Bachelor's Thesis

Czech
Technical
University
in Prague

F3

Faculty of Electrical Engineering
Department of Computer Games and Graphics

VR Games for Lying Patients

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Supervisor: Ing. David Sedláček, Ph.D.
Field of study: Open Informatics
Subfield: Computer Graphics
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Date of bachelor’s thesis assignment: **08.02.2025** Deadline for bachelor thesis submission: ____________

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III. Assignment receipt

The student acknowledges that the bachelor’s thesis is an individual work.
The student must produce her thesis without the assistance of others, with the exception of provided consultations.
Within the bachelor’s thesis, the author must state the names of consultants and include a list of references.

Date of assignment receipt Student’s signature

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Guidelines:

Meet the work of Tereza Langová [5], in which she created virtual reality (VR) games for relaxation and gentle exercise for lying patients. Assume elderly patients or patients with a spinal cord injury.
According to her work [5], extend this app with a tutorial and two new games. Design games to respect users' motor limitations while trying to subtly overcome them by making small changes to the gameplay.
Maintain all aspects of the implemented solution, i.e. support for control application and exercise monitoring [4].
Follow the UCD methodology for design and implementation. Test the application with at least five users from the target group.

Bibliography / sources:

1] Jason Jerald. 2015. The VR Book: Human-Centered Design for Virtual Reality. Association for Computing Machinery
and Morgan & Claypool, New York, NY, USA.
2] Steven M. LaValle - Virtual Reality, Cambridge University Press 2016
3] T. Lowdermilk, User-Centered Design, O’Reilly Media, 2013
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5] Tereza Langová, VR hry pro ležící pacienty. DP ČVUT FEL, 2025.

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Declaration

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DECLARATION

I, the undersigned

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declare that I have elaborated the bachelor's thesis entitled

VR games for lying patients

independently, and have cited all information sources used in accordance with the Methodological Instruction on the Observance of Ethical Principles in the Preparation of University Theses and with the Framework Rules for the Use of Artificial Intelligence at CTU for Academic and Pedagogical Purposes in Bachelor's and Continuing Master's Programmes.

I declare that I used artificial intelligence tools during the preparation and writing of this thesis. I verified the generated content. I hereby confirm that I am aware of the fact that I am fully responsible for the contents of the thesis.

In Prague on 14.05.2025

Ekaterina Chukina
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Abstract

Virtual reality (VR) offers great potential for rehabilitating patients with limited mobility, such as elderly people or those with spinal cord injuries. This thesis builds on the VR application created by Tereza Langová that was designed for lying patients. This work adds two new games and an audio tutorial system to improve the therapeutic value and make the application easier to use.

The new games consist of a balloon navigation game and a color-based catching game. Both have adjustable difficulty levels that help users increase their movement range while respecting their physical limits. The audio tutorial guides users step-by-step through setup and gameplay, helping people with different levels of tech experience. All these additions work with the existing system that tracks exercise performance.

Tests with the target user group showed better engagement and easier use.

Keywords: Virtual Reality, Rehabilitation, Gesture-Based Interaction, Lying Patients

Supervisor: Ing. David Sedláček, Ph.D.

Abstrakt

Virtuální realita (VR) nabízí významný potenciál pro rehabilitaci pacientů s omezenou pohyblivostí, jako jsou starší jedinci nebo osoby s poraněním míchy. Tato práce rozšiřuje VR aplikaci vyvinutou Terezou Langovou, která byla specificky navržena pro ležící pacienty. Na jejím základě tato práce představuje dvě nové hry a komplexní audio tutoriálový systém pro zvýšení terapeutického potenciálu a přístupnosti aplikace.

Nové hry zahrnují hru s navigací balónu a hru založenou na dosahování barevných objektů. Obě obsahují mechanismy progresivní obtížnosti, které povzbuzují zvětšování rozsahu pohybu při respektování fyzických omezení uživatelů. Audio tutoriálový systém poskytuje podrobné pokyny pro kalibraci a hraní, vyhovující uživatelům s různou úrovní technické znalosti. Všechna vylepšení zachovávají kompatibilitu se stávajícím monitorovacím systémem pro sledování výkonu cvičení.

Uživatelské testování s členy cílové populace prokázalo zlepšenou angažovanost a použitelnost.

Klíčová slova: Virtuální realita, Rehabilitace, Gesta-založená interakce, Ležící pacienti

Překlad názvu: VR hry pro ležící pacienty

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Chapter 1
Introduction

Virtual reality (VR) technology has become an important tool in healthcare, creating new ways to help with patient rehabilitation, especially for those who cannot move easily. For patients who must stay in bed or have limited mobility, like elderly people or those with spinal cord injuries, normal rehabilitation exercises can be difficult, boring, and sometimes not possible to do. Virtual reality can change these exercises into interesting, interactive experiences that motivate patients while helping them recover. The use of VR in rehabilitation has shown good results in making patients more involved in their therapy, helping them stick with it, and improving overall results [2]. By creating immersive environments that work with small physical movements, VR can help patients with severe mobility problems take part in therapy activities they couldn't do otherwise. This thesis continues the work started by Langová [1], who created a VR application specifically for patients who need to lie down. Her work showed that well-designed VR games could entertain and provide gentle exercise for bedridden people through features like upright redirection and using hand gestures instead of regular VR controllers.

1.1 Problem Statement

Despite progress in VR applications for rehabilitation, several challenges still exist in making these technologies fully accessible and useful for patients with limited mobility.

Many current VR applications lack proper tutorial systems that would help elderly patients or people with cognitive difficulties learn how to use them. Without clear guidance, these users often struggle to understand the controls and give up before experiencing the therapeutic benefits.

Rehabilitation games often don't adapt well to individual physical capabilities and don't target specific areas where patients need the most improvement. This means that some patients may find the games too difficult while others find them too easy, reducing the therapeutic effectiveness for both groups.

Many applications fail to provide a good balance between fun and therapeutic value, which means patients might lose interest in using them regularly. If the games are not engaging enough, patients won't continue using them long enough to see real improvement in their condition.

This thesis addresses these issues by adding two new games and an audio tutorial system to Langová's existing VR application. These additions are specifically designed to make the application more engaging and effective while remaining accessible for bedridden patients.

1.2 Research Objectives

The main goals of this research are:

1. To design and create two new therapeutic games that respect users' movement limitations while encouraging them to increase their range of motion through gradually adjusting difficulty.
2. To develop an audio tutorial system that helps users with calibration and gameplay, making it suitable for people with different levels of technical experience and cognitive abilities.
3. To make sure the new additions work with the existing system that collects data about exercise performance and progress.
4. To test the usability and therapeutic benefits of the improved application with members of the target user group.

1.3 Thesis Structure Overview

This thesis is divided into seven chapters. After this introduction, Chapter 2 explains the theory behind VR in healthcare, user-centered design, and the movement limitations of the target users. Chapter 3 looks at the original application made by Langová, including its technical structure, game mechanics, and how it connects with data collection systems. Chapter 4 describes the design process, covering user requirements and the concept design of the new games and tutorial system. Chapter 5 explains how these new features were implemented, focusing on adaptive mechanisms and accessibility features. Chapter 6 shows how the application was tested with users and presents the results. Finally, Chapter 7 summarizes what was accomplished and suggests ideas for future improvements.

Chapter 2

Theoretical Foundation

This chapter presents the key concepts needed to understand the development of VR games for lying patients, covering virtual reality in healthcare, user-centered design, and the motor limitations of our target users.

2.1 Virtual Reality in Healthcare

Virtual reality technology has evolved significantly in recent years, creating new opportunities for innovative healthcare applications. This section examines how VR has developed as a therapeutic tool, its current applications in rehabilitation, and the specific benefits it offers to patients with limited mobility.

2.1.1 Brief History and Evolution

Virtual reality (VR) technology has developed from its beginnings in 1990s aviation and military training to become a useful healthcare tool. Early medical VR systems were too expensive for clinical use. The breakthrough came with consumer headsets like Oculus Rift and Meta Quest, which made VR more affordable and easier to use [9]. Since 2015, these improvements have allowed VR to be widely used in rehabilitation, where immersive environments help engage patients and improve results [10].

2.1.2 Applications in Rehabilitation

In rehabilitation medicine, VR creates safe environments where patients can practice movements that might be difficult in real-world settings. VR is used in neurological rehabilitation (stroke recovery), musculoskeletal therapy (joint replacements), and cognitive training [11]. The best VR rehabilitation platforms include real-time feedback, performance tracking, and adjustable difficulty levels. Studies show that VR-enhanced therapy can improve coordination, balance, and cognitive function when combined with traditional approaches [12].

2.1.3 Benefits for Patients with Limited Mobility

For patients with limited mobility, VR offers special advantages. By providing immersive experiences without physical risk, VR allows patients to practice functional movements safely [13]. The game-like nature of VR therapy improves motivation—important for long-term rehabilitation success. In elderly populations, VR-based balance training has shown better results than traditional exercise in reducing fall risk [14]. For spinal cord injury patients, VR provides opportunities for coordination and motor planning through visual feedback, even for those with minimal voluntary movement [12].

2.2 User-Centered Design Methodology

User-centered design (UCD) is crucial for creating effective healthcare applications, especially for users with special needs. This section explores the principles of UCD, how they must be adapted for special populations, and their impact on rehabilitation technology effectiveness.

2.2.1 UCD Principles and Processes

User-Centered Design (UCD) is a methodology focused on creating systems that are tailored to the needs and limitations of end users. In healthcare, where usability directly affects patient outcomes, UCD is particularly important. The process involves four repeating phases: understanding the context of use, specifying user requirements, producing design solutions, and evaluating through testing [8].

These phases are cyclical, encouraging designers to continuously improve based on user input. In healthcare applications, this means involving patients, clinicians, therapists, and caregivers throughout the design process. The involvement of different specialists ensures that clinical safety, workflow efficiency, and emotional needs are all considered [17].

2.2.2 Adapting UCD for Special-Needs Populations

When designing for elderly users or people with motor impairments, standard UCD processes must be adapted. These users often have reduced vision, limited dexterity, cognitive impairments, and unfamiliarity with technology.

One common adaptation is interface simplification. Research shows that older adults benefit from larger text, high-contrast colors, simple layouts, and reduced cognitive load. Button sizes must be increased to accommodate tremors or imprecise motor control [15].

Personalization is another key strategy. For example, the iMHere 2.0 app for users with dexterity limitations included customizable font sizes, button spacing, and color themes. One innovative function measured the user's fingertip size to automatically resize buttons for more accurate interaction [16].

Inclusive participation is also critical. Even users with severe impairments can provide valuable design input when properly supported. Methods such as simplified interviews and testing in familiar environments have been shown to increase user comfort and data quality.

2.2.3 UCD Impact on Rehabilitation Technologies

Several recent studies highlight how applying UCD improves rehabilitation technologies:

- **VR Stroke Rehabilitation:** A 2021 study showed that involving therapists in the design process led to a more practical interface. Iterative testing helped simplify navigation and added meaningful feedback for both patients and clinicians [17].
- **Enhanced User Engagement:** UCD has been shown to improve user engagement and therapeutic outcomes. By incorporating feedback from both patients and healthcare providers, developers can create more intuitive systems that better address clinical needs [6].
- **Improved Adherence:** Studies indicate that rehabilitation technologies designed with UCD principles demonstrate higher rates of patient adherence, particularly among elderly users [18].

2.3 Motor Control Limitations

Understanding the specific motor limitations of our target users is essential for creating appropriate VR rehabilitation experiences. This section examines the common impairments found in elderly patients and those with spinal cord injuries, providing context for the design choices in our application.

2.3.1 Typical Impairments in Elderly Patients and Individuals with Spinal Cord Injuries

Motor impairments in elderly individuals and spinal cord injury (SCI) patients present significant challenges. In elderly populations, age-related muscle loss leads to decreased strength, while joint problems limit range of motion. These factors result in decreased balance, slower reaction times, and impaired coordination [19]. Tremors affect some individuals over age 65, often hindering fine motor activities [20].

Individuals with SCI experience motor impairments depending on the level and severity of the injury. Complete injuries often result in total paralysis below the injury, while incomplete injuries may preserve some voluntary motor control [21].

2.3.2 Therapeutic Gaming and Virtual Reality in Motor Rehabilitation

The use of VR and therapeutic gaming in rehabilitation has gained attention as a method to engage patients in motivating training. For elderly populations, motion-sensitive games have been shown to improve balance, coordination, and gait stability [12].

In SCI rehabilitation, VR has demonstrated positive outcomes for upper-limb function.

Chapter 3

Base Application Analysis

This chapter examines Langová's original VR application for lying patients, analyzing its technical structure, game mechanics, and integration with data collection systems. Understanding these elements provides essential context for the enhancements implemented in this thesis.

3.1 Overview of Langová's VR Application

Langová's application represents an innovative solution specifically designed for patients who must use VR while lying down. This section explores its technical architecture and key features that enable comfortable VR use in a reclining position.

3.1.1 Technical Architecture

Tereza Langová's VR application represents a specialized solution for rehabilitation of lying patients [1]. The system utilizes the Meta Quest platform, implementing gesture recognition that interprets simple hand signs like "Rock" and "Paper" that can be modified according to user's abilities instead of conventional controllers. This design choice accommodates users with limited dexterity and strength who may struggle with traditional VR controllers.

A key technical innovation in the application is the implementation of upright redirection, which reorients the virtual environment so that lying users perceive themselves as standing upright. This significantly reduces visual-vestibular conflict and creates a more natural interaction experience [26]. The system also includes custom networking components using the Mirror framework, enabling a separate mobile application to monitor and assist users during their VR sessions.

3.1.2 Existing Game Mechanics

The original application features three distinct games, each designed to encourage different motion patterns and cognitive engagement.

The Tangram puzzle is a spatial reasoning game requiring precise hand movements to manipulate puzzle pieces, promoting fine motor control and problem-solving skills. Players must arrange geometric shapes to match target patterns, encouraging careful positioning and rotation of objects.

The Shooting Gallery provides a targeting game with multiple difficulty levels where users aim and shoot at targets, encouraging arm extension and improving aim accuracy. This game helps patients practice controlled movements while engaging in an enjoyable activity that feels like play rather than exercise.

The Endless Runner offers a reaction-based game requiring timely gestures to jump or duck, promoting quick decision-making and smooth gesture transitions. Players must respond to obstacles by performing appropriate gestures at the right moment, combining physical movement with cognitive processing.

Each game incorporates adaptive elements that accommodate different levels of user ability, including adjustable difficulty settings and customizable control sensitivity [1]. This ensures that patients with varying physical limitations can engage with the therapeutic activities at their own comfort level.

3.1.3 Control Systems and Interaction Methods

The control system employs gesture detection rather than conventional VR controllers. This approach addresses multiple challenges faced by the target user group:

- **Reduced strength:** Many users cannot hold controllers for extended periods due to weakness or fatigue.
- **Tremors:** Hand tracking with appropriate smoothing accommodates users with unsteady movements.
- **Limited finger movement:** Simple hand gestures replace complicated button pressing, making the controls easier to use for people who have trouble moving their fingers.

The application also features customizable gesture recognition, allowing users or caregivers to adapt the control scheme to individual capabilities. This is particularly important for users with asymmetric mobility limitations [1].

3.2 Data Collection and Monitoring System

A crucial component of Langová's application is its integration with a comprehensive data collection system. This section examines how the application captures and processes therapy data to provide meaningful insights for clinical assessment.

3.2.1 Integration with Řeháček's System

The VR application integrates with a data collection framework developed by Řeháček [5], which captures and analyzes movement patterns during VR therapy sessions. This system logs hand positions, gestures performed, game scores, and session durations—creating a comprehensive record of each user's rehabilitation activities.

The data collection occurs in real-time and uploads to a centralized dashboard that allows therapists to monitor progress across multiple sessions. This integration provides valuable feedback for clinical assessment without requiring additional monitoring equipment or personnel [5].

3.2.2 Data Metrics for Therapeutic Assessment

The collected data serves multiple assessment purposes:

- **Movement analysis:** Tracking the range and frequency of head and hand movements helps evaluate motor function improvements over time.
- **Performance tracking:** Game scores and completion times provide objective measures of cognitive-motor progress.
- **Time:** Session duration and time spent in any game.

These metrics enable therapists to make evidence-based adjustments to treatment plans and provide users with concrete feedback about their progress [5].

3.3 Limitations and Opportunities for Enhancement

While Langová's application represents a significant advancement in VR rehabilitation for lying patients, several limitations present opportunities for enhancement:

- **Limited onboarding:** New users, particularly those unfamiliar with technology, face a steep learning curve without comprehensive guidance through calibration and game mechanics.
- **Limited game variety:** Additional game experiences could engage different movement patterns and maintain long-term interest.

These limitations provide clear direction for enhancements that could significantly improve the application's therapeutic potential and accessibility for patients with limited mobility.

Chapter 4
Design Process

This chapter outlines the user requirements that guided the design, presents the conceptual designs for the new games, and explains how these elements integrate with the existing application structure. The design process aimed to balance therapeutic benefit with engagement, ensuring patients would be motivated to use the application regularly.

4.1 User Requirements Analysis

Before creating new game concepts, a thorough analysis of user needs and constraints was conducted. This section examines the specific user profiles targeted by the enhanced application, the therapeutic goals that guided game design decisions, and the technical constraints that needed to be addressed to ensure compatibility with the existing system.

4.1.1 Target User Profiles

Based on Langová's work [1] for elderly patients and those with spinal cord injuries, this work defines specific user groups for the enhanced application. Elderly patients (65+) represent people with age-related mobility problems, possible tremors, slower reactions, and different levels of technology experience. Many have limited range of motion and may have cognitive issues that make learning new interfaces difficult.

Spinal cord injury patients include people with partial or complete spinal cord injuries who need upper body rehabilitation while lying down. This group includes those with different levels of control in their upper limbs and different levels of sensation, requiring careful adaptation of game mechanics to their specific capabilities.

Technology-unfamiliar users are patients with little or no previous VR experience who need step-by-step guidance through the application. This group often requires more detailed explanations and slower progression through the tutorial system.

Asymmetric mobility users are patients who have different abilities in their left and right hands, requiring adaptations that work with their stronger and weaker sides. The application must be flexible enough to accommodate these differences while still providing effective therapy for both sides of the body.

4.1.2 Therapeutic Goals

The enhanced application focuses on these therapeutic goals while respecting users' motor limitations:

1. **Improved Movement Range:** Gently encouraging patients to expand their movement range through game features that target areas they tend to avoid.
2. **Better Hand Coordination:** Improving coordination between both hands through activities that require using hands in sequence or together, while accommodating patients with different abilities in each hand.
3. **Mind-Body Connection:** Combining mental challenges (color recognition, pattern sequences) with physical movements to improve neural pathway development.
4. **Long-term Motivation:** Keeping long-term interest through varied activities and progress indicators that adapt to each person's performance level.
5. **Gradual Difficulty:** Implementing small increases in difficulty that encourage improvement without causing tiredness or frustration.

4.1.3 Technical Constraints

The design must address specific technical limitations while maintaining compatibility with Langová's existing system:

Constraint	Design Consideration
Existing Gesture System	New games must use only rock/paper gestures, maintaining consistency with current interface
Mobile App Integration	All features must support the existing mobile application that caregivers use to assist patients
Data Logging System	Integration with VR Dashboard Logger for monitoring therapeutic progress
Upright Redirection	All games must function correctly with the lying patient perspective
Network Architecture	Must be compatible with Mirror networking framework for VR/mobile device communicationn

Table 4.1: Technical constraints from existing system architecture

4.1.4 Integration with Existing Application

To successfully integrate new games into Langová's application, several key aspects of the original system needed to be preserved and respected:

- **Gesture Recognition System**: The new games had to utilize the existing rock/paper gesture system without modification, ensuring consistent user experience across all games.
- **Upright Redirection**: All new elements needed to work correctly with the upright redirection system that allows lying patients to perceive themselves as standing.
- **Mobile Assistant Application**: New games had to support monitoring and assistance through the existing mobile application used by caregivers.
- **Data Logging Framework**: Integration with Řeháček's logging system required implementing specific event tracking for therapeutic assessment.
- **Scene Structure**: The Unity scene hierarchy and prefab organization needed to maintain consistency with existing games.
- **Network Communication**: The Mirror networking framework required careful integration to ensure proper synchronization between VR and mobile devices.

These integration requirements significantly influenced design decisions, particularly in terms of control mechanisms and user interface elements. For example, while alternative control schemes might have been more intuitive for the balloon navigation game, maintaining consistency with the existing gesture system was prioritized to ensure a coherent overall experience.

4.2 Conceptual Design

The conceptual design phase focused on creating game experiences that would address the therapeutic goals while engaging patients through enjoyable gameplay. This section presents the core concepts for the two new games and the interaction models that support them.

4.2.1 Game Concept Development

Two new games were conceptualized to complement the existing Tangram, Shooting Gallery, and Endless Runner:

Balloon Navigation Game

This game addresses the need for side-to-side movement exercises with adjustable difficulty. The concept draws inspiration from classic arcade games while focusing on therapeutic benefits:

- **Main Idea:** Control a balloon character to avoid falling obstacles while collecting coins
- **Controls:** Side-to-side hand movement controls the balloon position with smoothing to help patients with hand tremors
- **Difficulty Levels:** Four different modes from Collection Only (easiest) to Fast Obstacles (hardest), suitable for different ability levels
- **Therapy Benefits:** Improves hand coordination and helps develop greater movement range

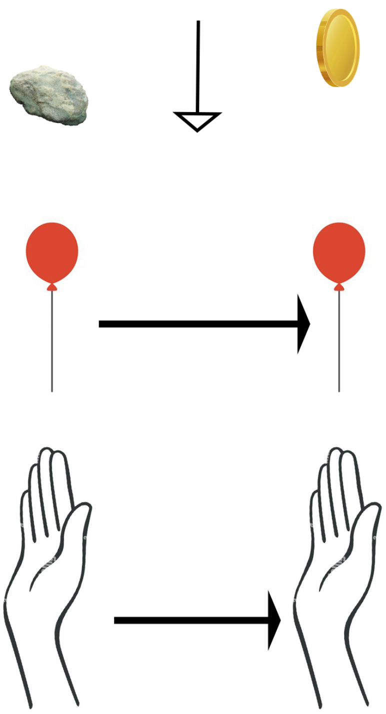

Figure 4.1: Conceptual design of the Balloon Navigation Game showing moving

Cube-Catching Game

This game combines reaching exercises with mental challenges:

- **Main Idea:** Catch colored cubes, creating combos by matching same-colored cubes in sequence
- **Controls:** Cubes move within defined area, requiring players to reach in different directions
- **Mental Challenge:** Color matching and creating sequences encourages purposeful movements

- **Rewards:** Increasing points and extra time for successful color combos
- **Therapy Benefits:** Improves fine motor control and mind-body connection

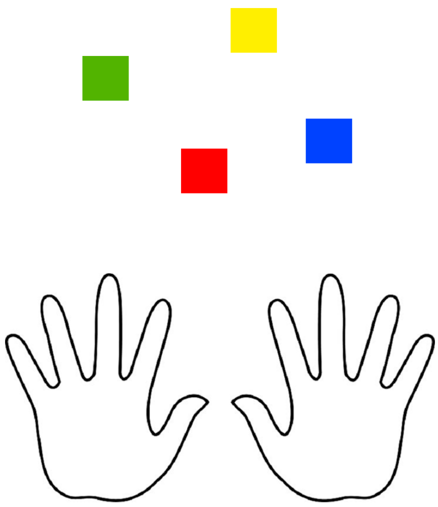

Figure 4.2: Conceptual design of the Cube-Catching Game

4.2.2 Interaction Model Design

The interaction model builds on Langová's gesture-based system while adding new features for better accessibility. The basic gesture system keeps the existing rock/paper gesture recognition for all main interactions, ensuring consistency with the original application. The movement control system uses smoothed hand tracking with adjustable sensitivity for character control, accommodating users with different motor capabilities. The feedback system combines visual and sound feedback to clearly confirm actions, helping users understand when their gestures are recognized. The helper system maintains the mobile application connection so caregivers can assist patients during gameplay when needed.

4.3 Game-Specific Progression Design

The two new games use different approaches to encourage gradual improvement while respecting patient limitations:

4.3.1 Balloon Game: Smart Coin Placement

The balloon game uses a clever spawning system that adapts to how the patient performs. The system separately tracks when patients miss coins on the left or right side to identify areas of difficulty. When a patient repeatedly misses coins on one side, the system starts spawning more coins in that area through targeted spawning. The therapy-focused positioning makes coins appear gradually further toward the difficult side with each miss, gently encouraging patients to expand their movement range. Safety limits with distance restrictions prevent coins from appearing too far from the patient's last successful catch. Additionally, falling rocks appear exactly above the character through obstacle spawning to force users to move their hand.

4.3.2 Cube-Catching Game: Reward System

The cube-catching game uses mental challenges combined with movement to keep patients engaged. Color combos reward purposeful movement patterns by giving points when patients catch same-colored cubes in sequence. The system provides increasing rewards where longer color combos give more points and extra time to continue playing. Cubes move unpredictably within a defined area through random movement patterns. Strategic placement ensures that four different colored cubes appear within the play area, encouraging reaching in different directions and promoting varied movement patterns.

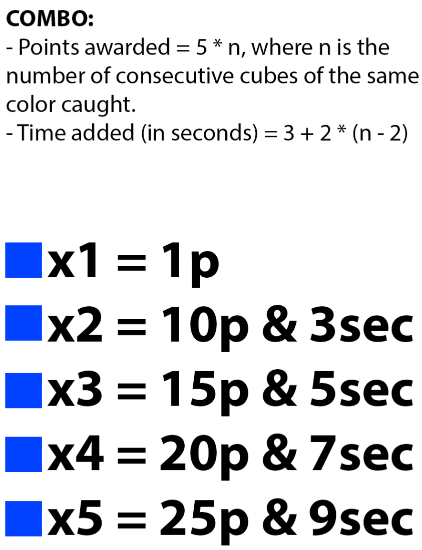

Figure 4.3: Example of the color combo system showing how increasing same-color sequence leads to greater rewards

4.4 Audio Tutorial System Design

One of the main problems was that new users, especially elderly people, had difficulty learning how to use it. The audio tutorial system was designed to solve this problem by providing step-by-step voice instructions in Czech. This section explains how the tutorial system was designed to help users learn to use the application.

4.4.1 Instructional Design Approach

The tutorial system addresses the lack of good user guidance in Langová's original application through several key approaches. Step-by-step learning provides gradual progression from basic setup to more advanced game controls, ensuring users don't feel overwhelmed by too much information at once. Situation-based instructions link guidance to specific user actions and game situations, making the help more relevant and easier to understand. Helpful reminders automatically repeat instructions for users who need more time to process the information or complete the actions. Gradual introduction ensures that advanced features are only explained after users have mastered the basics, building confidence before introducing more complex elements.

Tutorial parts include:

1. **Main Menu Tutorial:** Introduction to hand gestures and setup procedures
2. **Game Tutorials:** Specific instructions for each game's unique features

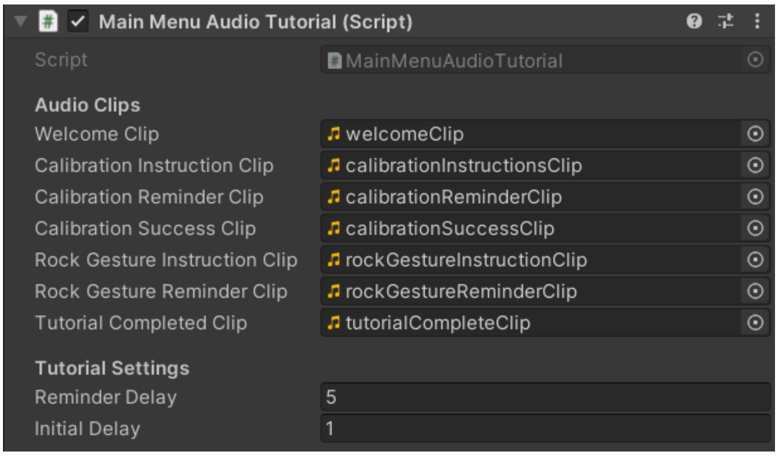

Figure 4.4: Unity screenshot showing the progression of the audio tutorial system in Main Menu

4.4.2 Accessibility Considerations

Audio design specifically addresses the needs of elderly and mobility-limited patients:

Accessibility Feature	Implementation Strategy
Native Language	All audio instructions in Czech for better understanding
Slower Pace	Deliberate pauses between instructions to give users time to process
Helpful Repetition	Automatic replay of instructions after customizable waiting periods
Clear Speech	Clear pronunciation with emphasis on important action words
Text Support	Text labels that are displayed on crucial points (like "Calibrated!")

Table 4.2: Accessibility features in audio tutorial design

Special considerations for the target population include several important adaptations. Audio frequencies are adjusted for older adults with hearing loss to ensure instructions can be heard clearly. The system uses simple and clear words instead of technical terms that might be confusing for users who are not familiar with technology. Confirmation checks are included before moving to the next instruction, giving users time to complete each step at their own pace. Emergency help is available through the mobile app, allowing caregivers to provide immediate assistance when users encounter difficulties during the tutorial or gameplay.

4.4.3 Integration with Main Application

The tutorial system works smoothly with all existing parts of the application through comprehensive system connections. Gesture tracking monitors rock/paper gestures in real-time to advance the tutorial automatically as users perform the correct actions. The setup system provides guidance for the upright redirection process, helping users calibrate their position properly. Device communication ensures that tutorial progress is shared between the VR headset and mobile phone, allowing caregivers to monitor and assist with the learning process when needed.

The tutorial system helps all users learn to use the enhanced VR application effectively, regardless of their technology experience or physical limitations, while staying fully compatible with Langová's existing framework.

Chapter 5

Implementation

This chapter details the technical implementation of the design concepts outlined in Chapter 4. It covers the development environment, the specific implementation of each new game, the audio tutorial system, and the integration with existing data collection systems. The focus is on how technical solutions address the therapeutic and accessibility requirements identified during the design phase.

5.1 Development Environment and Tools

The implementation was carried out in Unity 2022.3.10f1, building upon the existing VR application developed by Langová [1]. The project utilized the following key technologies:

- Unity with Mirror networking framework for VR/mobile application synchronization
- Meta Quest hand tracking for gesture-based interaction
- C# programming language for all game logic and systems
- VR Dashboard Logger [5] for therapy data collection and analysis

5.2 Balloon Navigation Game

The balloon navigation game was implemented to encourage side-to-side movement through an engaging collecting and avoiding gameplay. This section details the implementation of character movement, collectible spawning, obstacle mechanics, and difficulty settings.

5.2.1 Game Mechanics

The balloon navigation game involves controlling a balloon character that needs to avoid falling obstacles while collecting coins (or just collecting coins in the easiest mode). The game is designed to encourage side-to-side movement through smart placement of coins and rocks, and the gradual difficulty increases.

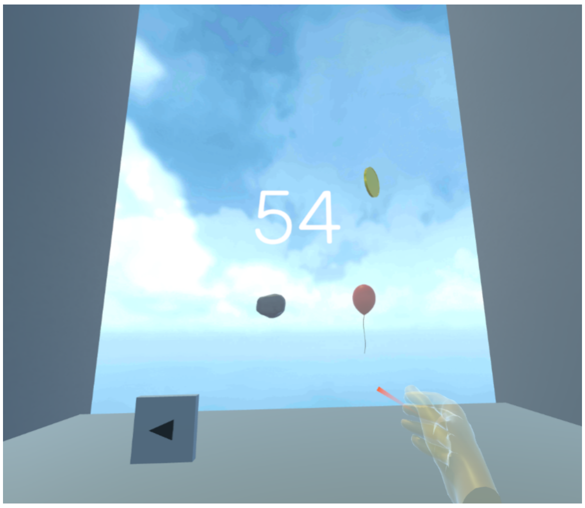

Figure 5.1: Screenshot of the balloon game showing obstacle avoidance and collectible coins

5.2.2 Character Movement System

The balloon character's movement system was specifically designed to accommodate patients with hand tremors.

The movement system creates a smooth, responsive connection between the patient's hand position and the balloon character by implementing several key features:

1. **Smoothed Movement Response**: Instead of the balloon instantly jumping to match the position of the player's hand, the system creates a gradual acceleration toward the target position. This acts as a natural filter for the small, rapid movements characteristic of hand tremors.

2. **Direction Change Assistance**: One of the most challenging aspects of hand tremors is changing movement direction. When the system detects that a patient is trying to reverse the balloon's direction, it automatically applies an increased acceleration rate to help overcome motion inertia.

3. **Speed Limiting**: Maximum speed caps ensure that even if a patient makes sudden large movements, the balloon maintains a controllable velocity. This prevents frustration while still allowing full range of movement.

The tremor filtering approach implemented in the balloon game was designed based on principles from assistive technology research described by Smith et al. [27].

5.2.3 Adaptive Collectible Spawning System

The game features an intelligent system that adapts to each patient's movement abilities by strategically placing collectible coins.

The adaptive spawning system continuously tracks which areas are difficult for each player by monitoring where they successfully collect coins and where they miss them. It keeps separate counts for the left and right sides of the screen.

When a player consistently misses coins on one side (for example, the right side), the system recognizes this as a potential movement limitation. It then begins to place more coins in that challenging area, but does so gradually and strategically:

- First, it slightly increases the probability of coins appearing on the difficult side
- With each consecutive miss, coins begin to appear a bit further toward the difficult side
- This creates a gentle "stretching" effect that encourages the player to extend their movement range

Rather than suddenly placing coins in hard-to-reach areas, the system creates a smooth increasing of difficulty.

5.2.4 Obstacle Spawning Strategy

In contrast to collectibles, obstacles are designed to spawn directly above the player to encourage active movement:

```
// Pseudocode for obstacle spawning strategy
function GetObstacleSpawnPosition(spawnHeight)
    // Simply spawn obstacles directly above the player
       with a small random offset
    // This forces player movement and reaction
    playerPosition = character.position

    // Add small random offset to avoid exact
       predictability
    randomOffset = Random.Range(-obstacleOffset,
       obstacleOffset)

    // Ensure obstacle stays within playable area
    xPosition = Clamp(playerPosition.x + randomOffset,
       minX + buffer, maxX - buffer)

    return new Position(xPosition, spawnHeight,
       playerPosition.z)
```

Listing 5.1: Obstacle spawning implementation that encourages player movement

This spawning strategy makes sure players have to actively move to avoid obstacles, promoting therapeutic movement. At the same time, the coin spawning system encourages players to explore areas they find difficult.

5.2.5 Difficulty Levels

The game implements four distinct modes to accommodate different patient capabilities:

Mode	Obstacle/Coins Speed	Spawn Interval	Player Speed
Collection Only	0.6-2 units/s	Configurable	5.0 units/s
Slow Obstacles	0.6 units/s	5.0s	4.0 units/s
Medium Obstacles	0.8 units/s	4.0s	5.0 units/s
Fast Obstacles	1.2 units/s	3.0s	6.0 units/s

Table 5.1: Balloon game difficulty settings for different patient capabilities

The difficulty levels are carefully designed to provide appropriate challenges for users with different movement abilities. The Collection Only mode lets users practice movement without any time pressure or risk of failure, making it perfect for those with severe mobility limitations or those just starting their therapy.

5.2.6 Progressive Features

The system includes several therapeutic features designed to gradually build patient confidence and ability. Smart targeting makes coins appear more often in areas where patients have trouble reaching, encouraging therapeutic movement patterns that help expand their range of motion. Distance control ensures the system avoids spawning items too far from the player's current position to prevent frustration and maintain engagement. In collection-only mode, gradual speed increase makes coins fall faster step by step to build confidence as players become more comfortable with the controls. Strategic placement in obstacle modes positions coins away from obstacles to create safe opportunities for movement and successful collection.

5.3 Color Cubes-catching Game

The second new game added to the application focuses on reaching exercises combined with mental challenges. This game encourages patients to catch colored cubes that move around the play area, with a reward system for catching cubes of the same color in sequence. This section describes how the game works and how it was implemented to provide therapeutic benefits.

5.3.1 Game Mechanics

The cube-catching game challenges patients to catch colored cubes using their hands, with a combo system that rewards catching same-colored objects in sequence. This design encourages deliberate movement while improving the connection between thinking and moving.

Figure 5.2: Screenshot of the cube-catching game with colored cubes and combo system UI

5.3.2 Cube Movement System

The colored cubes move within a defined zone using simple target-based navigation that creates slightly predictable but engaging movement patterns:

```
// Pseudocode for cube movement implementation
function Update()
    // Calculate direction toward current target position
    direction = (targetPosition - currentPosition).normalized

    // Move toward target at current speed
    position += direction * speed * deltaTime

    // Check if reached target
    if (distanceTo(targetPosition) < arrivalThreshold)
        // Pick a new random target position
        GetNewTargetPosition()

    // Boundary checking - keep within playable area
    if (position.x < minX OR position.x > maxX)
        // Bounce off horizontal boundaries
        moveDirection.x = -moveDirection.x

    // Similar checks for Y coordinate
    if (position.y < minY OR position.y > maxY)
        moveDirection.y = -moveDirection.y
```

Listing 5.2: Pseudocode for cube movement implementation with boundary checking

The movement system creates smooth, partly predictable trajectories that allow patients to anticipate where the cubes will move, supporting those with slower reaction times or limited fine motor control.

5.3.3 Combo System Implementation

The combo system encourages patients to catch sequences of same-colored objects, providing both cognitive challenge and motor motivation:

This system provides multiple ways to engage with the game. Patients can simply catch individual cubes for basic success, or try to create long color combos for better rewards. The system tracks both short-term progress (current combo) and long-term performance (overall session), supporting different therapy goals.

5.3.4 Reward Mechanisms

The game uses a layered reward system that provides both immediate satisfaction and long-term motivation:

- **Basic Points**: Each caught cube gives base point, ensuring all players experience some success

- **Combo Bonuses**: Points increase for catching multiple same-colored cubes in a row, encouraging focused attention and planning
- **Extra Time**: Successful combos add time to the game session, allowing players to practice longer
- **Visual Effects**: Colorful text and sound update highlight successful actions, helping players understand their progress

Figure 5.3: Visual feedback for successful color combo completion

5.4 Audio Tutorial Implementation

The audio tutorial system provides guidance for users at each stage of the application, from initial setup to game-specific instructions. This section details how the system is implemented to support users with varying levels of technological familiarity.

5.4.1 Main Menu Tutorial

The main menu tutorial provides essential onboarding for first-time users, covering calibration and basic hand gestures with clear, step-by-step instructions.

The tutorial system uses a state machine approach to guide users through the setup process at their own pace. This is particularly important for elderly users or those with cognitive limitations who may need additional time to process instructions.

5.4.2 Game-Specific Tutorials

Each game includes tailored tutorial content that explains specific mechanics in context:

- **Balloon Game**: Explains movement, dodging and collecting
- **Cube-Catching Game**: Covers catching mechanics and combo system

5.4.3 Calibration Instruction in Balloon Game and Feedback

The tutorial system includes comprehensive calibration support with visual and audio feedback. If it's a repeated try - instruction can be skipped with the "paper" sign (successful calibration):

```
// Pseudocode for calibration completion handling
function OnCalibrationComplete(isCollectionMode)
    // Mark calibration as complete and stop any active
       reminders
    calibrationComplete = true
    StopReminderCoroutine()

    // Provide success feedback
    PlayAudioClip(calibrationSuccessClip)
    DisplaySuccessMessage()

    // Check if this is a returning player
    if (player has used the application before)
        // Skip extended instructions for experienced
           users
        StartGameImmediately()
    else
        // Provide full instructions for new players
        WaitForGameRulesExplanation()
        then StartGame()
```

Listing 5.3: Pseudocode for calibration completion handling with experience-based branching

Figure 5.4: Calibration success feedback display

This approach recognizes that repeat users have different needs than first-time players, providing adaptive tutorial experiences that respect users' growing familiarity with the system.

5.5 Integration with Data Collection System

The new games need to work with the existing data collection system so that therapists can track patient progress. This section explains how the new games connect with Řeháček's VR Dashboard Logger to record patient movements and game performance. The system collects this information automatically during gameplay without interrupting the patient's experience.

5.5.1 Event Tracking

All implemented games integrate with Řeháček's VR Dashboard Logger [5] to track therapeutic progress comprehensively:

```
// Pseudocode for data logging implementation
// Game events
function LogCubeCaught()
    // Log event for cube caught
    LoggerCommunicationProvider.Instance.
    RecordEvent("CubeCaught")

function LogCoinCollected()
    // Log event for coin collected
    LoggerCommunicationProvider.Instance.
    RecordEvent("CoinCollected")

// Session data
function LogSessionData(score, difficulty, maxCombo)
    // Log overall session metrics
    LoggerCommunicationProvider.Instance.
    AddToCustomData("score", score.ToString())
    LoggerCommunicationProvider.Instance.
    AddToCustomData("difficulty_level", difficulty)
    LoggerCommunicationProvider.Instance.
    AddToCustomData("max_combo", maxCombo.ToString())
```

Listing 5.4: Pseudocode for data logging implementation for therapeutic progress tracking

The logging system records both specific events (like the moment a cube is caught) and ongoing data (like patterns of hand movement), giving therapists detailed information about how patients are performing.

5.5.2 Session Management

The logging system manages session data to support longitudinal therapy tracking through several key mechanisms. Automatic session boundaries ensure that sessions start with game initialization and end with game completion, creating clear data segments for analysis. User association links all collected data to specific patient profiles for accurate progress tracking over time. Cross-game analytics enables combined analysis of performance across different activities, allowing therapists to see how patients improve in various therapeutic exercises and identify patterns in their rehabilitation progress.

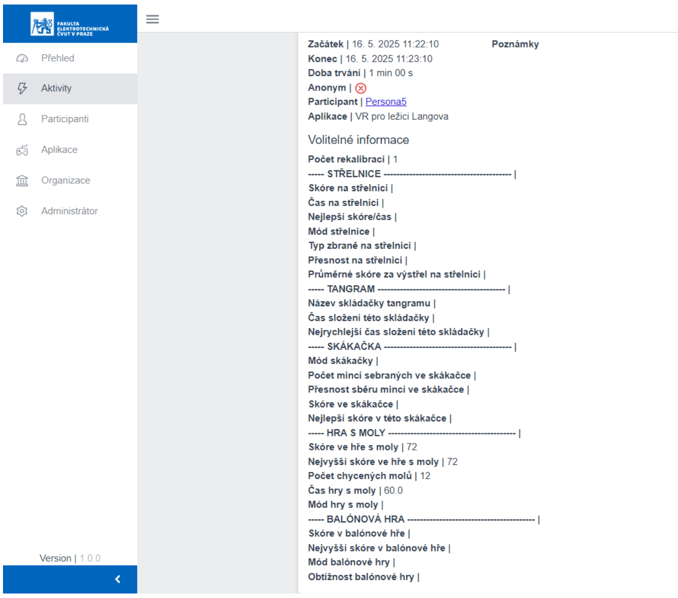

Figure 5.5: Example of therapy session data in Cubes game in the VR Dashboard

The gameplay demonstrations of both new games can be viewed online[1][2]. Additionally, the audio tutorial system can be experienced in a demonstration video[3].

[1] Balloon Navigation Game Demonstration: `https://youtu.be/Wa6KiB4jY4k`
[2] Cube-Catching Game Demonstration: `https://youtu.be/q_Bb2XA1FOg`
[3] Audio Tutorial System Demonstration: `https://youtu.be/zLbAzfddWiY`

Chapter 6
Usability Testing

This chapter describes the usability testing conducted with the enhanced VR application featuring the new balloon navigation and color cube games. The testing aimed to evaluate the usability, intuitiveness, and enjoyment of the games for the target user population.

6.1 Testing Methodology

The testing methodology followed the user-centered design approach, focusing on how well the application met the needs of elderly patients with varying degrees of mobility limitations and technological experience.

6.1.1 Participant Selection

Five participants from Nová Slunečnice were recruited for the testing. The participants ranged in age from 80 to 91 years old, with varying degrees of physical capabilities:

- Participant 1: 80 years old, no visible mobility limitations and no prior VR experience
- Participant 2: 91 years old with shoulder mobility issues, limiting ability to reach upward
- Participant 3: Experienced pain in right hand, had small previous VR experience
- Participant 4: 88 years old, no visible mobility limitations but expressed limited interest in games generally
- Participant 5: Used mobility assistance and had previous VR experience from rehabilitation activities

This diverse group represented the range of potential users for the application, including those with different physical limitations, cognitive approaches to games, and varying levels of technological familiarity.

6.1.2 Testing Protocols

The testing was conducted in a controlled environment within the senior care facility. Each participant was given the opportunity to try both the balloon navigation game and the color cube game. The testing process followed these steps:

1. **Introduction and consent**: Participants were informed about the purpose of the testing and provided verbal consent.
2. **Application setup**: The VR headset was calibrated for each participant's comfortable position, with appropriate upright redirection.
3. **Game introduction**: Participants were introduced to each game through the audio tutorial system and, when necessary, through additional verbal explanation.
4. **Gameplay observation**: The participants played each game while their interactions were observed, noting any difficulties or moments of confusion.
5. **Post-game feedback**: After playing each game, participants were asked about their experience, preferences, and any difficulties they encountered.

The entire session for each participant lasted approximately 20-30 minutes, depending on their interest and comfort level.

6.1.3 Evaluation Metrics

The testing focused on several key metrics to evaluate the effectiveness of the enhanced application:

1. **Control intuitiveness**: How easily participants understood and used the gesture-based controls
2. **Tutorial effectiveness**: How well the audio tutorial system guided participants through gameplay
3. **Game comprehension**: Whether participants understood the objectives and mechanics of each game
4. **Enjoyment and engagement**: Participants' expressed enjoyment and observed engagement with each game
5. **Physical accommodation**: How well the games accommodated different physical limitations
6. **User preference**: Which game participants preferred and why

6.2 Testing Results

The testing sessions provided both numerical data from the VR Dashboard Logger and feedback from participants about their experience with the games. This section presents the results from both types of data collection.

6.2.1 VR Dashboard Data Analysis

The integration with Řeháček's VR Dashboard Logger was successfully implemented, allowing the collection of game performance data during the testing sessions. Figure 6.2 shows an example of the logged data from one of the testing sessions, demonstrating the successful integration of the new games with the existing monitoring framework.

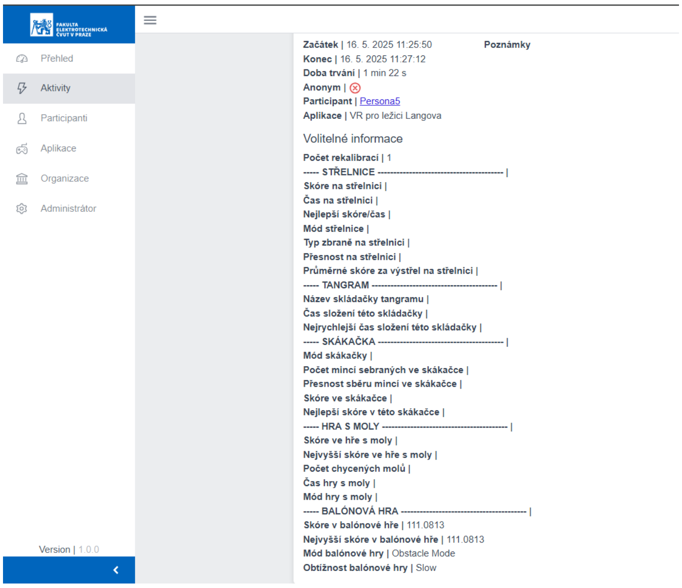

Figure 6.1: Example of therapy session data in Balloon Game in the VR Dashboard

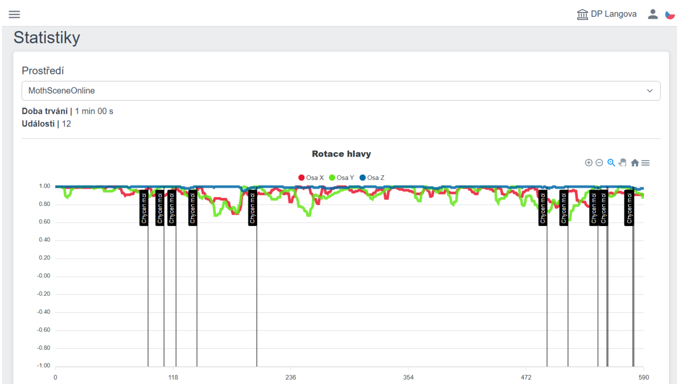

Figure 6.2: Example of therapy session data of the head rotation

The logged data provided valuable insights into:

- Head movement patterns during gameplay
- Score progression throughout the session
- Time spent in each game
- Successful interactions (cube catches)

This data complemented the observational findings and participant feedback, providing a more comprehensive picture of user performance and engagement.

6.2.2 Verbal Feedback Analysis

After playing each game, participants were asked about their experience and any difficulties they had.

Balloon Navigation Game Results

The balloon navigation game presented mixed results in terms of initial control intuitiveness, but generally positive engagement once participants understood the mechanics:

1. **Control comprehension challenges**: Participants 1 and 4 initially had difficulty understanding how hand movement translated to balloon movement. They attempted to directly interact with the coins rather than moving the balloon to collect them.
2. **Effectiveness of demonstration**: The visual demonstration significantly improved understanding, and participants were able to play successfully after seeing the game controlled properly.
3. **Experience correlation**: Participants 3 and 5, who had prior VR experience, found the controls more intuitive from the start, suggesting that technological familiarity plays a significant role in the learning curve.
4. **Engagement level**: Despite initial control challenges, Participants 3, 4, and 5 expressed enjoyment playing the balloon game once they understood the mechanics. Participant 3 particularly enjoyed playing even at higher difficulty levels despite experiencing right-hand pain.

Color Cube-catching Game Results

The color cube game demonstrated stronger initial comprehension but varying levels of engagement with the combo mechanics:

1. **Control intuitiveness**: All five participants quickly understood how to catch the cubes, with minimal instruction required beyond the audio tutorial.

2. **Combo mechanic comprehension**: Participants 1, 3, and 5 understood the color combo mechanic from the audio instructions alone. Participants 2 and 4 required additional explanation to fully grasp this aspect.

3. **Motivational elements**: Participant 1 was particularly motivated by the score tracking, attempting multiple plays to improve their result. Others were less driven by score improvements.

4. **Conceptual understanding**: Participants 3, 4, and 5 questioned the purpose of collecting cubes, finding the activity somewhat abstract compared to the balloon game. When explained that this game was more like an exercise activity, understood it.

5. **Physical accommodation**: Adjusting the position of the player relative to the cubes allowed even Participant 2 with limited reach to engage successfully.

Tutorial System Effectiveness

The audio tutorial system showed different levels of effectiveness depending on the game and participant:

1. **Cube game instructions**: The audio tutorial was generally effective in explaining the cube game mechanics, with most participants understanding the basic gameplay and combo system from the instructions alone.

2. **Balloon game instructions**: Audio instructions alone were insufficient for most participants to understand the balloon movement mechanics. Visual demonstration helped a lot, supporting the audio tutorial.

3. **Menu navigation instruction**: Some participants struggled to understand menu navigation solely through audio guidance, suggesting a need for visual demonstration components.

4. **Experience factor**: Participants 3 and 5 with prior VR experience followed the tutorial instructions more easily than those without such experience.

6.2.3 Observations and Issues Identified

Several key issues and observations emerged from the testing:

1. **Need for visuals**: The balloon game controls were difficult to understand from audio instructions alone. Participants needed to see how hand movements controlled the balloon character.

2. **Importance of explaining purpose**: The cube game became more engaging when participants understood it was designed as an exercise activity rather than just an abstract game. Explaining the therapeutic purpose helped participants understand why they were performing the activity.

3. **Previous VR experience helps learning**: Participants who had used VR before learned the new games much faster than complete beginners. Even limited prior VR experience improved how quickly people understood the controls and game objectives.

4. **Motivation variability**: Different participants were motivated by different elements - some by score, others by visual appeal of the game, highlighting the need for multiple engagement approaches.

5. **Physical positioning**: The need to adjust player position relative to game elements was critical for participants with limited mobility, emphasizing the importance of flexible calibration options.

6.3 Data Analysis Insights

Analysis of the VR Dashboard data from testing sessions revealed several important insights about how different users interact with the games. The impact of VR experience on performance was clearly visible, as participants with prior VR experience (Participants 3 and 5) achieved higher scores in the Balloon Navigation Game compared to first-time VR users. This demonstrates that previous experience with VR technology significantly helps with game performance and control understanding.

Understanding game mechanics also proved to increase engagement substantially. Participants who grasped the color combo system in the Cubes game from the beginning spent considerably more time playing that specific game. This indicates that when patients understand the game mechanics quickly, they are more likely to engage with the activity for extended periods and derive greater therapeutic benefit.

These findings highlight the importance of considering both technological familiarity and clear instruction when designing VR rehabilitation applications. They also suggest that gradual introduction to VR concepts and comprehensive tutorials are essential for maximizing therapeutic outcomes.

6.4 Iterative Improvements

Based on the testing results, several potential improvements were spotted that could improve the application in the future. The feedback from participants and observations during testing showed some usability challenges.

Adding visual tutorial components alongside audio instructions would significantly improve the learning curve, particularly for the balloon game controls. This could include animated demonstrations showing the connection between hand movements and balloon control, making the understanding between user and character more intuitive for new players.

Better explanation of the game's purpose would also help improve the application by clearly explaining why the cube game is useful for therapy. This could include a short introduction that explains how reaching for cubes and recognizing colors helps with exercise, so participants understand why they are doing these activities and feel more motivated to play.

From a technical point of view, better feedback for successful color combos would help players understand the game mechanics more clearly. Adding more obvious visual and audio signals when players successfully match colors would help participants like Participant 4 who had trouble understanding the combo system. This would make sure that all users can understand and get the most benefit from the therapeutic parts of the game.

6.4.1 Final Adjustments

The testing demonstrated that while the enhanced application successfully engaged the target population, several final adjustments would optimize the experience:

1. A brief video-based tutorial showing hand movements and their effects in the balloon game
2. Better explanation of the therapeutic benefits of the Cube game

These adjustments would address the primary issues observed during testing while maintaining the core therapeutic benefits of the application. The overall positive reception of both games, particularly after initial control challenges were overcome, suggests that the enhanced application has genuine therapeutic and entertainment potential for elderly patients.

Chapter 7

Conclusion

This bachelor thesis extended Tereza Langová's VR application for lying patients by adding two new games and an audio tutorial system. These additions work with the existing systems while introducing features that help patients improve their movement range and motor abilities.

7.1 Achievements and Contributions

The main contributions of this work include:

1. **Balloon Navigation Game**: Created a game with four difficulty modes that helps patients improve hand coordination and side-to-side movement. The game has different difficulty levels and includes a smart system that spawns collectible items in areas where individual patients struggle, encouraging therapeutic movement while respecting physical limitations.

2. **Color Cubes-catching Game**: Developed a reaching exercise game with colored cubes that improves fine motor control and mind-body connection. The combo system gives increasing rewards and time extensions, motivating patients to make purposeful movements by matching colors in sequence.

3. **Audio Tutorial System**: Created a complete guidance system with Czech-language instructions that helps users through setup, gesture recognition, and gameplay. This solves the important need for accessible tutorials for elderly patients and those new to VR technology.

4. **Better Difficulty Adjustment**: Both games use different approaches to make challenges progressively harder - the Balloon game adapts the environment based on player performance, while the Cube-Catching game uses rewards to keep players engaged.

All additions remain fully compatible with Langová's existing system, including the mobile application for caregiver help and the VR Dashboard Logger for tracking therapy progress.

7.2 Design and Implementation Process

Following the User-Centered Design approach, the development process involved:

- Analysis of movement limitations in elderly patients and spinal cord injury patients
- Design focused on accessibility and gradual therapeutic improvement
- Step-by-step implementation with technical solutions for gesture recognition, movement smoothing, and network connection
- Integration with existing data collection systems for therapy assessment

The technical implementation solved key challenges such as tremor compensation, connection between VR and mobile devices, and fine-tuning algorithms to provide meaningful therapeutic progression without overwhelming patients.

7.3 Future Directions

Future development could focus on several key areas to further improve the application. Adding visual elements to the tutorial would help users understand the controls better, especially for complex movements like controlling the balloon character. Improving the graphics in the Cube-Catching game would make it less confusing and help players understand the connection between catching cubes and therapeutic exercise. Adding new games would provide more variety for patients and target different types of movement and cognitive skills, keeping the application engaging for long-term use.

7.4 Final Remarks

This work successfully builds on Langová's foundation by creating a more complete VR rehabilitation platform for bedridden patients. The combination of therapeutic gameplay, accessible tutorials, and integrated monitoring systems provides a practical tool that can significantly improve quality of life for patients with limited mobility. The implementation shows that VR technology, when properly adapted to patient needs, can effectively support rehabilitation while keeping patients engaged and respecting their physical limitations. The modular design ensures the system can continue to evolve with future therapeutic needs and technological advances. Through these improvements, VR rehabilitation for lying patients becomes more accessible and practical for long-term use in clinical settings, supporting the broader goal of improving patient outcomes through innovative therapeutic technologies.

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Appendix A
Set up manual

Note: The structure and format of these appendices are based on the appendices from Tereza Langová's master's thesis [1], adapted for this bachelor's thesis.

This appendix contains a brief manual on how to properly set up the devices so that the enhanced application works correctly.

First, follow the instructions listed below:

1. Enable developer mode on both mobile device and Meta Quest headset.
2. Install the VR application on the Meta Quest headset.
3. Enable hand tracking in the device settings of the Meta Quest headset.
4. Check if hand tracking works correctly by putting away the VR controllers and looking at your bare hands. Virtual hands should appear in the headset that copy your hand movements.
5. Install the mobile application on the mobile device.
6. Connect both devices to the same network.
7. Start the application on both devices.

After performing the steps above, the mobile application should display a screen with a single button "Connect to the VR". Press the button. The application should connect the devices and the mobile application should show a Main Menu. If the devices do not connect, it is possible the network you are connected to has security precautions that do not allow two devices to connect to each other. In this case, try to connect to a different network.

Appendix B
List of used packages

The Unity project of the enhanced application contains the following packages:

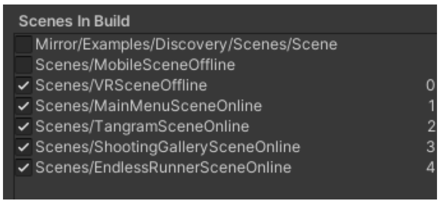
- VR dashboard logger[1] (Version 1.0.8): Used to log VR data to a server.
- Mirror[2] (Version 81.4.0): Used for networking.
- Easy Buttons[3] (Version 1.4.0): Used for creating buttons for the Unity editor that serve for easier creation of game levels.
- XR Hands[4] (Version 2.5.0.): Used to visualize VR hands.
- Oculus XR Plugin[5]: Provides display and input support for Oculus devices.

[1] VR dashboard logger: gitlab.fel.cvut.cz/rehacleo/vr_dashboard_logger.git
[2] Mirror: mirror-networking.gitbook.io/docs
[3] Easy Buttons: github.com/madsbangh/EasyButtons.git#upm
[4] XR Hands: docs.unity3d.com/Packages/com.unity.xr.hands@1.3/manual/index.html
[5] Oculus XR: docs.unity3d.com/Packages/com.unity.xr.oculus@4.0/manual/index.html

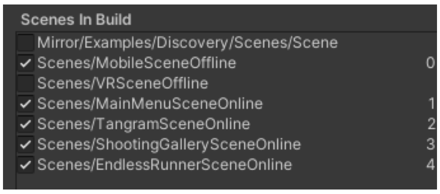
Appendix C

Building the application

The difference between building the application for mobile device and the VR headset is in including different "offline" scenes into the build using Unity Editor's Build Settings. Figure C.1 shows how the settings should look for each of them. To build the VR application, "VRSceneOffline" must be included in the build, and "MobileSceneOffline" must be excluded. These should be checked in the opposite way when building for mobile devices.



(a) : Scenes included for VR device build



(b) : Scenes included for mobile device build

Figure C.1: Build Settings - scenes to be included to build for different devices

Appendix D
List of attached files

- ProjectLinks.txt – Text file containing links to: GitHub repository with the complete Unity project source code, Google Drive link for VR application build (Meta Quest 2), and Google Drive link for mobile application build.