Quantitative usage data collection processes integrated with both qualitative feedback methods and observation and interview techniques. A demographic sample composed of ten nursing home residents aged 85.7 on average enrolled in the study.

A total of three different survey interview types were employed. The researchers began by asking participants about their environmental preferences while gathering their feedback on credibility and relaxation responses. Participants in the second survey evaluation had to select their preferences between pairs of environmental characteristics shown in the survey (such as open spaces against enclosed areas). The third research study adopted a memory test by presenting 33 images from various spots within the four environment types to measure both recognition skills and the ability to identify key memorable features in these locations.

When studying elderly participants with diverse cognitive abilities and communication needs researchers selected multiple data collection approaches that could verify findings among different methods. This approach resolved potential limitations that could stem from using single methods with such participants.

Key Findings and User Preferences

The research data showed multiple important trends between user choice patterns and environmental involvement measurement. The study results did not demonstrate any dominant chosen environment among participants indicating that individual preferences strongly affect environmental selection. The study participants found all environments realistic for behavioral purposes and every participant showed appreciation for the nature-based materials. Users primarily experienced relaxation effects during utilization which demonstrates proper application of restorative design principles.

Interestingly participants displayed equal fascination between nearby elements and distant environmental features which opposes some designer hypotheses about near-path fixation among elderly users. Despite equal recognition skills of nature-based features and man-made elements participants consistently rated nature-based features higher in importance thus suggesting recognition stands autonomous from environmental preference in the experience of nature.

Usage logs showed that Lake Park received the highest amount of selection throughout the ten-month tracking period with Country Side next in line and Mountain Top and Winter Forest following behind them. All data metrics used for evaluation confirmed this ranking between the areas Lake Park at top followed by Country Side then Mountain Top and finally Winter Forest. Recognition data from the third research demonstrated that locations in Lake Park received the most recognition among participants.

Users highlighted memorable aspects during qualitative content evaluation of their responses. People who visited Lake Park remembered flowers and water features most often and Country Side appeared recognizable to visitors because of its unique willow trees and housing layouts. Participants at Mountain Top described whole places together with the surrounding context in unique ways which indicated their extensive understanding of the spectacular mountainous landscape. Users primarily remembered snow as well as torch lighting among all elements of Winter Forest.

The research indicates that striking environmental features and distinctive characteristics make lasting impressions but cohesive accessible designs with extensive proximal nature elements lead to better prolonged engagement. The analysis demonstrates why it is necessary to provide different environmental options which cater to varying psychological requirements of multiple age groups within elderly demographics.

5.Conclusion and Future work

The evaluation process of restorative virtual environments (RVEs) for nursing home resident use reveals important opportunities to enhance standard rehabilitation techniques through immersive nature-based interactions. The researched findings deliver essential details regarding effective virtual environments design features for older users as well as the necessity of providing different options to support individual choice and requirements.

Research used the four virtual reality environments Lake Park, Mountain Top, Winter Forest and Country Side which brought out unique aesthetic features and user experiences for participants. All participants found virtual nature at a comparable level of reliability while showing universal appreciation for nature-oriented content through their findings which verify fundamental acceptance of this experience for elderly people. The diverse user preferences show that healthcare facilities need to offer various environment types instead of focusing on a singular perfect design.

Some conventional beliefs about elderly users' preferences face challenges due to the study results which focus on

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environmental characteristics. Research results indicate older adults still value up-close scenic elements together with broader distant views because their physical mobility decreases. Users showed successful retention during identification tests which established that they remembered "the whole" environment along with "the background" aspects as well as detailed features like "flowers," "trees" and "snow." RV design effectiveness depends on combining close observations with broader environmental elements to develop total user engagement.

The usage pattern during a ten-month implementation timeline provides helpful suggestions that future designers can use for their projects. Lake Park demonstrates that environments with balanced nature-oriented features while providing accessibility through a path system achieve higher popularity levels than spaces designed to be plain or dramatic in nature. This significant interest in the smaller Country Side environment illustrates how coherence combined with intentional design remains more significant than environmental dimensions for this user population.

The investigation proving the worth of both longitudinal data collection and blended research techniques when working with elderly testers can be used for methodology principles. Quality understandings about programming emerged through the combined assessments of system usage statistics with recognition evaluation results and volunteer feedback. The recognition study provided an innovative method to identify which environmental aspects produce enduring memorability by showing how user preferences relate to actual memorial effect.

Future development of RVE should pursue directions according to these observations. Single environment development should move toward a different approach that involves creating multiple themes with a consistent internal structure while each theme maintains a unique identity. Each themed environment requires attention to abundant proximal details especially plants along with water elements while suitable wildlife rather than realism or sophistication takes precedence. The therapeutic power of virtual nature settings might increase through user customization options which help people connect their personal experiences to the simulated environments.

Virtual nature experiences supported by growing technology accessibility have begun to show significant potential for physical therapy and psychological care benefits for elderly people. Programs based on evidence-based design guidelines derived from the combination of environmental psychology and user studies offer solutions to meet the dual problems of physical decline and nature access barriers within the nursing home population. Virtual nature environments act as valuable alternatives since they enable people who cannot access true nature to find restoration leading to better quality of life.

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Conflicts of interest

The authors have no conflicts of interest to declare

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